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Influence of Foliar Dust Deposition on *Ficus Benjamina Variegata* Stomatal Conductance

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Abstract

Kuwait is frequently subjected to severe dust storms that may last many days at times in addition to the fact that suspended dust particles is a common problem almost all year round in this part of the world. Indoor plant leaves attract suspended dust and consequently dust deposition and accumulation on leaves may have negative effect on photosynthetic activities and thus growth and development of ornamental indoor plants are effected as a consequence. Very little information is available in the literature on the effect of dust deposition on foliar surfaces of plants as this area is poorly investigated. Therefore, the objective of this study was to determine effect of dust deposition on stomatal conductance, transpiration and chlorophyll index of the indoor plant species *Ficus benjamina variegata*. Experiment was conducted in a chamber with 16-hrs per day artificial HPS lighting system with ambient relative humidity and temperature. executed in semi-controlled room temperature. Foliar dust cover was applied on both sides of leaves at three levels: very heavy (III), moderate (II) and slight (I) in addition to undusted plants used as control treatment. Results showed that deposition of dust on foliar surfaces remarkably reduced stomatal conductance in all selected plant species under investigation. Reduction in stomatal conductance of *F. benjamina,* for example, was reduced 57.1% and 5.7% in the slightly dusted plants (I), 59.5% and 26.3% in the moderately dusted (II), and 61% and 47.6% in the heavily dusted (III) treatments at adaxial and abaxial surfaces, respectively, during the first week of the study. Furthermore, the reduction in stomatal conductance, transpiration rates and chlorophyll indices were much greater at the end of the experimentation period for all plant species. Therefore, it is recommended that periodic cleaning of foliar parts of indoor plants is practiced for healthier plants.

Keywords: Foliar surface, dust deposition, ornamental plants, photosynthesis.

Introduction

No information available on effect of dust on photosynthesis and other growth parameters. Kuwait is frequently subjected to severe dust storms that may last many days at times in addition to the fact that suspended dust particles is a common problem almost all year round in this part of the world. Indoor plant leaves attract suspended dust and consequently dust deposition and accumulation on leaves close stomata and therefore negatively influence photosynthesis and thus growth and development of these plants. Deposited dust in indoor plants cannot be removed unless washed or wiped away. As reported in the literature, this is also a problematic in plants outdoors in spite of the fact that fallen dust particles on leaves are likely flown away by wind action or washed away by rains and therefore influence their growth and development. Sensitivity to dust deposition varies among plant species.

Windblown dust is a common feature of arid ecosystems where scarcely vegetated soils act as a major source of small particulate matter (Sharifi et al., 1997). Dust may settle on leaves, twigs and bark surfaces of plants for extended periods of time. Dust deposition on above ground plant organs may induce various chemical or physical effects (Grantz et al., 2003). Excessive dust deposition is known to cause defoliation, shoot death and lowered primary production in desert shrubs (Sharifi et al., 1997). In desert environments, with high summer ambient temperatures, this may lead to adverse heat stress effects in plants. Secondly, complete covering of a significant proportion of stomata with dust may lower transpiration rates and therefore also evaporative cooling of the leaf surface (Sharifi et al., 1997). This may lead to additional heat stress effects in these plants. Thirdly, dust is known to reduce the water use efficiency of plants under certain circumstances. For example, dust particles may prevent complete nocturnal closure of stomata, leading to excessive water loss through nighttime transpiration (Flückiger et al., 1979, Rawson and Clark, 1988 and Hirano et al., 1995).

In arid environments, decreased water use efficiency because of dust deposition, could therefore contribute substantially to drought stress. The physical effects of dust accumulating on leaf surfaces, on leaf physiology, such as photosynthesis, transpiration, stomatal conductance and leaf temperature of cucumber and kidney bean plants were investigated by Hirano et al., 1995. It was found that dust decreased stomatal conductance in the light, and increased it in the dark by plugging the stomata, when the stomata were open during dusting. When dust of smaller particles was applied, the effect was greater (Hirano et al. 1995). However, the effect was negligible when the stomata were closed during dusting. The dust decreased the photosynthetic rate by shading the leaf surface. The dust of smaller particles had a greater shading effect. Moreover, it was found that the additional absorption of incident radiation by the dust increased the leaf temperature, and consequently changed the photosynthetic rate in accordance with its response curve to leaf temperature. The increase in leaf temperature also increased the transpiration rate (Hirano et al., 1995). Dust may allow the penetration of phytotoxic gaseous pollutants into plant leaves. Visible injury symptoms may occur and generally there is decreased productivity. Most of the plant communities are affected by dust deposition so that community structure is altered (Farmer 1993).

Correia et al., 2004 studied the deposition of dust on the foliar surface of the evergreen *Olea europaea* and a semi-deciduous (*Cistus laurifolius*). They found that the affect mainly on the reflectance, it increased with increasing deposition levels, causing a complementary decrease in light absorbance by the leaves of both species. As a consequence, the energy balance of the leaves and net photosynthesis may be altered, thus reducing the productivity of the affected vegetation. However, this effect seems to be more pronounced in *C. laurifolius* compared to *O. europaea*. This could mean that some species maybe more susceptible to dust pollution. In this sense, one could expect an alteration on the specific composition of the vegetation of the affected areas in response to dust pollution (Correia et al., 2004). Effects of limestone dust were determined in *Zygophyllum prismatocarpum* plants with heavy, moderate and no visible foliar dust cover by means of chlorophyll *a* fluorescence measurements (van Heerden et al., 2007). Limestone dust deposition decreased overall plant performance through loss of chlorophyll content, inhibition of CO_2 assimilation, uncoupling of the oxygen-evolving complex and decreased electron transport. Recovery was accelerated by rainfall, mainly because of dust removal

from leaves and stimulation of new growth. These results indicate that limestone dust has severe effects on photosynthesis in desert shrubs, but that recovery is possible and that, in arid environments, this process is modulated by rainfall (van Heerden et al., 2007). The objective of this study was to determine effect of dust on photosynthesis and growth of the indoor plant species; *Ficus benjamina.*

Materials and Methods

The study was executed in semi-controlled chamber with 16-hrs per day artificial HPS lighting system with ambient room temperature of 20-24C. Plants were fertilized monthly throughout the experimentation period with half-strength liquid fertilizer or slow-release fertilizer.

Ficus benjamina variegata. It is one of the most popular houseplants that is grown especially for its very decorative shiny, green oval leaves, it can be pruned to almost any shape and size, grown as an evergreen tree or large shrub in offices and used for interior landscaping. Cultivars are available with variegated foliage, wavy leaves and pendulous branches. *Ficus benjamina variegata* stems are often trained in ornamental shapes, while the stems are young and flexible they may be braided, spiraled or twisted into different shapes. Plants were watered when growth medium was 1 cm deep. *F. benjamina variegata* prefer bright light, but direct sunlight was avoided.

Effect of Dust Deposition on Leaves

Different level of dust deposition on the foliar surface of *Ficus benjamina variegata* were determined. Dust was collected from piles settled around desert plants and was applied on leaves by means of soft brushes.

Clean leaves plants were cleaned with slightly moistened cloth on weekly bases. These were considered control plants (0) (Plate 1). Foliar dust cover was applied on both sides of leaves at four levels. Levels of dust applied were applied qualitatively. Plates 1, 2, 3 and 4 illustrate dust treatments control (0), lightly dusted (I), moderately dusted (II) and heavily dusted (III) *Ficus benjamina variegate*, respectively.

The following parameters were measured regularly in the present study:

Stomatal Conductance. Measurement was taken using LI-1600 (LI-COR, Inc., Lincoln, NE) steady-state diffusion porometer. On each day, leaf resistance was measured on fully expanded leaves from three selected plants in each plant species under the investigation. Measurements were taken on a central portion of leaf. Relative humidity of the air at canopy height was determined immediately before clamping a leaf inside the LI-1600 cuvette. Measurements of stomatal resistance (s cm^{-1}) were

Plate 1: *Ficus benjamina variegata* (Control, 0)

Plate 2: *Ficus benjamina variegata* (dusted slightly, I)

Plate 3: *Ficus benjamina variegata* (dusted moderately, II)

Plate 4: *Ficus benjamina variegata* (dusted heavily, III)

obtained from the adaxial (upper) and abaxial (lower) surfaces of the leaf. Total leaf conductance ($1/r_{leaf}$) was calculated as:

$$1/r_{leaf} = 1/r_{adaxial} + 1/r_{abaxial}$$

where, r_{leaf} is the total leaf resistance, and $r_{adaxial}$ and $r_{abaxial}$ are the resistances of the adaxial and abaxial leaf surfaces, and were expressed as mmol H_2O m^{-2} s^{-1}. Resistance to mass flow was indirectly related to leaf conductance as the inverse of the time (1/s) required to pass a specific volume of air through the leaf (Fischer et al., 1998; Clarke and Clarke, 1996; McDermitt 1990).

Chlorophyll content. The chlorophyll content of the same leaves used for chlorophyll *a* fluorescence measurements was determined with a hand-held chlorophyll content meter (CCM-200, Opti-Sciences Inc., Tyngsboro, MA 01879, USA). These measurements provide a chlorophyll content index (CCI) for each leaf. A highly linear relationship (R^2 = 0.98) between CCI values obtained with the chlorophyll content meter and actual extractable chlorophyll content of leaves was established (Hirano et al., 1995). Measurement will be recorded on weekly bases.

Analysis of variance (ANOVA) was performed by Statgraphics 5 Plus (Manugistics Leveraged Intelligence). Fischer's protected least significant difference (LSD) test was used to separate means.

Results and Discussion

Effect of dust deposition on the adaxial surface of *Ficus benjamina* leaves on the stomatal conductance of leaves was more pronounced than that on the abaxial surface of the leaves during the first week of the experiment (Fig. 1). The stomatal conductance at the adaxial surface was significantly greater in the control plants compared to all levels of dust depositions, where stomatal conductance of leaves at the adaxial surfaces of leaves in dust levels I, II and III were the same. The stomatal conductance of leaves at the abaxial surface illustrated gradual decrease as level of dust deposition increased. The LSD test at 5% significance, showed segregation in the response to dust deposition, viz., there was no significant difference in stomatal conductance between the control and dust level I, yet significantly different from the II and yet from the III dust deposition level (Fig. 1). Fig. 1 illustrates this relationship clearly. The situation differed at the last week of the experiment where both sides of the leaf had similar conductance and control was significantly greater than all other dust levels of deposition (Fig. 2). Reduction in stomatal conductance of *F. benjamina,* was reduced 57.1% and 5.7% in the slightly dusted plants (I), 59.5% and 26.3% in the moderately dusted (II), and 61% and 47.6% in the heavily dusted treatments at adaxial and abaxial surfaces, respectively, during the first week of the study. The leaf transpiration in both adaxial and abaxial surfaces showed very much similar patterns in both first (Fig. 3) and last (Fig. 4) week of experimentation. This is expected as dust deposition on leaves of plants clog stomata openings so performance of leaves in terms of leaf conductance and transpiration are severely affected as a consequence.

Effect of level of dust deposition on leaves on the chlorophyll index over three periods (immediately following initiation of the experiment (0), 30 and 60 days) from initiation of the experiment) are illustrated in Fig. 5. The general trend observed that chlorophyll indices of leaves statistically significantly decrease as levels of dust deposition increases over the 60 days period of the experiment (Fig. 5). van Heerden et al., 2007 study revealed that limestone dust deposition decreased overall plant performance through loss of chlorophyll content. Recovery was accelerated by rainfall, mainly because of dust removal from leaves and stimulation of new growth. These results indicate that limestone dust has severe effects on photosynthesis in desert shrubs, but that recovery is possible by rainfall.

Figure 1: Leaf conductance of *Ficus benjamina* at both surfaces when subjected to different levels of dust deposition on leaves at the first week of the experiment.

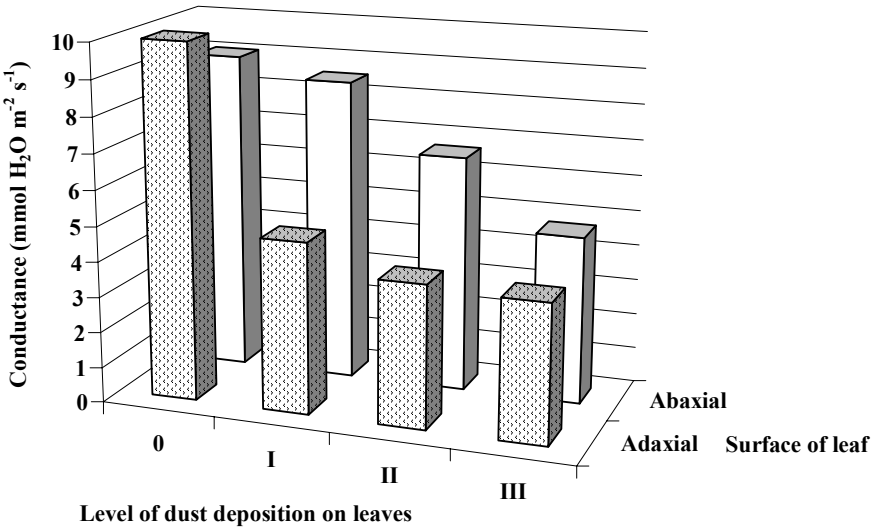


Figure 2: Leaf conductance of *Ficus benjamina* at both surfaces when subjected to different levels of dust deposition on leaves at the last week of the experiment.

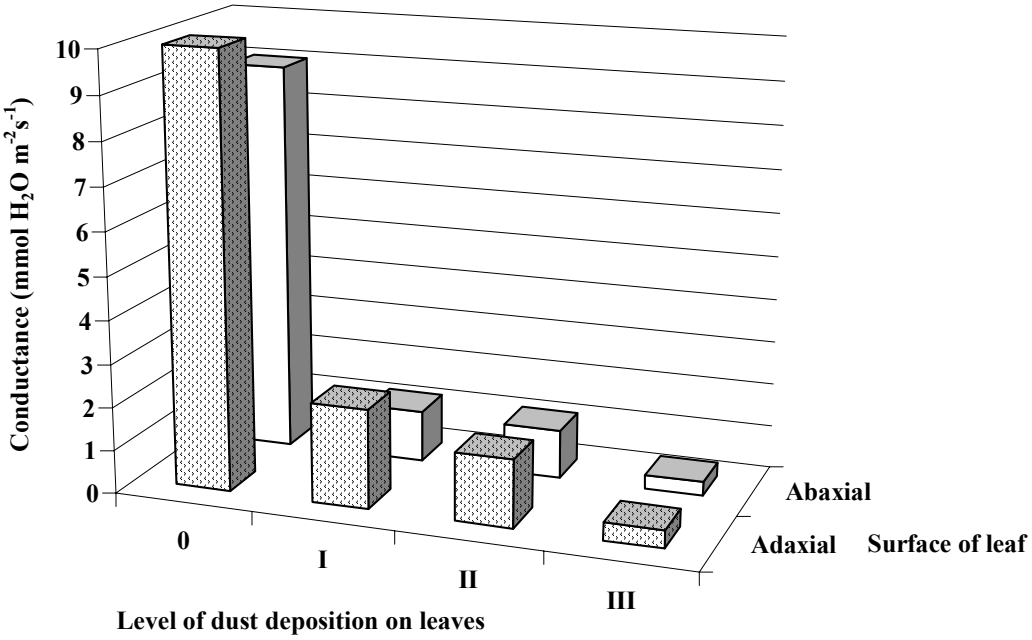


Figure 3: Transpiration rate of *Ficus benjamina* at both surfaces when subjected to different levels of dust deposition on leaves at the first week of the experiment.

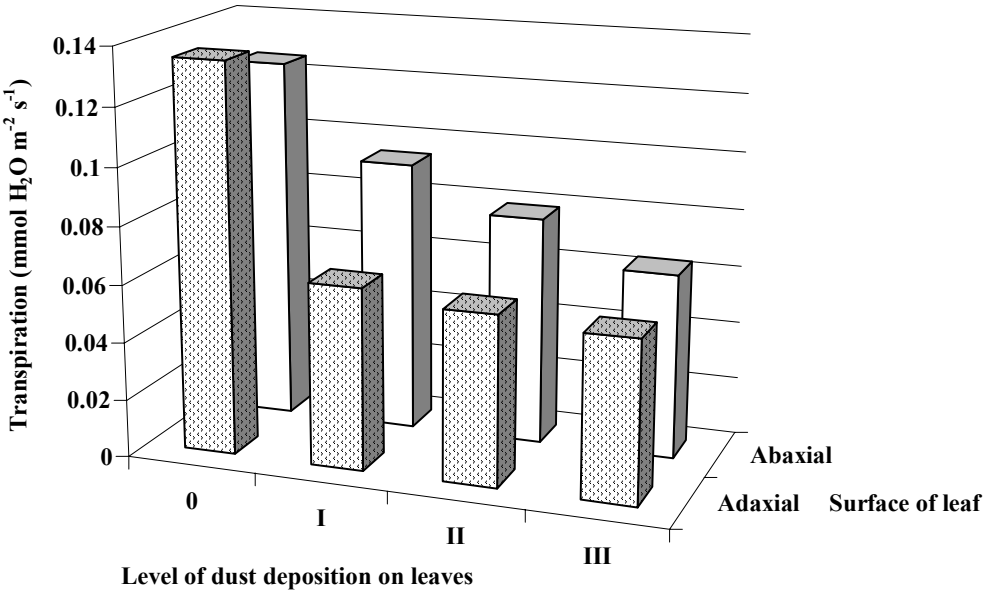


Figure 4: Transpiration rate of *Ficus benjamina* at both surfaces when subjected to different levels of dust deposition on leaves at the last week of the experiment.

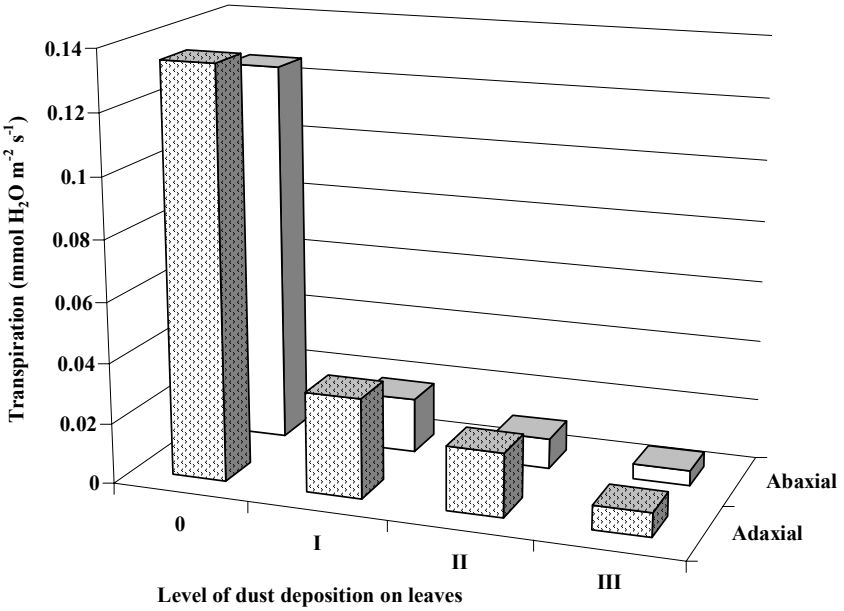
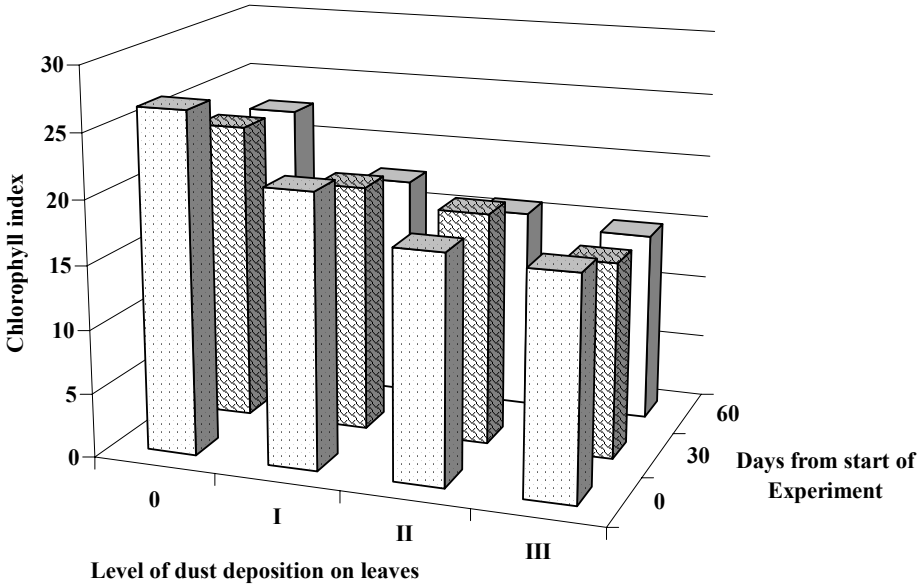


Figure 5: Chlorophyll index of *Ficus benjamina* leaves when subjected to different levels of dust deposition on leaves at three intervals.



Conclusion

The results obtained in this investigation revealed a remarkable impact of foliar dust deposition on stomatal conductances, rate of transpiration as well as chlorophyll indices in the selected ornamental indoor plant species. Furthermore, the study has illustrated that the affect of dust deposition on leaves has caused a more pronounced reduction in these parameters with time as was the case during measurements in the last week of the study. The impact of dust is illustrated clearly in the present study where reduction in stomatal conductance could reach as high as 97% with increasing levels of dust deposition over time.

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Psycho-Cultural Variables for Sport Participation Among Students in Third Generation Nigerian Universities

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Abstract

The study dealt with psycho-cultural variables such as patents, religion and gender for sports engagement among students of third generation Nigerian Universities. The instrument was a self-developed validated questionnaire. The respondents of the study comprised students drawn randomly from five selected third generation Nigerian universities. Percentages and Chi-square X^2 inferential statistics at 0.05 alpha level were applied for data analysis. The outcomes of the study vividly indicated significance of psycho-cultural factors for sports involvement among student. On this promise, enlightenment programmes for the parents on the role of sports for holistic development of students should be promoted. Religious values should influence and inform the context the way sporting activities are structured and accessed.

Introduction

Sport participation is governed by many psycho-cultural factors, even among students in tertiary institutions in developing countries. This is due to the fact that frantic efforts are often made in Africa to expose the children to psycho-socialization from the childhood. The line of action to be toed is greatly influenced by the parents at the early years of age because the child has to depend on the family, as he cannot meet his demands of life. Sohi (1995) maintained that the child has to seek the approval and has to avoid disproval in his day-to-day behaviour in form of learning of various skills, attainment of knowledge, development of attitudes and introduction of competitive sport. Studies have shown that a sport parent usually provided a social milieu, which was conducive to involving of the children into competitive sport. Various psycho-cultural factors such as parents, gender, religion and others determine the extent and limitation of sports participation among students in higher institution especially in developing nations. Religion as an integral part of culture significantly determines acceptability and non-acceptability of any line of action in certain human society (Fadoju 1999).

Sohi (1995) and Babatunde (2001) stressed that parents have been seen as more influential in socializing their wards into sport, with the father being stood out as the most influential in their respect. An important thing to note in the socialization process is that the values which are imbibed or planted in the early years of children continues to pervade their behaviour in one way of the other in later years, even when such individuals are in higher institutions where academic and social independence are provided for the purpose of optimizing their potentials.

The conversations and utterances of parents reflected the importance that parents place on what they feel are basic school activities. Many parents give much thought when their children are going to

schools to how they can help them do well in the so-called academic courses but spend very little effort encouraging their wards to do well in sport that relates to their health, social and physical well-being. To such parents sport and kinetic activities are sometimes regarded as appendages or frills in the school programmes. When parents show interest in sport for their children, it is much likely that substantial energy will be expended to motivate them to participate in it. Fadoju (1999) noted that a participating father in sport is likely to influence the children to take part in sport whereas, a non-participatory one is likely to discourage them. Babatunde (2001) and Onifade (2001) opined that a participation parent stands better chance to influence the children in the choice of sport through provision of equipment.

Despite the passage of Title IX in (1972) which states that no persons in the United States shall, on the basis of sex, be excluded from participation in, be denied the benefits of, or be subjected to discrimination under any education programme or activity receiving Federal financial assistance. The implementation has been difficult and politically controversial, and although changes have occurred, gender inequalities in sport still exists worldwide, having it more pronounced in developing nations (Robbert and Daniel 1995). Empirical observations such as Fadoju, (1999), Nwankwo (2001), Otinwa (2005) and Babatunde (2006) convincingly, revealed great disparity of sport participation among student in Nigerian universities on the basis of gender. Universities all over the globe are centres where several educational opportunities are made available for every body irrespective of race, gender, ethnicity and cultural differences, since education serves as a leveler. Under normal circumstance should not constitute any barrier for sport involvement at this level of education considering the prime role of higher institutions in the production of high level manpower without any prejudice.

Nwankwo (2001) stated that generally, the ratio of female/male participation – as university athletes – is approximately 1:3. The ratio is lower in universities in the North, where due to religious affiliation women (particularly Moslem women) participation is in sport is discouraged. Akinsanmi (1997), Ituh (1997), Orunaboka (1997) and Nwankwo (2001) attributed the insignificance female sport participation to dress code, which is a thorny issue. According to Awosika (1992) the restriction of religion on sport participation has been observed to be more pronounced on female than male counterparts. Rather than sporting activities, the problem surrounding sport participation is the way in which sport, physical activities and physical education are organized and made available. Hasina (1997) reflected that the factors which inhibit Muslim young women involvement in sport are related to family responsibilities, cultural values and lack of understanding of and respect for Muslim women's view. Associated with religious dogmas in Nigeria setting, Ituh (1997) asserted that women wearing shorts which expose their thighs is regarded as religious immorality attracting men to women sex. Akinsanmi (1997) and Orunboka (1997) buttressed that religion like Islam does consent to female sport participation on the basis of dress code, which in some sport like soccer violates a particular religious prescription. Adeyanju (1999) reported that religion plays a significant role in the attitude towards women's involvement in sports especially as regards free association of men and women and the exposure of one's body party in the public. Dosunmu (2001) informed that there is an agitation among sports observers that female soccer may never see the light of the Moslem countries.

Sport administration and participation in tertiary institutions have diverse but significant merits for hitch-free general school administration and the production of healthy and self-reliant graduates. Hence its pursuance is justified and unequivocally advocated. A continuing upward demand to produce top sport men and women particularly by Nigerian Universities as obtained in advanced nation requires that the institutions should be strategize to ensure societal relevance in sport matter on the basis of gender equity.

Method and Procedure

Descriptive survey research design was applied for the study. With the use of randomization male and female undergraduates in selected third generation Nigerian Universities were used for the study. The Third Generation Nigerian Federal Universities are the third batch of universities established by the

Federal Nigerian Government on the basis of Federal character. Such universities, which are nine in number, are universities of Agriculture and Technology. Those universities as involved in the study include University of Agriculture, Abeokuta, Federal University of Technology, Minna; University of Agriculture, Umudike; University of Agriculture, Makurdi; and Federal University of Technology, Akure.

The study instrument was self-developed, validated questionnaire trigged Psycho-Cultural Factors for Sport Participation among students in Nigerian universities (PCFSP) with Likert Scaling format of Strongly Agree, (SA), Agree (A), Disagree (D), and Strongly Disagree (SD). Three thousand (3,000) questionnaire with six hundred (600) for each university of the study were administered to students with the use of convenient sampling technique. Only two thousand six hundred and ten (2,610) correctly filled and returned are coded for analysis. The test-retest method is used to establish the reliability of the measuring instrument of the study. A value of 0.85 reliability was obtained through the application of Correlation Co-efficient test.

Data Analysis and Discussing

Hypothesis I

Parents would not be perceived as a significant factor of sport participation among students in the third generation Nigerian universities.

Table 1: Parents as a perceived factor for sport participation by Universities students

Responses	Frequency	%	X^2	Agreement Disagreement	Remarks
SA	483	18.5	105.49	75.5	Significant
A	1542	59.0			
D	325	12.5		22.4	
SD	260	10.0			
Total	**2,610**	**100%**		**100%**	

Table 1 above shows responses to hypothesis relating to parents as a perceived factor of sport participation among universities students in Nigeria. From the statistical analysis as provided in the table, the calculated chi-square (X^2) value of 105.49 that is greater than the table value of 7.815 at 0.05 alpha level with three degrees of freedom is obtained. With this information, the researchers concluded that the hypothesis of the study was rejected.

This result agrees with Sohi (1995), Fadoju (1999) and Babatunde (2001) that students' participation in sport is a function of parents. Sohi (1995) and Fadoju (1999) emphasized that father is often a stronger sport socializing agent especially if the father had been previously involved in sport during his school days. Awosika and Babatunde (2003) noted that educated parents often encourage their wards to participate in sport.

To secure better attitude of students to sport, Babatunde (2001) suggested that parents should be enlightened on the role of sport in the holistic development of their wards. It is expected that when parents pick interest in sport having understood its role in the optimum growth of their children frantic but importunate efforts by parents will be made to motivate them participate in the school sport.

Hypothesis 2

Religious affiliation would not be perceived as a significant factor of sport participation among students in third generation Nigerian universities

Table 2: Religion as a perceived factor of sport participation by students in third generation Nigerian universities

Responses	Frequency	%	X^2	Agreement Disagreement	Remarks
SA	230	8.8	328.6	75.3	Significant
A	1683	64.5			
D	662	25.4		26.7	
SD	35	1.3			
Total	**2,610**	**100%**		**100%**	

The above table provides vivid statistical information on religion as a perceived factor of sport participation among students in third generation Nigerian universities. According to statistical provision contained in the table, the obtained chi-square (X^2) 328.6 which is higher than the table value of 7.815 revealed that religion was perceived as a significant factor of sport participation among students in third generation Nigerian universities.

Religion poses a tremendous influence on the conduct of people in developing countries like Nigeria. Akinboye et al (1992) emphasized that one psychological principle is that a person's belief system often develops from childhood as he had been exposed to the psycho-socialization rituals of the system. The finding confirms Babatunde (2001) and Awosika (1999) that religious belief has significant impact on student sport participation in their campuses. Ituh (1997), Akinsanmi (1997) and Orunaboka (1997) traced low sport participation among female in tertiary institutions to religion-psychosocial dimension and cultures, a view which aligns with Dosunmu (2001) who reported strong opposition to female soccer in Moslem countries.

Hypothesis 3

Gender would not be perceived as a significant factor of sport participation among students in third generation Nigerian universities.

Table 3: Gender as a perceived factor of sport participation by students in third generation Nigerian Universities

Respondents	SA	A	D	SD	Total	X^2	Remark
Male	900	300	310	100	1610	245.45	Significant
Female	500	400	60	40	1000		
Total	**1400**	**700**	**370**	**140**	**2610**		

Disparity in social engagement on the basis of gender is a common phenomenon and no one can safely turn a blind or at least a jaundiced eye to the significance of gender in social issues, sport inclusive. Observations such as Babatunde (2001), Nwankwo (2001), and Otinwa (2005) show that female sport participation in Nigerian universities is still far below the expectation.

In the above table 3, it could be seen that sport participation in Nigerian universities has a strong bearing with gender characteristic as the obtained chi-square of 245.45 is significantly greater than the table value of 7.815 at 0.05 level of significance, with three degrees of freedom. Robbert and Daniel (1995) traced differences between male and female sport experience to opportunity, psychosocial orientations, and reactions to sport participation. Nigerian universities sport records according to Nwankwo (2001) revealed the ratio of female/male sport participation of approximately 1:3. The outcome this study corroborates Otinwa (2005) who exposed that sport has been considered a male domain while access to physical education and coaching in sport for women has been defined as out of the ordinary to the point of being discouraged. Babatunde (2003) noted the acute gender inequality in Nigerian universities sport.

Conclusion

From the above aforementioned empirical findings, the following inferences are made:

1. Parents were identified as a significant factor that determined students' sport participation in third generation Nigerian universities.
2. Religion produced a significant effect on students' sport participation in third generation Nigerian universities.
3. There is a pronounced gender inequality in sport participation among students in third generation Nigerian universities.

Recommendations

The imperativeness of research is to accurately identify the problems of a particular social issue with a view to proffer appropriate and relevant therapies. Based on this, the following are suggested for promote better sport involvement among students in tertiary institutions

1. Enlightenment programmes for the parents through mass media on the benefits of sport for holistic development of students are essential.
2. Management of all tertiary institutions having realized the complimentary role of sport in the wholesome development of students should provide sport education for students to enhance better orientation to sports that may enable them correct already developed misconceptions about sport.
3. Age-long myths surrounding female students sport apathy should be de-emphasized while values of sport irrespective of gender classification be unequivocally stressed.
4. To increase sport participation among students who share different but strong religious beliefs as the case in Africa, their religious values should influence and inform the context the way activities are structured and accessed. Such strategies may include special dress code for female athletes, recruitment of more female sport officials and more female leadership role in sport.
5. Parents and sport professionals should device scientific strategies to kindle sport awareness among female student in Nigerian higher institutions
6. There is urgent need to establish more widely inclusive network for recruiting female sport professionals in order to secure and stabilize the confidence of female athletes.

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The Practice of Effective Inter-Group Communication Among Hospitality Employees in a Selected Hotel

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Abstract

The study was to examine the relationship between level of knowledge, skills, and attitude with practice of effective inter-group communication. A total of 102 samples responded the questionnaires. The findings revealed that level of knowledge was high, whereas skill, attitude and practices were moderate. Correlation analysis showed that practices has a strong and significance relationship to skills, and attitude of effective inter-group communication, while, practices has a moderate and significance relationship to knowledge. Regression analysis showed that skills in effective inter-group communication were highly related to practices compare to other variables.

Keywords: Practice, Effective Inter-group Communication

Introduction

The Malaysian government, in its effort to make Malaysia a developed nation by the year 2020 has taken many steps towards achieving this ambitious aim. Therefore, hospitality industry is fully support as one of the sector that can contribute to Malaysia economic. The objective was simple in that through the Tourist Development Corporation and the Malaysian Tourism Promotion Board, The Ministry of Culture and Tourism Development has heavily campaigned for Malaysia as a tourist destination. One such activity that was successfully implemented was the "Cuti-Cuti Malaysia" (Holidays in Malaysia) campaign since 2000 has brought about an estimated 30% growth in domestic tourism, reported the Star, 2003. We have seen the great diversity of people in the hospitality industry. Both managers and employees must work collaborate to satisfy the needs of the customers. Perhaps one of the most important elements in hospitality employees is that practicing effective inter-group communication. According to Clark (1993), hospitality employees' communication competence is particularly important, social interactions are part of the product itself. It is eminently clear that effective inter-group communication is essential in hospitality industries, or anywhere that people deal with another. It is difficult, in fact, to imagine in some form or other.

Employees in an organization spend more time with each other than they do with friends or family. They have to work side by side with their managers and colleagues almost daily. An effective

inter-group communication can influence both the employees and organizaton development. In the last decade, increasing work across the social, and communication sciences has been developed to inter-group behavior and processes (Giles, 2001). Borchers (1999) defines inter-group commnication as having at least three and no more than twelve or fifteen members. A group member must be able to communicate freely and openly with other group. The group will develop norms about discussion and group members will develop roles, which will affect the group's interaction. Inter-group communication must have a common purpose or goal and they must work together to achieve that goal. As summary, an inter-group communication is interaction across social groups in many contexts. According to Omar (2001), problems in communication can negatively affect the quality of work, as well as the achievement of performances goals at the individual and organization level. The ability to effective communication is one of the soft skills that is important for success in an organization. Effective inter-group communication perhaps can be considered as one of the characteristics of a true professional.

Knowledge, Skills and Attitude towards Effective Inter-group Communication

Knowledge is something that everyone takes for granted. It rarely occurs to anyone to consider that what they see or hear or feel may be different to what someone else is seeing, hearing or feeling. Knowledge inter-group communication is important because there is no simple comprehensive recipe to follow in applying the skill once the employees have mastered them (Jensen & Chilberg, 1991). Just as perception is essential for effective learning, so learning is required before the employees' perception is improved (Lockwood & Jones, 1994). To understand human communication as fully as possible, the hospitality employee must attempt to understand the communicator, the relationships between him/her and those with whom he/she communicates, and the organizational setting in which they may be communicating (Bovee & Thill, 2000). Anthropologists found that "meaning" is to be understood not through dictionaries and glossaries of the tongues under consideration, but through an understanding (preferably through participation) of the lives, habits, and social institutions of the people whose language one wishes to understand. This is one of the element ineffective inter-group communications, which they called as mindful. Whereas according to Adams & Galanes (2003), perfect understanding isn't necessary. In a group, the employees need only communicate well enough to coordinate our behavior toward a common goal. When they can do this, they are communicating well enough for group success, even though they haven't achieved perfect understanding. Content of effective inter group communication is very large, in this study; they will concentrate in elements in reducing anxiety and uncertainty recommended by Gudykunst (1994).

Dwyer (2000) also stated that communication skills are all essential in the workplace. Being a good communicator means acknowledging and can communicating skillfully. The inter-group communication, negotiation skills are crucial in labor management disputes. Effective skills are well grounded in theory. Skills can be seen as the evidence of a more complex set of theoretical principle that have been systematically examined and applied by the performer, and communication skills are no exception. They rely just as heavily on research and theory as more familiar psychomotor skills do. The term 'competency' is perhaps intended to convey because competent people not only know how to do something but also why it should be done a certain way. Skills in communication gives the individuals some control over the environment, a means of emotional catharsis, and a way to make relationship, all of which are critical to a meaningful existence (Mirenda, Iacono, & Williams, 1990; Nordstrom, Lorenzi, & Hall, 1990). If someone can use the effective inter-group communication in reducing anxiety and uncertainty when mix around with different kind of people, this will built a professional images as a great hospitality employees.

In some cases, an employee's attitude may, at first glance, appear not to be communicative. The initial assumption may be that the attitude is not intended to communicate thoughts or feelings; however, because these employees have limited ways of making themselves understood, they may be

engaging in these attitudes precisely for that purpose. Holding a right attitude among the group members are likely to encourage more interaction in the future, possibly leading to more meaningful relationship in the group (Adams & Galanes, 2003). Therefore, attitude can be stated as standpoint of doing something wherever they like it or not and this can become common or habitual where it can be called practice. Having a positive attitude can bring up the interest in doing something, when the things get done regularly, it become practice and once again it will enhance our skill. By having a right attitude, an individual will also be interested in gaining more knowledge. Employees need to adopt a 'learning for life' attitude towards their development (Foley, Lennon & Maxwell, 1997).

Hospitality industry is a large work place, employees have to deal with all kind of people from the different culture and social. Salience of the out-groups is likely to be associated with members' group identification (Suzuki, 1998) which may affect the members attitude as well as their perceptions. The practice of effective inter-group communication is necessary here. This is implies effective inter-group communication means being particularly sensitive to the attitude and beliefs, rules and norms during interaction with others, and specially so in situations which the hospitality employees are not familiar, or in situations which unexpectedly change during the interaction (Clark, 1995). Therefore, the practice of effective inter-group communication in reducing anxiety and uncertainty is extremely important because the hospitality employees have no more chances to interact with different kind of people from different background.

New age employees are expecting more equitable treatment in the workplace, and improve the workplace landscape. The new workforce is quite articulate about their needs and expectation of the workplace (Mir, Mir, & Mosca, 2002). Practicing of effective inter-group communication can create a flexible and harmony workplace. The phenomenon of today is many organization are using yesterday communication approaches to meet tomorrow demands, and they are not delivering what organizations and employees need (Quirke, 1996). This shows that the hospitality employees lack of knowledge, skills and they seldom practice it. Therefore, the practice of effective inter-group communication is the key for employees to become more productive and create a better workplace. More interaction also gives management more credibility with employees, which can be a tremendous asset in both good times and bad. "If you want to attract and retrain the best customer, you need to attract and retrain the best employees," say Skarlicki & Latham (1997).

Practice of Effective Inter-group Communication

As noted by Jensen & Chilberg (1991) that practice is inappropriate habits that work against adequate differentiation and integration. When the typical workplace fails to provide the requisite opportunities for an employee to practice skills, certain accommodations and modifications may be needed to make the environment more supportive of interactions for the employees. Some skills can be learned on the job or formal programs, but require continual practice and reinforcement so that they become part of an employees' tool box when interacting with other people (Ludlow & Panton, 1992). The customer service environment encourages every group to interact frequently the whole day offer greater opportunities to practice effective inter-group communication. Analyzing communicative exchanges can often identify certain opportunities for employees to practice inter-group communication. People need the opportunity to practice what they have learned, knowledge and skills atrophy with disuse (Ludlow & Panton, 1992). Hospitality employees should have the right attitude to practice the effective inter-group communication in order to provide a good service to the customers and work efficiency with the subordinates. Every levels of management need to practice effective inter-group communication to perform better.

The Relationship between Knowledge, Skills, Attitude, Demographic Information with Practice of Effective Inter-group Communication

According to Salazar (1996), practice can be influenced by knowledge and skills of an individual. This implicit that the hospitality employees not only learn to gain knowledge but also concerned to required skills and developing the knowledge and skills so that their standards of performance achieve the

desirable level (Reid & Parsons, 1996). Knowledge and skills that staffs hold in hand can motivate them continues develop it until become a practice. Inter-group communication in workforce usually involving the imparting of knowledge on-the-job, conducted actually in the place of work and usually concerned with developing skills. This was support by the finding of previous research done by Muhajir (1996) where knowledge was correlated with practice where $r = 0.345$, $p=0.001$. Essential skills are necessary for creating meaningful conversation between two people. According to Brewster & Pickard (1994), skills can help to built up practice for an individual. When someone obtains the skills, this will motivate them to apply it in order to become better. Environment factors also influence the skills that we needed. Positive attitude always help us in gaining skills. Therefore, it can state that practice can achieve efficiency when the employees learn some skills and keep going on repeated it.

As Dwyer (2000) stated that the ability to communicate is learned by gaining skills from others and from experience. Skills can motivate the employees keep going on practice something, but of course it has to follow specific rules. Employees also need to practice in order to how well they are doing it, so they can improve on their areas of weakness. And it is only with practice that the employees will become a good bridge player or an effective inter-group communicator (Ludlow & Panton, 1992). Clark (1995) also stated that skills mean an ability, which we acquire through learning and will lead to practice. It can state that attitude is ability for someone to reaction wherever positively or negatively and it can affect by the viewpoint and opinion from different demography and environment. If the hospitality employees having a positive attitude, they will easily accept something and repeated exercise done in order to improve one's skills. Smeltzer (1996) stated that practice can build up attitude because it keeps going on repeating. Therefore, attitude can lead to practice. According to previous research done by Muhajir (1996), the finding showed that attitude was correlated significantly with practice.

Car & Durrand (1985) reinforce this opinion stated that knowledge related with the psychology activity that influence someone's attitude. Attitude can built up practice. Jordan (1998) reinforce this opinion by stated that increasing in knowledge in particular field will increase the interest in practicing that field also. As time goes by, it will become practice. Therefore, it can say that there are relationship between knowledge, skills, attitude and practice. They learn to get skills, they practice to enhance the skills, but to learn and perform better, they must have a correct attitude. According to Beukelman & Mirenda (1998), stages of age also play an important role in practice, where the most productive age is between 30-50, and it will decrease when the individual getting older. We can say that practice can be influence by age. Different job level and department need to practice some specific inter-group communication. Therefore, the opportunities to practice the skills also different, for example the front office department may have a better opportunity to practice inter-group communication skills if compare with housekeeping department.

Objectives

The general objective of this study was to examine the relationship between knowledge, skills, attitude and practice of effective inter-group communication among the hospitality employees in a selected hotel. The specific objectives were to identify the level of knowledge, skills, attitude and practice in effective inter-group communication of the hospitality employees and to determine the relationship between knowledge, skills, attitude, and demography with practice of effective inter-group communication.

Method

The study was a survey research to determine whether the hospitality employees in a selected hotel perceived that they were practicing effective inter-group communication. Questionnaire based on the ideas of Gudykunst (1994) in assessing four out of six elements in effective inter-group

communication; knowledge, skills, attitude and practice, was used to obtain the descriptive statistics. The study computed the perceived level of each variable by calculating the total average scores of the dimensions. These scores would be put in a category of high, moderate or low level. A sample of 102 respondents that is employees from food and beverage and front office departments were selected. The Cronbach's coefficient alpha values were tested and presented for pre-test and pos-tests as well. If the alpha value was closed to 1.0, this was considered having a high reliability level.

Table 1: The Cronbach's Alpha Reliability Test Results

Variables	Number of Items	Cronbach's Alpha	
		Pre-test n=10	Post-test n=102
Knowledge	14	0.5578	0.8634
Skill	12	0.7128	0.8544
Attitude	17	0.7518	0.8150
Practice	18	0.6549	0.7942

Results and Discussion

Socio-Demographic of Respondents

Table 2 shows that majority of respondents were female, 68.6% and the age of 26-30 years old representing 43.1%

Table 2: Distribution of the Respondents' according to Demographic Information (n=102)

Demographic Information	Frequency	%	
Gender			
Male	32	31.4	
Female	70	68.6	
Age (year)			
<25	36	35.3	Mean: 27.43
26-30	44	43.1	S.D.: 5.57
31-40	8	17.6	
>40	4	3.9	
Job Level			
Managerial Level	6	5.9	
Operational Level	68	66.7	
Administrative Level	28	27.5	
Years of working experience			
< 1	40	39.2	Mean: 2.59
1-5	44	43.1	S.D.: 2.42
6-10	18	17.6	
>11	0	0	
Department			
Front Office	35	34.3	
Food & Beverage	67	65.7	

of the respondents with mean of 27.43. 66.7% of the respondents were from the operational level and 43.1% has worked in the hotel for 1-5 years. 65.7% of the respondents represented the food and beverage department.

Level of knowledge, skills, attitude and practice of respondent in effective inter-group communication

The finding from Table 3, shows that overall the level of knowledge of all respondents in effective inter-group communication was high, which the mean is 56.08 and standard deviation is 7.62 with

score ranging from 30 to 67. Overall the respondents have basic knowledge in the practice of effective inter-group communication. There some of the employees are still new and don't have the experience and they seldom practice in the inter-group communication. Another reason might be they do not taking seriously the importance of effective inter-group communication and do not learn it before. According to Ludlow & Panton (1992), employees need to learn to get knowledge about the rules and the conventions. Whereas Lockwood & Jones (1994) stated that knowledge could achieve by learning, learning is required before out perception is improved. Knowledge (understanding and perception) will affect by the experience.

Table 3: Level of knowledge, skills, attitude and practice of respondent in effective Inter-group communication n = 102

Level	Percentage	Mean	s.d.
Knowledge			
Low (14-32)	3.9	56.08	7.26
Moderate (33-51)	16.7		
High (52-70)	79.4		
Skills			
Poor (12-28)	2.0	42.75	6.10
Moderate (29-44)	60.0		
Good (45-60)	38.0		
Attitude			
Unfavorable (17-39)	0	61.80	6.95
Moderate (40-62)	49.0		
Favorable (63-85)	51.0		
Practice			
Low (18-41)	1.0	62.68	8.70
Moderate (42-65)	63.0		
High (66-90)	36.3		

Table 3 also shows that majority of the respondents that are 60.0% had moderate level of skills in the effective inter-group communication. The mean is 42.75 and standard deviation is 6.10 with score ranging from 26 to 55. Overall the respondents had moderate level of effective inter-group communication but there are still have respondents who obtain poor skills. Skills in important in inter-group communication, individual can use their communication skills to be part of the action that held in the job. As stated by Kaye (1994), good communication hospitality employees need all the inter-group communication skills that is relevant to their system. This is supported also by the Chasey-Rusch, Drasgrow, Reinoehl, & Halle (1993), which communication skills is essential to an improve work quality, allowing individuals to acquire information and form relationships with others.

Further, the result shows that more than half of the respondents has a positive & moderate attitude in effective inter-group communication, showing a percentage of 51.0% with mean 61.80 and standard deviation is 6.95 with score ranging from 43-77. Having the right attitude can bring up the interest in practicing the effective inter-group communication. Adams & Galanes (2003) support this

by noted that holding a right attitude among the group members are likely to encourage more interactions in the group. As according to Lerbginger (1972), attitude is organized and varies in the degree of organization. The concern is with how narrow or wide a perspective an individual takes.

Table 3 also indicates that 63.0% of the respondents generally had a moderate level of practice in effective inter-group communication. The mean for this variable was 62.68 and a standard deviation of 8.70. Moderate level in practice shows that most of the respondents had a great action and habitual in effective inter-group communication. As stated by Jensen & Chillberg (1991) that practice is appropriate habits. This is important to become competitive employees. This is matched with what stated by Argenti (1998) that always practice the inter-group communication enables organizational members to gain necessary information and skills to cope with their changing work environment. It also shows that respondents need to use inter-group communication in their daily duty, slowly inter-group communication will become thing done regularly and turn up to be habit or custom, and that is named as practice in this study.

Relationship between Practices of Effective Inter-group Communication with the Selected Variables

The high correlation is marked relationship with r= 0.831 at significant level of 0.001 between practice and skills indicate that the ability for an employee in effective inter-group communication motivates them to practice it. This is supported by the statement of Brewster & Pickard (1994), practice can help to build up skills for an individual. Mayfield, Mayfield & Kopf (1998) stated also that skills could be enhanced by practice. Tierney (1998) also stated that if someone is keep going on work on diminishing the weakness and enhancing their skills, this will lead to practice. Therefore, we can say that practice can achieve efficiency when we learn the skills and keep going on repeated it. There is a significant relationship between the skills and practice of effective inter-group communication because it is useless if someone has a skills but they did not practice it. This is supported by Jensen & Chilberg (1991) as they say that employees need to apply the skills once they have mastered them.

The r value of 0.734 being more than the significant value of 0.001 shows that there was high correlation; marked relationship between attitude and practice, which means that positive attitude among the respondents, will motivate them in practicing effective inter-group communication. This is match with the previous research done by Muhajir (1996), the finding also showed that attitude was correlate with practice where r=0.233, p=0.032. This is support with the basic premises say by Leavitt (1972) that attitude is motivated, which provide the employees with the energy to attain employees' goals or at least to move in the direction of employees' goals. Having a positive attitude can bring up the interest in doing something, when the things get done regularly, it become practice.

Table 4: Correlation coefficients for the relationship between practices of effective Inter-group communication with selected variables n=102

Selected Variables	r	Significance level
Knowledge	0.415**	0.001
Skill	0.831**	0.001
Attitude	0.734**	0.001
Age	-0.059	0.555
Years of working experience	0.061	0.543

**. Correlation is significant at the 0.01 level (2-tailed)

The moderate correlation; substantial relationship within practice and knowledge with r=0.415 at the significance level of 0.001 that smaller than ∞=0.01 shows that high and moderate level of knowledge only has small influxes for respondents in practicing the effective inter-group communication. This was matched with the finding of previous research done by Muhajir (1996) where knowledge was correlated with practice where r=0.345, p=0.001. According to Jordan (1998), that knowledge has relationship with practice, which increasing knowledge in particular field will

increase the interest in practicing that field as well. Anyhow practice in effective inter-group communication is less influenced by level of knowledge, which knowledge is not an important variable compare with skills and attitude in motivate the respondents to practice effective inter-group communication in their dairy jobs. This is match with what stated by Adams & Galanes (2003), perfect understanding is not necessary. This is because in a group, we need only communicate well enough to coordinate our behavior towards a common goal.

Age with r= -0.059 with significant level of 0.555 displays almost negligible relationship with practice in effective inter-group communication. The negative r shows that as age increase, the practice of inter-group communication decrease and vice versa. According to Ng, Liu, Weatherall & Loong (1997) that age will affect the way people practice the effective inter-group communication. This shows that age is not the important factor in practicing the effective inter-group communication. It is possible that the higher percentages of younger age in the sample with only a few years of working experience. .No matter how old or how young the employees are, they need to practice the inter-group communication in order to become competitive employees.

Generally, knowledge, skills and attitude in this study have significant relationship with practice of effective inter-group communication. The analysis by using Regression 'method enter' in table 5 shows that skills (beta = 0.612) has the strongest relationship with practice of effective inter-group communication with significant value (p=0.001) compare with knowledge and attitude. Overall, the conclusion can make is that the skills and attitude have the biggest influence in practice of inter-group communication. Skills and attitude have positive relationship with practice of inter-group communication, which mean when skills and attitude increase, practice of effective inter-group communication will also increase.

Table 5: Analysis Regression: Practice with selected variables

Selected Variables	Beta	t	Sig. t (p)
Knowledge	-0.094	-1.724	0.088
Skills	0.639	11.042	0.001
Attitude	0.415	7.153	0.001

This makes it difficult to appreciate that the ability to interact effectively with others in social situation is needed skills, or more accurately, a package of skills. This is support by Clark (1995) which stated that a skill means ability, which acquire through learning and practicing. Hunt (1989) also stated that inter-group communication skills play an important role in the development and growth of human resources. Whereas Dwyer (2000) stated that skills are all essential in the workplace. The ability to communicate is learned by gaining skills from others and from experience. Being a good communicator means communicating skillfully.

Conclusion

Overall, the respondents have high level of knowledge, moderate level of skills, moderate level of attitudes and also moderate level of practices. The results show that there was moderate correlation between knowledge with practice of effective inter-group communication. Therefore, we can conclude that the level of knowledge is not so important role in practicing effective inter-group communication. Anyhow, substantial relationships indicate that when the respondents have certain level of knowledge, this will bring up the interest in practice the effective inter-group communication. Skills have a marked relationship with practice of effective inter-group communication. In fact, skills is consider the highest correlation among the selected variables. This shows that the ability and competence in effective inter-group communication can motivate the respondents to practice it. Good skills among the respondents will ensure they practice the effective inter-group communication. By the other had, keep going on

practicing something will increase the skills as well. Attitude is the second highest correlation with the practice of effective inter-group communication. Holding the positive viewpoint and acceptance can influence the respondents in practicing the effective inter-group communication. When the attitude is positive, the practice of effective inter-group communication will increase.

Recommendation

The findings of the study showed that there were some elements of effective inter-group communication that were not fully practiced in the organization. The result in this study highlighted most of the variables were only on a moderate level. However, the appropriate authorities should take remedial steps to ensure that the level will be pushing up and all elements will practice more effectively by determine the causes and taking appropriate measure to correct it. Some of the practical recommendation was made after the finding. The selected variable like skill and attitude are the main factor in influence practice of effective inter-group communication among the employees. Therefore, these two aspects need to be stress on in up grade the level of practice of effective inter-group communication among the employees. Skills can be enhanced through the daily jobs during the program, which the aspect of technical will always play an important part. In addition, the appraisal should be held on from time to time in order to make sure that the employees really skilled. For those employees who are not really skilled or do not hold positive attitude, the authorities should send them for development program, such as training.

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Effect of Air Gap on Power Density for Various Types of Double-Sided Axial Flux Slotted PM Motors using Analytic and FEM Evaluation

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Abstract

Double-sided axial flux PM motors (AFPM) are the most promising and widely used types. There are two topologies for slotted double-sided AFPM motors. Selecting an AFPM motors with high power density is an important parameter in applications. So, comparison of power density between different topologies of double-sided AFPM motors seems to be necessary.

In this paper, the sizing equations of axial flux slotted one-stator-two-rotor (TORUS) and two-stator-one-rotor (AFIR) type PM motors is presented and comparison of the TORUS and AFIR topologies in terms of power density is illustrated. Field analyses of both Topologies of slotted motors are investigated using Finite Element method (FEM) software. Finally a high power double-sided AFPM motor is introduced in the paper.

Keywords: Axial flux PM motors (AFPM), power density and Finite Element method (FEM).

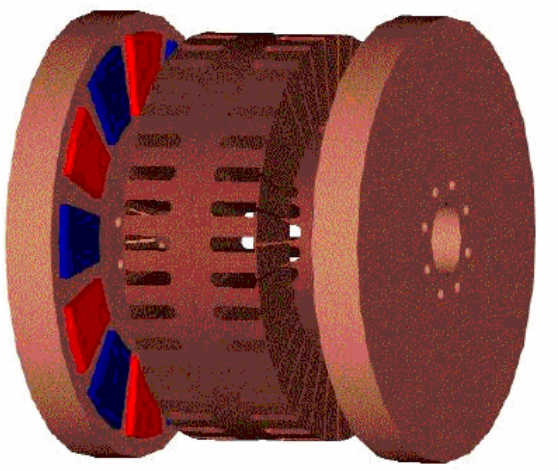
I. Introduction

AFPMs (commonly called disc machines) are synchronous machines. In conventional machines, the air gap flux density has normally radial direction; in AFPMs, the air gap flux density presents mainly axial direction. In general, AFPMs exhibit an axial length much smaller than the length of a conventional motor of the same rating [1].

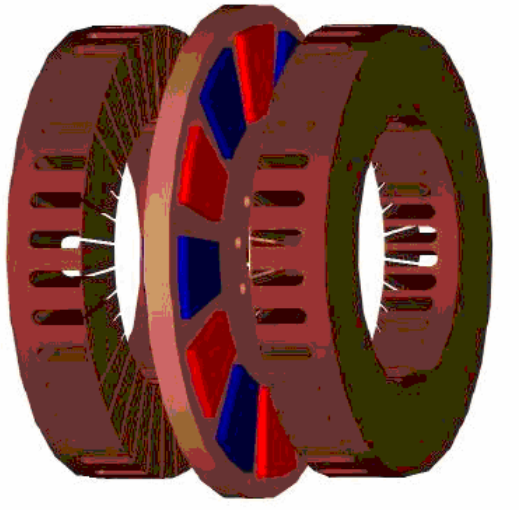
There are two topologies for slotted double-sided AFPM motors. These topologies are axial flux slotted one-stator-two-rotor (TORUS) and two-stator-one-rotor (AFIR) type PM motors. Two AFPM motors and their acronyms are selected TORUS-S (Axial flux slotted external rotor internal stator PM stator) and AFIR-S (Axial flux slotted internal rotor external stator PM motor) for detailed analysis. The stator cores of the machine are formed by tape wound core with a lap and short-pitched polyphase AC winding located in punched stator slots. The rotor structure is formed by the axially magnetized NdFeB magnets [3-4].

The topologies used in the study are illustrated in Fig.1.

Figure 1: Axial flux slotted (a) one-stator-two-rotor TORUS-S type (b) two-stator-one-rotor AFIR-S type



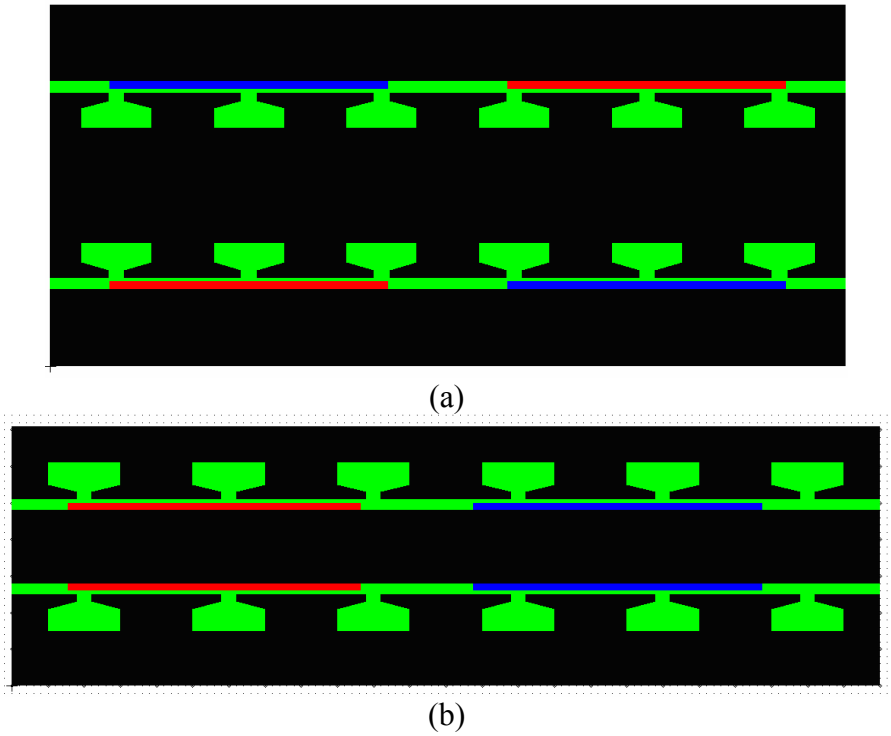
(a)



(b)

Flux directions of both AFIR and TORUS slotted topologies at the average diameter in 2D are also shown in Fig.2a and 2b.

Figure 2: One pole pair of the (a) TORUS-S (b) AFIR-S



(a)

(b)

Selecting a double-sided AFPM motors with high power density is an important parameter, especially in electrical vehicle applications. So, comparison of power density between different topologies of double-sided AFPM motors seems to be necessary.

Increasing the air gap length, maximum power density will change in AFPM motors. These changes are not the same in different topologies. Maximum power density of TORUS-S is higher than AFIR-S in large air gap length.

In Section2, the generalized sizing approach for TORUS-S and AFIR-S types PM motors is briefly discussed. Then, some results of comparisons of the TORUS-S and AFIR-S topologies in terms of power density are illustrated in Section3. In Section4, Field analyses of both Topologies of slotted motors are investigated using Finite Element method (FEM) by MAXWELL10 software. The conclusions are given in Section 5.

II. Sizing Equation of AFPM Motors

In general, if stator leakage inductance and resistance are neglected, the output power for any electrical machine can be expressed as

$$P_{out} = \eta \frac{m}{T} \int_0^T e(t).i(t)\, dt = mK_p \eta\, E_{pk} I_{pk} \tag{1}$$

where

$e(t)$ and E_{pk} are phase air gap EMF and its peak value, $i(t)$ and I_{pk} are phase current and the peak phase current, η is machine efficiency, m is number of phases of the machine and T is period of one cycle of the EMF[2-4].

The quantity K_p is termed the electrical power waveform factor and defined as

$$K_p = \frac{1}{T} \int_0^T \frac{e(t) \times i(t)}{E_{pk} \times I_{pk}}\, dt = \frac{1}{T} \int_0^T f_e(t).f_i(t) dt \tag{2}$$

where

$f_e(t)=e(t)/E_{pk}$ and $f_i(t)=i(t)/I_{pk}$ are the expressions for the normalized EMF and current waveforms. In order to indicate the effect of the current waveform, a definition for current waveform factor, K_i, is also useful,

$$K_i = \frac{I_{pk}}{I_{rms}} = \left[\frac{1}{T} \int_0^T \left(\frac{i(t)}{I_{pk}} \right)^2 dt \right]^{-0.5} \tag{3}$$

where

I_{rms} is the rms value of the phase current. The peak value of the phase air gap EMF for AFPM in (1) is given by:

$$E_{pk} = K_e \, N_{ph} \, B_g \, . \frac{f}{p} . (1 - \lambda^2) \, D_o^2 \tag{4}$$

where

K_e is the EMF factor which incorporates the winding distribution factor K_w and the per unit portion of the total air gap area spanned by the salient poles of the machine (if any), N_{ph} is the number of turn per phase, B_g is the flux density in the air gap, f is the converter frequency, p is the machine pole pairs, is the diameter ratio for AFPM defined as D_i/D_o, D_o is the diameter of the machine outer surface, D_i is the diameter of the machine inner surface. The peak phase current in (1) is given by:

$$I_{pk} = A \, \pi \, K_i \, \frac{1+\lambda}{2} . \frac{D_o}{2 m_1 \, N_{ph}} \tag{5}$$

where

m_1 is number of phases of each stator and A is the electrical loading.

Combining (1) through (5), the general purpose sizing equations take the following form for AFPM.

$$P_{out} = \frac{m}{m_1} \frac{\pi}{2} K_e \, K_p K_i A \, B_g \, \eta \frac{f}{p} (1 - \lambda^2)(\frac{1+\lambda}{2}) D_o^3 \tag{6}$$

The machine power density for the total volume can be defined as

$$P_{den} = \frac{P_{out}}{\frac{\pi}{4} D_{tot}^2 L_{tot}} \tag{7}$$

where

D_{tot} is the total machine outer diameter including the stack outer diameter and the protrusion of the end winding from the iron stack in the radial direction, L_{tot} is the total length of the machine including the stack length and the protrusion of the end winding from the iron stack in the axial direction [2-4].

A. Sizing equations for the TORUS-S

The generalized sizing equation approach can easily be applied to axial flux permanent magnet TORUS type motor [4].

The outer surface diameter can be written as

$$D_o = \left(P_{out} \Big/ \frac{\pi m}{2 m_1} K_e \, K_p K_i A \, B_g \, \eta \frac{f}{p} (1 - \lambda^2)(\frac{1+\lambda}{2}) \right)^{1/3} \tag{8}$$

The machine total outer diameter D_{tot} for the TORUS-S motor is given by

$$D_{tot} = D_o + 2 W_{cu} \tag{9}$$

where

W_{cu} is the protrusion of the end winding from the iron stack in the radial direction. For the back-to-back wrapped winding, protrusions exist toward the axis of the machine as well as towards the outsides and can be calculated as

$$W_{cu}=\frac{D_i-\sqrt{D_i^2-\left(2AD_g/K_{cu}J_s\right)}}{2} \tag{10}$$

where

D_g is the average diameter of the machine, J_s is the current density and K_{cu} is the copper fill factor.

Note for the slotted topology machines the depth of the stator slot for slotted motors is $L_{ss}=W_{cu}$.

The axial length of the machine L_e is given by

$$L_e=L_s+2L_r+2g \tag{11}$$

where

L_s is axial length of the stator, L_r is axial length of the rotor and g is the air gap length. The axial length of the stator L_s is

$$L_s=L_{cs}+2L_{ss} \tag{12}$$

The axial length of the stator core L_{cs} can be written as

$$L_{cs}=\frac{B_g\ \pi\alpha_p\ D_o(1+\lambda)}{4p\ B_{cs}} \tag{13}$$

where

B_{cs} is the flux density in the stator core and α_p is the ratio of average air gap flux density to peak air gap flux density.

The axial length of rotor L_r becomes

$$L_r=L_{cr}+L_{PM} \tag{14}$$

Also, the axial length of the rotor core L_{cr} is

$$L_{cr}=\frac{B_u\ \pi\ D_o(1+\lambda)}{8p\ B_{cr}} \tag{15}$$

where

B_{cr} is the flux density in the rotor disc core, and B_u is the attainable flux density on the surface of the PM.

The PM length L_{PM} can be calculated as

$$L_{PM}=\frac{\mu_r B_g}{B_r-\left(\frac{K_f}{K_d}B_g\right)}K_c g \tag{16}$$

where

μ_r is the recoil relative permeability of the magnet, B_r is the residual flux density of the PM material, K_d is the leakage flux factor, K_c is the Carter factor, $K_f=B_{gpk}/B_g$ is the peak value corrected factor of air gap flux density in radial direction of the AFPM motor. These factors can be obtained using FEM analysis [4].

B. Sizing equations for the AFIR-S

The concept of Double-sided Axial Flux two-stator-one-rotor (AFIR) type PM motors was presented in [2-3].

The outer surface diameter D_o is obtained from (6).

$$D_o=\left(2P_{out}/\frac{\pi m}{2m_1}K_e K_p K_i A B_g \eta\frac{f}{p}(1-\lambda^2)(\frac{1+\lambda}{2})\right)^{1/3} \tag{17}$$

The machine total outer diameter D_{tot} for the AFIR type machines is given as

$$D_{tot}=D_o+2W_{cu} \tag{18}$$

where

W_{cu} is the protrusion of the end winding from the iron stack in the radial direction and can be calculated as

$$W_{cu} = \frac{(0.46 - 0.62) D_o}{p} \tag{19}$$

The axial length of the machine L_e is

$$L_e = L_r + 2L_s + 2g \tag{20}$$

where

L_s is axial length of the stator, L_r is axial length of the rotor and g is the air gap length. The axial length of a stator L_s is

$$L_s = L_{cs} + d_{ss} \tag{21}$$

where

L_{cs} is the axial length of the stator core, and the depth of the stator slot for slotted machines d_{ss} is

$$d_{ss} = \frac{D_i - \sqrt{D_i^2 - \left(2 A D_g \Big/ \alpha_s K_{cu} J_s \right)}}{2} \tag{22}$$

where

α_s is the ratio of stator teeth portion to the stator pole.

The axial length of the stator core L_{cs} *can* be written as

$$L_{cs} = \frac{B_g \pi \alpha_p D_o (1 + \lambda)}{8 p B_{cr}} \tag{23}$$

Since there is no rotor core in rotor PM topologies, the axial length of rotor L_r is

$$L_r = L_{PM} \tag{24}$$

The PM length L_{PM} can be calculated as

$$L_{PM} = \frac{2 \mu_r B_g}{B_r - \left(\frac{K_f}{K_d} B_g \right)} K_c g \tag{25}$$

III. Comparoson of TORUS-S and AFIR-S

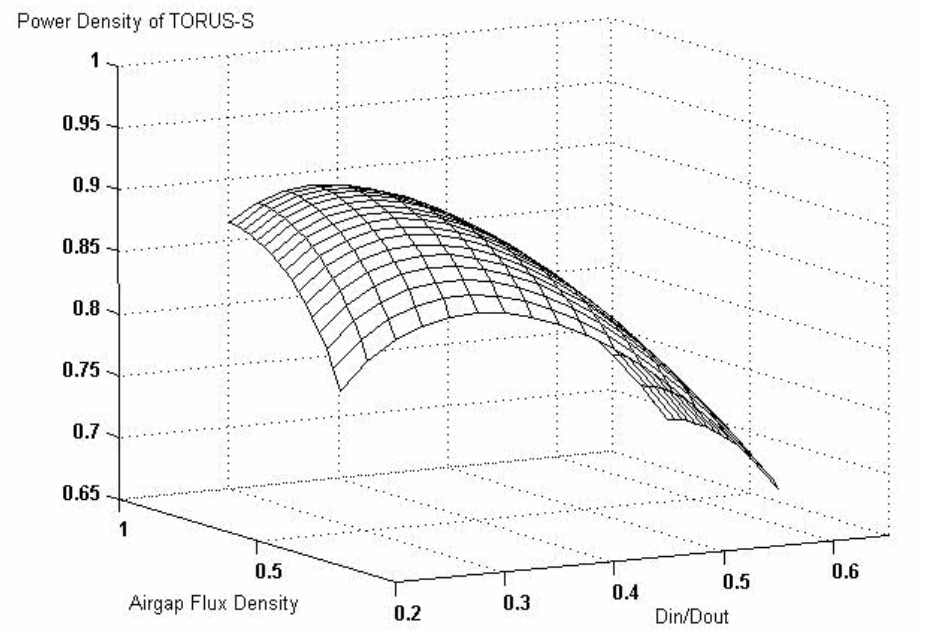
Comparison of two different Double-sided axial flux slotted PM motors in terms of power density is accomplished for 10KW output power, 4 poles and 60Hz drive. In this comparison, other constant parameters of motors are tabulated in table1.

Table 1: Constant parameters of motors in comparison

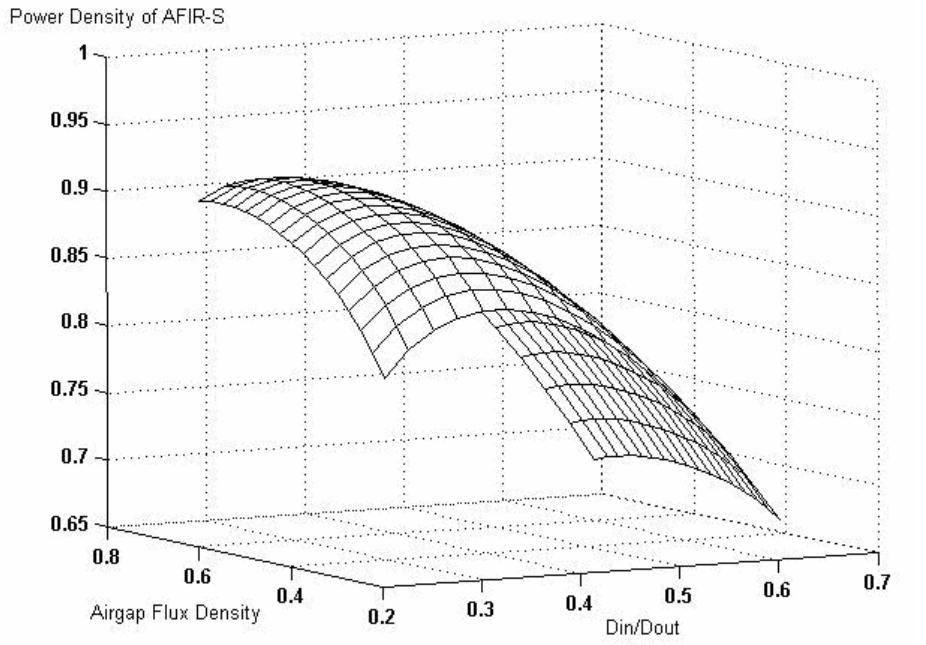
Number of phases	3
Slot fill factor	0.8
Pole arc ratio	0.75
Slot per Pole per Phase	1
flux density in stator	1.5 T
flux density in rotor	1.5 T
Efficiency	90%
Residual flux density of PM	1.1 T

In AFPM motors, the air gap flux density and diameter ratio are the two important design parameters which have significant effect on the motor characteristics. Therefore, in order to optimize the motor performance, the diameter ratio and the air gap flux density must be chosen carefully. Fig.3 shows the power density variation as a function of air gap flux density and the diameter ratio for the AFIR-S and TORUS-S motors.

Figure 3: Power density vs. air-gap flux density and diameter ratio for A=20000 (A/m), g=1 (mm), J_s=6000000 (A/m^2) a) TORUS-S b) AFIR-S



(a)



(b)

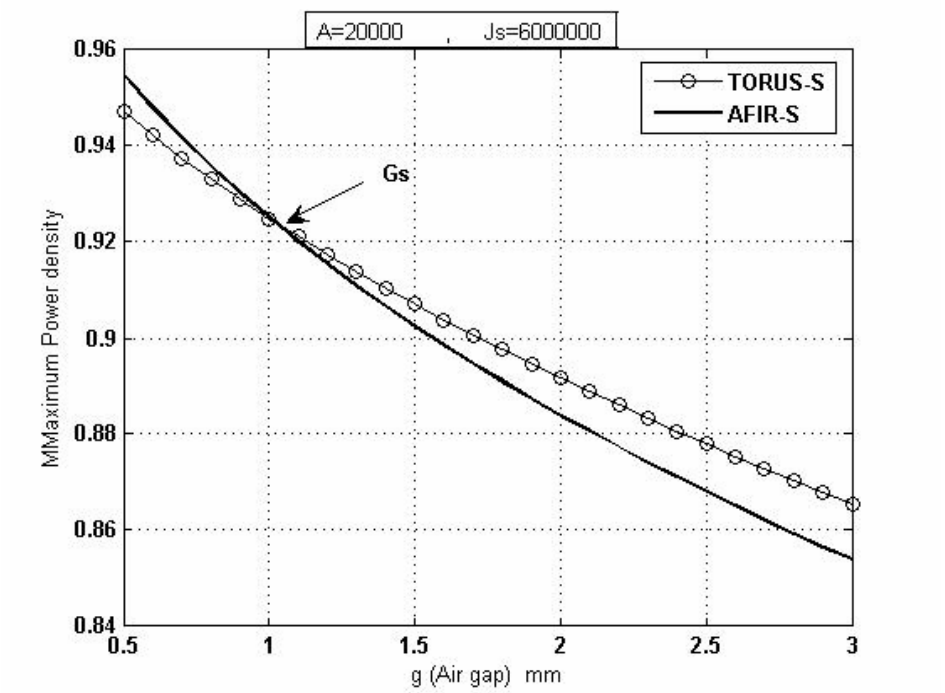
As can be seen from Fig.3b, the maximum power density occurs at Bg=0.528 (T) and $\lambda = 0.261$. In various air gap length, the maximum power density occurs in different *Bg* and λ. Table2 shows maximum power density with corresponding *Bg* and λ.

Table 2: Maximum power density with corresponding Bg and λ

Type	g (mm)	*Bg* (T)	λ	Maximum power density (W/cm^3)
TORUS-S	1	0.579	0.289	0.925
	1.5	0.569	0.271	0.907
	2	0.565	0.271	0.89
	2.5	0.569	0.271	0.878
AFIR-S	1	0.528	0.261	0.925
	1.5	0.518	0.261	0.902
	2	0.507	0.26	0.884
	2.5	0.518	0.251	0.87

Fig.4 shows the maximum power density variation as a function of air gap length for the AFIR-S and TORUS-S motors for A=20000 (A/m), J_s=6000000 (A/m^2).

Figure 4: Maximum power density AFIR-S and TORUS-S vs. air gap length



In special air gap length (this air gap length is called G_s) maximum power density of AFIR-S and TORUS-S motors will be the same. Considering Fig.4, it can be concluded that in large air gap length, slotted TORUS motor has high power density.

IV. 2D Finite Element Analysis of Field

In order to analyze the magnetic circuit and power density, 2D Finite Element Analysis was used for both TORUS-S and AFIR-S type motors. The purpose of the FEM is to get the overall picture of the saturation levels in various parts of the machine, to compare the flux densities obtained from FEM and sizing analysis.

A. FEM of the AFIR-S Motor

The motor parameters and important design dimensions used for the AFIR-S model are shown in Table 3.

Fig.5 shows the flux distribution over one pole pair using FEM.

Fig.6 shows the air gap Flux density over one pole at the average diameter (Dg) using FEM. This curve shows that the flux density on the edge of the Slots is about 13% lower than the flux density on the center of the PM because of the magnet leakage flux.

Table 3: Parameters and dimensions of slotted AFIR-S motor

Air gap length	1 mm
Slot depth	9 mm
Pole-arc-ratio	0.75
Axial length of stator core	16 mm
Axial length of rotor core	40 mm
Axial length of PM	2 mm
Outer diameter	367 mm
Inner diameter	95.5 mm

Figure 5: flux distribution over one pole pair for AFIR-S

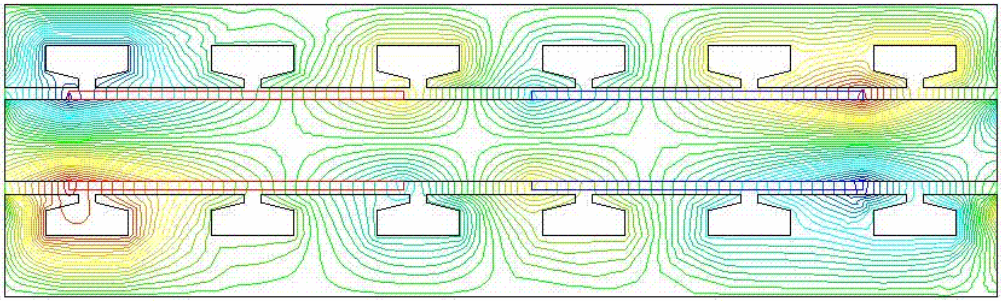
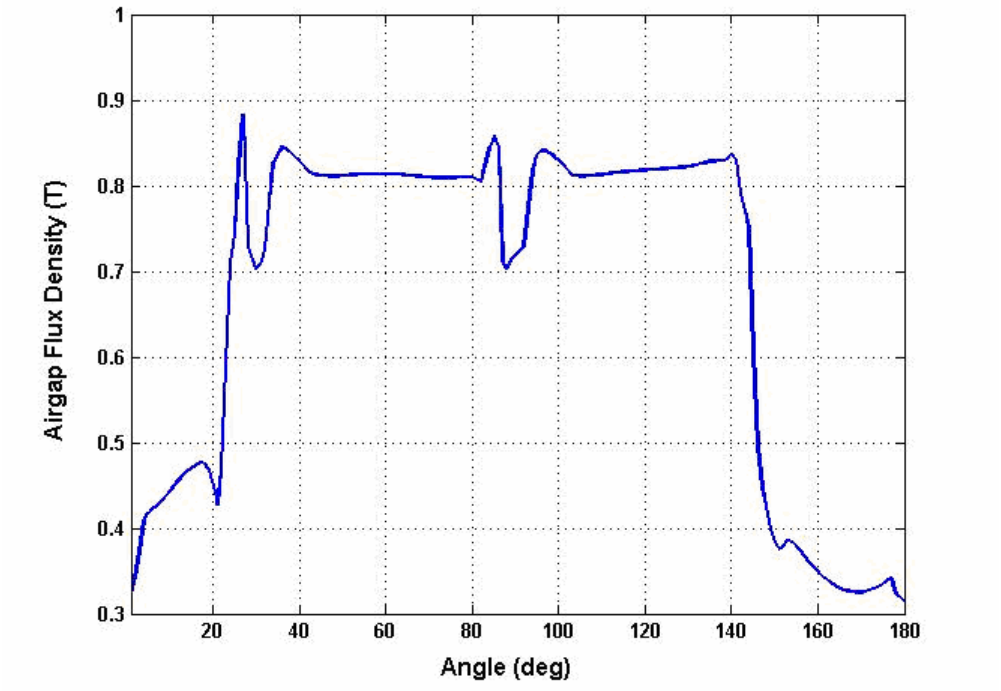


Figure 6: Air gap flux density over one pole for AFIR-S



A flux density comparison between the FEM results and sizing analysis results on various parts of the slotted AFIR motor at no load is tabulated in Table4. The comparison table shows that the FEM results are consistent with the results obtained from the sizing analysis.

Table 4: Flux density comparison of slotless AFIR-S motor

	Rotor	Air gap		Stator
	B_{cr}	B_{max}	B_{avg}	B_{cs}
FEM	1.5	0.82	0.55	1.45
Sizing Eq.	1.5 T	0.8	0.53	1.5

B. FEM of the TORUS-S Motor

The parameters and optimized TORUS-S motor dimensions used in the design which are calculated using sizing equations are shown in Table 5.

Table 5: Parameters and dimensions of slotted TORUS-S motor.

Air gap length	1 mm
Slot depth	10 mm
Pole-arc-ratio	0.75
Axial length of stator core	42 mm
Axial length of rotor core	25 mm
Axial length of PM	2 mm
Outer diameter	356 mm
Inner diameter	103 mm

Fig.7 shows the flux distribution over one pole pair using FEM. The air gap flux density at the average diameter (*Dg*) over one pole using FEM was obtained and is shown in Fig.8.

Figure 7: flux distribution over one pole pair for TORUS-S

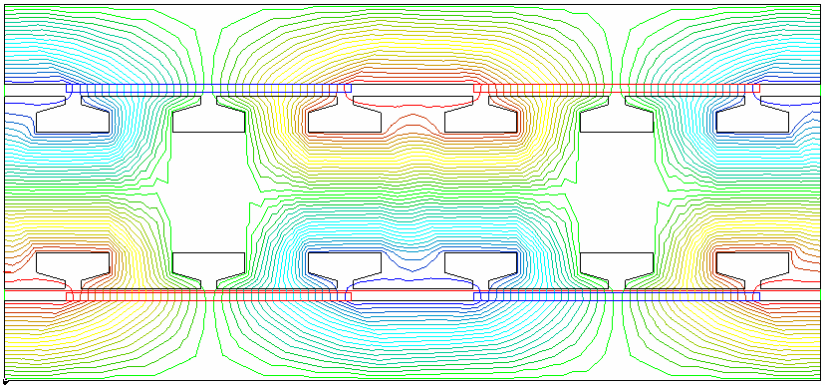
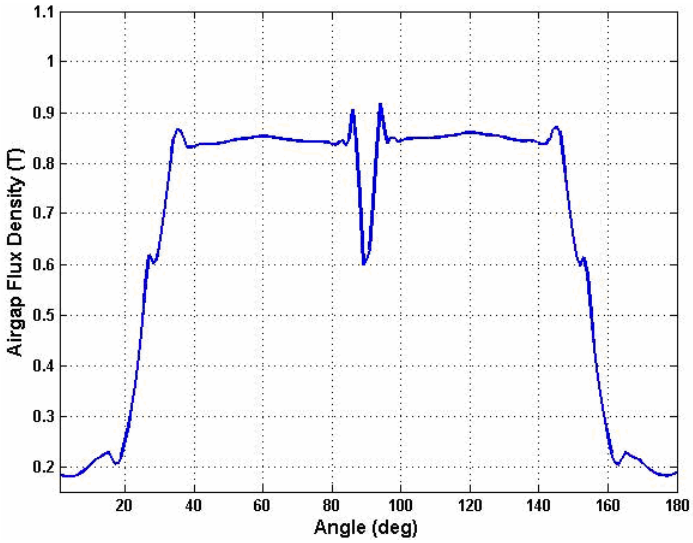


Figure 8: Air gap flux density over one pole for TORUS-S



A comparison of the flux densities between the FEM results and sizing analysis results for different parts of the machine at no load is tabulated in Table 6.

Table 6: Flux density comparison of slotless TORUS-S motor

	Rotor	Air gap		Stator
	B_{cr}	B_{max}	B_{avg}	B_{cs}
FEM	1.52	0.85	0.6	1.44
Sizing Eq.	1.5 T	0.8	0.58	1.5

From the no load flux density plots, it is seen that the results are again consistent with the results obtained from the sizing analysis, the maximum flux density values on the rotor and stator came out almost the same. Also, the maximum and average airgap flux densities obtained from the FEM and sizing analysis agree well.

C. Effect of electrical loading and current density

The considerable point is that the value of Gs will vary when the electrical loading *'A'* and current density *'Js'* changes. Fig.9 shows the variation of the maximum power density as a function of air gap length in A=25000 (A/m), J_s=6000000 (A/m^2) for the AFIR-S and TORUS-S motors. Fig.10 shows the variation of the maximum power density as a function of air gap length in A=20000 (A/m), J_s=7000000 (A/m^2) for the AFIR-S and TORUS-S motors also.

Figure 9: Maximum power density AFIR-S and TORUS-S vs. air gap length

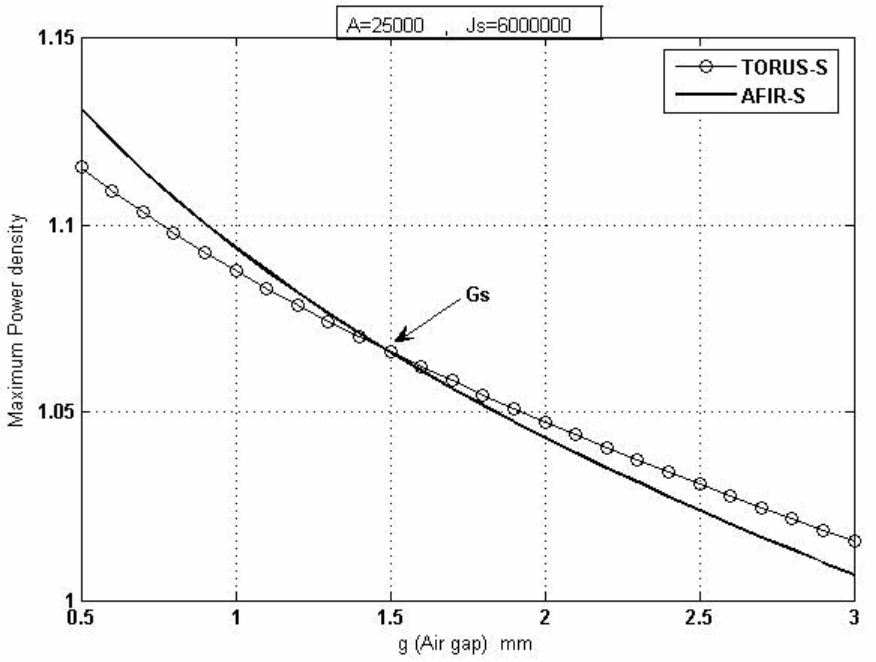
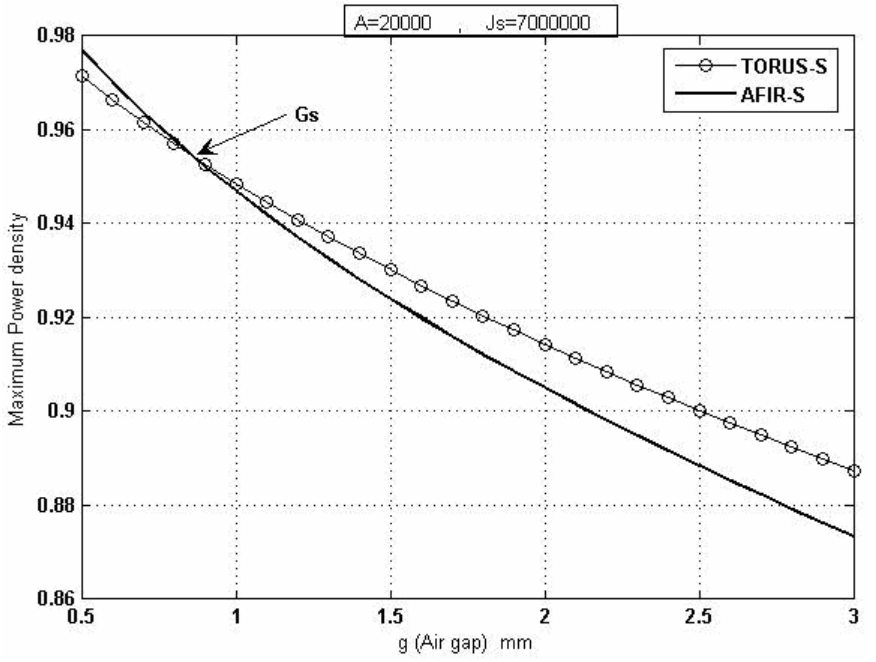


Figure 10: Maximum power density AFIR-S and TORUS-S vs. air gap length



According to Fig.9 it can be concluded that point *Gs* is shifted to larger air gaps and this means that in smaller air gaps AFIR-S motor has higher maximum power density. According to Fig.10 it can be concluded that point *Gs* is shifted to smaller air gaps and this means that in higher air gaps TORUS-S motor has higher maximum power density. Other value of *Gs* for various A and Js are tabulated in table 7.

Table 7: Other value of Gs for Various A and Js

A *(A/m)*	Js *(A/m^2)*	Gs *(mm)*
20000	6000000	1.02
22000	6000000	1.2
25000	6000000	1.5
30000	6000000	2.23
20000	6500000	0.89
20000	7000000	0.83
20000	8000000	0.7
20000	9000000	0.58

V. Conclusions

Selecting an AFPM motors with higher power density is an important parameter in applications. The main goal of this paper has been introduce to double-Sided Axial Flux Slotted PM Motors with maximum power density. There are two topologies for slotted double-sided AFPM motors.

The maximum power density is changed by different value of the air gap, electrical loading and current density. TORUS-S topology has high power density in high current density and low electrical loading. But, AFIR-S topology has high power density in low current density and high electrical loading.

A flux density comparison between the various parts of the slotted AFIR-S and TORUS-S motors obtained from the FEM and sizing analysis at no load agree well.

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State Oriented Software Integration Testing for Object Oriented Applications

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Abstract

In the Object Oriented Integration testing of application on state based approach, the novel method in research is SCOTEM (State Collaboration Test Model), analysis of SCOTEM model is done and various Mutants are analyzed. This knowledge is put forth in a sample Object Oriented application we have developed and the Integration testing strategy is sketched out, various test path generation criteria, and test flow sequence has been analyzed with the help of UML.

The present SCOTEM model deals with only flat objects testing, it do not deal with objects which are changing the state of the other objects. We have come out with an algorithm which can work for interacting objects. In this paper we have modified the SCOTEM construction algorithm.

1. Introduction

1.1. Constraints in Object Oriented Integration Testing

Object oriented programs are Event-Driven in nature. These events are of more concern during the Integration Testing phase where it is not during the Unit Testing phase. Dynamic binding in Object oriented programs also creates indefiniteness. The encapsulation concept leads Class Firewall concept. Integration testing can *access Memory [1]* events and conditions that are invisible at the system level. Much of the descriptive power of graph theory based structural testing techniques will not be applicable for OO integration testing [1].

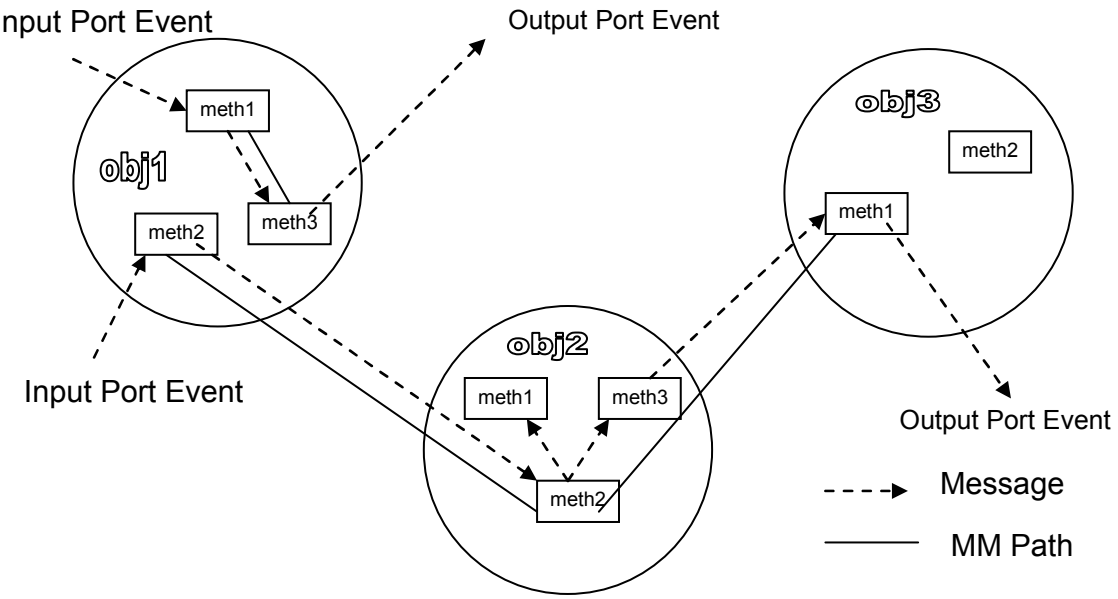
1.2. Five distinct levels of object-oriented Integration testing [2]

- A method,
- Message quiescence,
- Event quiescence,
- Thread testing,
- Thread interaction testing

1.3. The Interactive Nature of Objects [1]

As in Fig 1, the objects in OO program will interact the interaction may be between methods in the same objects or between methods of two different objects. So the integration testing will be concentrating on Object-Object interaction [1] rather than inside the objects.

Figure 1:



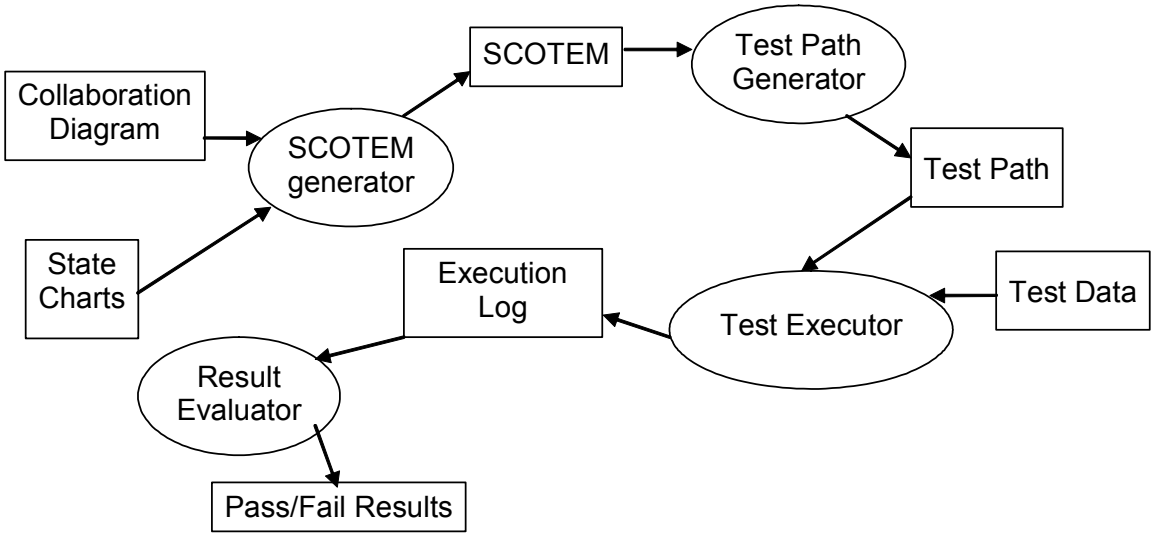
2. State Collaboration Test Model (Scotem) [3]

SCOTEM [3] is an intermediate test model constructed from a UML collaboration diagram, and the corresponding state charts. It is a very novel approach to OO Integration Testing. The various phases in SCOTEM are given below.

- ***SCOTEM Generation***: An intermediate test model, called SCOTEM (State Collaboration Test Model) is constructed from a UML collaboration diagram, and the corresponding state charts.
- ***Test Paths Generation***: Test paths are generated from the SCOTEM based on several possible alternative coverage criteria.
- ***Test Execution***: All selected test paths are executed by using manually-generated test data and an execution log is created, which records object states before and after execution of each message in a test path. The object states are determined using state invariant assertions.
- ***Result Evaluation***: The object states in the execution log are compared with the expected object states in the test paths generated from SCOTEM. This means that these test paths also contain oracle information in the form of expected states of the objects. If any state of any object after execution of a test path is not in the required resultant state, then the corresponding test case is considered to have failed.

Collaboration charts and state charts [3] are given as input to the scotem generator using which it as generate various test path state charts. Refer Fig.2 for the entire SCOTEM model flow

Figure 2:



The SCOTEM is a specific graph structure: A vertex corresponds to an instance of a class (in a particular state) participating in the collaboration.

A *Modal Class [3]* can receive a message in more than one state and exhibit distinct behavior for the same message in different states. To capture this characteristic, for modal classes, the SCOTEM contains multiple vertices, where each vertex corresponds to an instance of the class in a distinct abstract state (corresponding to states defined in state charts). On the other hand, a non-modal class only requires a single vertex in the SCOTEM graph [3].

The edges in the SCOTEM test model are of two types: message and transition edges. A message edge represents a call action between two objects, and a transition edge represents a state-transition of an object on receiving a message. Each message [3] edge may also contain a condition or iteration. Each message may cause a state transition to occur. A transition edge connects two vertices of the same class. State charts may have multiple transitions to distinct states for the same operation. Hence, there may be multiple transition edges (representing a conditional state transition) for the same message edge in SCOTEM. Each of these transitions is generally controlled by mutually exclusive conditions (to prevent non-determinism). The internal representation of a vertex holds the class name and state of the instance it corresponds to. Message edges are modeled in the SCOTEM by attributes of a message including message sequence number, associated operation, receiver object, and the sender object. The transition edges are modeled by the attributes of a transition including sequence number, associated operation, accepting state and sending state.

2.1. Mutants for Integration Testing

During the Integration Testing using SCOTEM, the following mutants [3], that is metrics have to be taken into consideration.

- Parameter Changed Operator
- Wrong Initial State
- Replace Return Statement
- Remove Function Call – removing each function call in an object one at a time.
- Loop Error Set
- Missing Called Function – removing functions that are called by an object one at a time
- Wrong Calling State – set state of calling object to invalid state

- Conflicting State Operator – setting of two objects of different classes in states that are conflicting each other

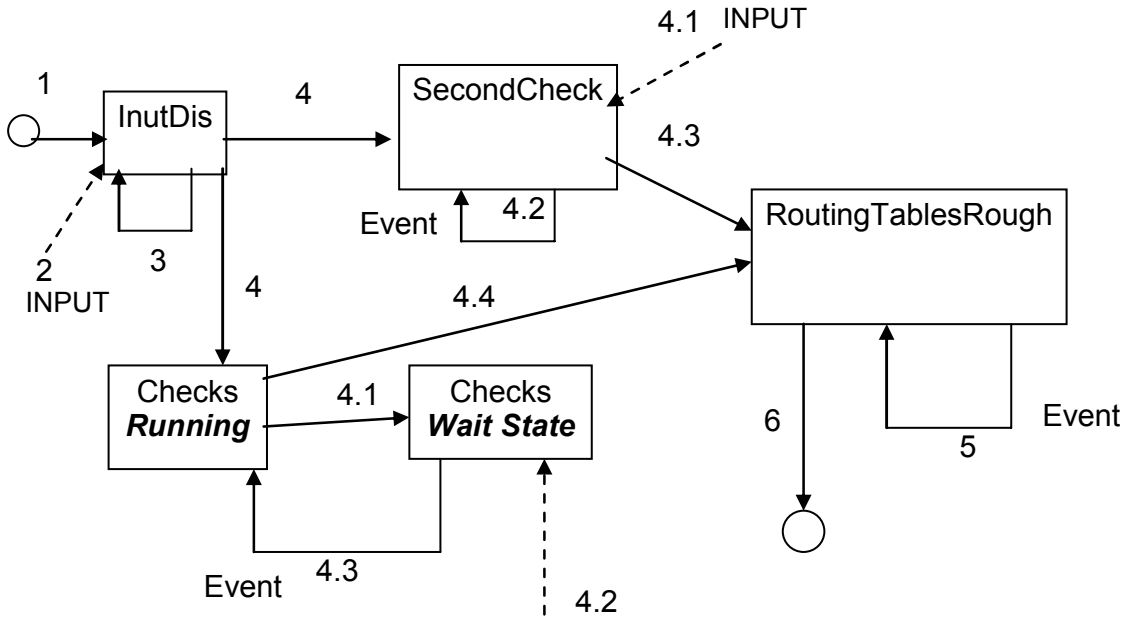
3. Case Study -Tesing Distance Vector Routing Algorithm Simulation

We have developed distance vector routing algorithm simulation in java to test out based on the SCOTEM model. The details of the classes in the application are in the Table.1.

Table 1:

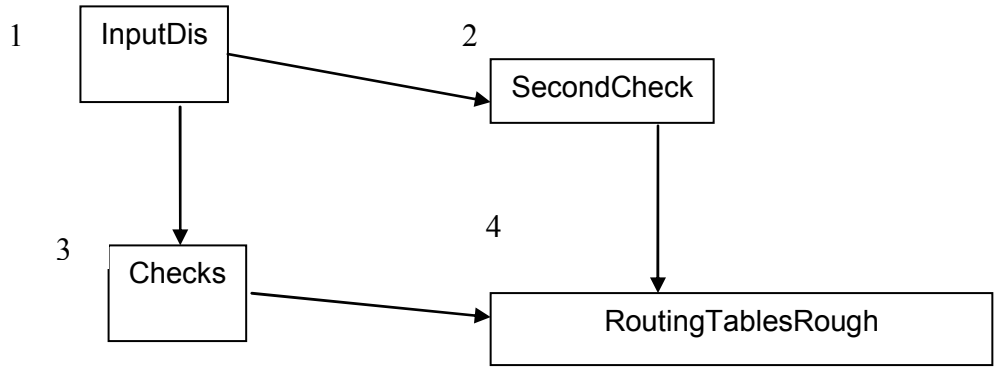
#	Classes	#Methods	#Instance Variables	Test Specials
1	InputDis.java	3	3	Interfaces, Event Driven
2	Checks.java	3	7	Threads
3	RoutingTables.java	5	15	Interfaces, Event Driven
4	SecondCheck.java	2	11	Interfaces, Event Driven

Figure 3:



3.1. The Integration Sequence

Figure 4:



The above Fig.4 shows the order in which the integration of the application has to be carried out.

4. Modified Scotem Generation Algorithm

The SCOTEM generation[3] in the present scenario did not take care of objects which are changing the state of other objects in the case of events appearance we have modified the existing the SCOTEM algorithm and made some more changes to increase the early detection of the inconsistency of state matching.

4.1. Algorithm

Inputs

C: Collaboration Diagram corresponding to a message
S: Set of state charts required for classes involved in a collaboration diagram C
E: Set of Events
ES: Event State Map table

Output

T: SCOTEM test model generated by the algorithm

Assumptions

- State of one object influencing the state of other objects
- The collaboration has synchronous call messages and composition visibility only

Declare

- ***RESULTANTSTATES$_{Set}$***:
  A set of resultant states corresponding to a message
- ***STATE$_{Set}$***:
  A set of states of a particular class
- ***CURRENTSTATESOURCE$_{Set}$***:
  A set of states of source class of current message of collaboration diagram
- ***CURRENTSTATETARGET$_{Set}$:***
  A set of states of target class of current message of collaboration diagram
- ***ME$_{Seq}$:***
  Sequence of message edges of collaboration diagram C
- ***msg:***
  A message edge in T
- ***v, v$_{source}$,v$_{rs}$:***
  All these variables represent vertices in a SCOTEM test model
- ***Event Detected:***
  What event has occurred during testing
- ***Event State:***
  State of the Object after event has occurred
- ***addVertex(v, T):***
  A function that adds a vertex v to the SCOTEM test model T
- ***addMessageEdge(v$_{source}$, v$_{target}$):***
  A function that adds a message edge from source vertex to target vertex including loop and path condition if any exists.
- ***addTransitionEdge(v$_{source}$, v$_{target}$):***
  A function that adds a transition edge from source vertex to target vertex including guard if any exists.
- ***getVertex(state, class):***

A function that returns a vertex of test model T representing class in a state

- ***createVertex(state, class):***

A function that creates a vertex of test model T representing class in a state

```
1. Begin
2. v <- null
3. AddVertex (v, T)
4. CURRENTSTATESOURCE_Set ← null
5. ME_Seq ← Ç.message
6. RESULTANTSTATES_Set ← {}
7. for all msg ∈ ME_Seq do
8.      if (not msg.source = null)
9.      RESULTANTSTATES_Set -> Select (state: State¦Select(s:S¦s.class = msg.target).transition =
        msg and state=transition.sourceState)
10.     end If
11.     STATESet -> Select(s:S¦s.class = msg.target).state
12.     if (not RESULTANTSTATES_Set ⊆ STATE_Set)
13.     Report Inconsistency
14.          if (continueVertexAddting = Yes);
15.          else break;
16.          end If
17.     end If
18.     if (Event Detected ⊆ E_Set)
19.          if (not EventState = ES_Set)
20.          Report Inconsistency
21.          if (continueVertexAddting = Yes);
22.          else break;
23.          end If
24.     end if
25.     CURRENTSTATETARGET_Set -> Select (state: State¦Select(s:S¦s.class =
        msg.target).transition = msg)
26.     for all os ∈ CURRENTSTATESOURCE_Set do
27.          vsource <- getVertex (os,msg.source)
28.               for all ot ∈ CURRENTSTATETARGETSet do
29.                    v ← createVertex (ot,msg.target)
30.                    AddVertex (v, T)
31.                    AddMessageEdge (vsource, v)
32.                    CURRENTSTATESsource ← RESULTANTSTATESSet ←
                       Select(state:State¦ Select(s:Š¦s.class = msg.target).transition = msg
                       and state=transition.targetState)
33.                    for all rs ∈ RESULTANTSTATESSet do
34.                         if (not rs ∈ Ť)
35.                         vrs <- createVertex(rs,msg.target)
36.                         AddVertex (vrs,Ť)
37.                         end If
38.                         AddTransitionEdge (v, vrs)
39.                    end for
40.               end for
41.          end for
42.     return Ť
43.     end
```

4.2. Modified Algorithm's Description and its features

The existing SCOTEM algorithm deals only with the flat objects, it is not dealing with interacting objects based on events, and the existing algorithm is a design for entire integration testing, even in any step during the integration testing, if inconsistency failure occurs, the algorithm will report and go on till building the entire application, that is it will do the building of all the vertices, so in our modified algorithm we have given a check for event based objects(from line number 18) and the corresponding declaration for event-state mapping is done in the start of the algorithm. If any discrepancies occurred in the state of the test result object and the state in the log, then the tester can abort the test in the middle, this functionality has been added.

4.3. SCOTEM Model Simulation Code

The Java code for the simulation of the SCOTEM model is given in the Appendix I. The application is developed with the user interface in Java Swing.

5. Conclusion

A detailed study has been carried out on Object Oriented Integration Testing based on SCOTEM model and OO Integration testing strategy has been done for the case study application we have developed and the SCOTEM generation algorithm has been modified to get the step by step integration approach for a very large OO applications and the algorithm is proposed for the interactive objects. Regarding the future work on this model, this SCOTEM is efficient for a standalone application, but if some modifications are done, this can be implemented for Service Oriented Software Architecture applications when we go for UML-RT as input for the SCOTEM. Port concept has to be taken into account when we go for SOA kind of applications using SCOTEM.

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Appendix I

First.java

```
package scotem;

import javax.swing.*;
import javax.swing.event.*;
import java.awt.event.*;
import java.awt.*;
import java.util.*;

public class First extends JFrame implements ActionListener
{

	JLabel totalClasses,totalMessages,totalEvents,totalStates;
	JTextField totClasses,totMessages,totEvents,totStates;
	JButton butSubmit;
	public First()
	{
			setSize(1000,700);
			getContentPane().setLayout(null);
			setTitle("Scotem Model Simulation");

			totalClasses = new JLabel("Enter Total Number of Classes");
			totalClasses.setFont(new Font("Times New Roman",Font.BOLD,15));
			totalClasses.setBounds(90,20,250,20);
			getContentPane().add(totalClasses);

			totClasses = new JTextField();
			totClasses.setBounds(400,20,40,20);
			totClasses.addActionListener(this);
			getContentPane().add(totClasses);

			totalMessages = new JLabel("Enter Total Number of Messges");
			totalMessages.setFont(new Font("Times New Roman",Font.BOLD,15));
			totalMessages.setBounds(90,50,250,20);
			getContentPane().add(totalMessages);

			totMessages = new JTextField();
			totMessages.setBounds(400,50,40,20);
			totMessages.addActionListener(this);
			getContentPane().add(totMessages);

			totalEvents = new JLabel("Enter Total Number of Events");
			totalEvents.setFont(new Font("Times New Roman",Font.BOLD,15));
			totalEvents.setBounds(90,80,250,20);
			getContentPane().add(totalEvents);

			totEvents = new JTextField();
			totEvents.setBounds(400,80,40,20);
			totEvents.addActionListener(this);
```

```
                getContentPane().add(totEvents);

                totalStates = new JLabel("Enter Total Number of States");
                totalStates.setFont(new Font("Times New Roman",Font.BOLD,15));
                totalStates.setBounds(90,110,250,20);
                getContentPane().add(totalStates);

                totStates = new JTextField();
                totStates.setBounds(400,110,40,20);
                totStates.addActionListener(this);
                getContentPane().add(totStates);

                butSubmit=new JButton();
                butSubmit.setText("Submit");
                butSubmit.addActionListener((ActionListener) this);
                butSubmit.setBounds(410,220,100,30);
                getContentPane().add(butSubmit);

                setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
                setVisible(true);

        }

        public static void main(String[] args)
        {

                new First();

        }

        public void actionPerformed(ActionEvent arg0)
        {

                int totalClasses=Integer.parseInt(totClasses.getText());
                int totalMessages=Integer.parseInt(totClasses.getText());
                int totalEvents=Integer.parseInt(totClasses.getText());
                int totalStates=Integer.parseInt(totClasses.getText());

                new Second(totalClasses,totalMessages,totalEvents,totalStates);

        }
}
```

Second.java

```
package scotem;

import javax.swing.*;
import javax.swing.event.*;
import java.awt.event.*;
import java.awt.*;
```

```
import java.util.*;

public class Second extends JFrame implements ActionListener
{
	JButton butEvent,butMessage;
	ArrayList stateArrList,eventArrList;
	int totalClasses,totalMessages,totalEvents,totalStates;

	public Second(int totClasses,int totMessages,int totEvents,int totStates)
	{
		setSize(1000,700);
		getContentPane().setLayout(null);
		setTitle("Scotem Model Simulation");

		totalClasses=totClasses;
		totalMessages=totMessages;
		totalEvents=totEvents;
		totalStates=totStates;

		stateArrList = new ArrayList();
		eventArrList = new ArrayList();

		for (int i=0;i<totalStates;i++)
		{
			stateArrList.add(Integer.toString(i+1));
		}

		for (int i=0;i<totalEvents;i++)
		{
			eventArrList.add(Integer.toString(i+1));
		}

		butMessage=new JButton();
		butMessage.setText("Messages Input");
		butMessage.addActionListener((ActionListener) this);
		butMessage.setBounds(410,220,160,30);
		getContentPane().add(butMessage);

		butEvent=new JButton();
		butEvent.setText("Trigger Event");
		butEvent.addActionListener((ActionListener) this);
		butEvent.setBounds(410,280,160,30);
		getContentPane().add(butEvent);

		setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
		setVisible(true);

	}

	public void actionPerformed(ActionEvent ae)
	{
```

```
int randomResultantState,randomEvent;
int stateArrListSize,flag=0,eventflag=0;
Object arrayStates[],arrayEvents[];
ArrayList output = new ArrayList();
ArrayList errorClasses=new ArrayList();

arrayStates=stateArrList.toArray();
if (ae.getSource().equals(butMessage))
{

        for (int z=0;z<totalClasses;z++)
        {

                for (int i=0;i<totalMessages;i++)
                {
                        randomResultantState = (int) (Math.random()*(totalStates+1));
                        randomResultantState = randomResultantState + 1;
                        System.out.print(randomResultantState);

                        for (int j=0;j<stateArrList.size();j++)
                        {
                                flag=1;
                                if (randomResultantState == Integer.parseInt
                                (arrayStates [j]. toString()))
                                {
                                        flag=0;
                                        break;
                                }
                         }
                         if (flag==0) continue;
                         if (flag==1)
                         {
                         errorClasses.add(Integer.toString(z+1));break;
                         }
                }
        if (flag==0)output.add(Integer.toString(z+1));
        }

System.out.println("Classes with Inconsistencies in their states"+errorClasses);
System.out.println("Classes without Inconsistencies in their states"+output);
new MessageResults(errorClasses,output);
}
if (ae.getSource().equals(butEvent))
{
        randomEvent = (int) (Math.random()*(totalEvents+1));
        randomEvent = randomEvent+1;
        System.out.println(eventArrList);
        System.out.println("Random Event Generated = "+randomEvent);
        System.out.println(stateArrList);
        arrayEvents=eventArrList.toArray();
        for (int i=0;i<eventArrList.size();i++)
```

```
                        {
                                if (randomEvent == Integer.parseInt(arrayEvents[i].toString()))
                                {
                                        eventflag=1;
                                        break;
                                }
                                continue;
                        }

                        if (eventflag==1)
                        {
                                randomResultantState = (int) (Math.random()*(totalStates+1));
                                randomResultantState = randomResultantState + 1;
                                for (int i=0;i<stateArrList.size();i++)
                                {
                                        if (randomResultantState ==
                                        Integer.parseInt(arrayStates[i].toString()))
                                        {
                                                JOptionPane.showMessageDialog(null,"WARNIN
                                                G: No Error", "Alert",
                                                JOptionPane.INFORMATION_MESSAGE);

                                                eventflag=0;
                                                break;
                                        }

                                }
                                if (eventflag==1)
                                        JOptionPane.showMessageDialog(null,"WARNING: State
                                        Error Has Occured Due to the Event", "Alert",
                                        JOptionPane.INFORMATION_MESSAGE);

                        }
                        else if (eventflag==0)
                        {
                                JOptionPane.showMessageDialog(null, "WARNING: Unidentified
                                Event", "Alert", JOptionPane.INFORMATION_MESSAGE);
                        }
                }

        }
}
```

MessageResults.java

```
package scotem;

import javax.swing.*;
import javax.swing.event.*;
import java.awt.event.*;
import java.awt.*;
```

```
import java.util.*;

public class MessageResults extends JFrame
{

	JLabel withError,withOutError;
	JList jListError,jListNoError;

	public MessageResults(ArrayList errorArray, ArrayList noErrorArray)
	{
		setSize(1000,700);
		getContentPane().setLayout(null);
		setTitle("Test Results");

		Object error[]=errorArray.toArray();
		Object Noerror[]=noErrorArray.toArray();

		withError=new JLabel("Classes - Inconsistency");
		withError.setBounds(90,60,150,20);
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Electrochemical Study for the Corrosion Inhibition of Mild Steel in Hydrochloric Acid by Untreated and Treated Camel's Urine

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Abstract

The corrosion inhibition of mild steel in 0.5 M Hydrochloric acid solution by untreated camel's urine (UTCU) and treated camel's urine by anion exchanger resin (TCUAE) has been studied by electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization (PDP) measurements. Results showed that the inhibition efficiency increases with inhibitor concentration up to critical one then it tends to decrease with further increase in concentration. Polarization curves revealed that both UTCU and TCUAE are mixed type inhibitors. Adsorption of inhibitor species for both UTCU and TCUAE was found to follow the modified form of Lngmuir adsorption isotherm. The trend of inhibitor adsorption with temperature suggested chemisorption process. Kinetic corrosion parameters and heat of adsorption process were determined and discussed. A correlation between Camel's urine constituents and its inhibitive action is obtained.

1. Introduction

Humans have most likely been trying to understand and control corrosion for as long as they have been using metal objects. The most important periods of prerecorded history are named for the metals that were used for tools and weapons (Iron Age, Bronze Age). Metals are usually extracted from ores through the application of a considerable amount of energy. ***Corrosion***, then, is simply the strong tendency of an elemental metal to revert to its natural state [1]. Hence, corrosion is the primary means by which metals deteriorate.

Most metals corrode on contact with water (and moisture in air), acids, bases, salts, oils and other solid liquid chemicals. Metals will also corrode when exposed to gaseous materials like acid vapors. Like other hazards such as earthquakes or severe weather disturbances, corrosion can cause dangerous and expensive damage to every thing from vehicles, home applications and water and wastewater systems, to pipelines, bridges and public buildings. Attempts to halt this natural phenomenon can cost fortunes. Several techniques abound for preventing or controlling corrosion in metals or engineering components. Some attempts to modify the properties of the metals in an environment while some try to alter or modify the environment with the aim of curtailing the corrosive effect of the environment on metals. Many years ago scientists have succeeded in modifying the environments among other methods through the injection of substances that can reduce the rate of corrosion. These substances, which are sometimes referred to as retarding catalyst, are generally called inhibitors [2].

Inhibitors often work by adsorbing themselves on the metallic surface, protecting the metallic surface by forming an invisibly thin or perhaps visibly bulk precipitates [2]. As the corrosion process is electrochemical in nature with four components are: an anode, a cathode, an electrolyte, and some direct electrical connection between the anode and cathode, the adsorbed inhibitor then acts to slow corrosion process by either:

- Increasing the anodic and/or cathodic polarization behaviour;
- Reducing the movement or diffusion of ions to the metallic surface;
- Increasing the electrical resistance of the metallic surface.

The use of inhibitors for corrosion prevention has been well established and numerous inhibitors have been documented. Unfortunately, some of the technically most important and most effective inhibitors for use in corrosion inhibition are toxic and therefore subjected to extensive handling and storage restrictions. So, due to increasing environmental awareness and the need to develop environmentally friendly processes, attention has been focused on the corrosion inhibiting properties of natural products mainly of plant origin to keep the environment more healthy, safely and under pollution control.

Recently, various natural products from plant origins e.g. Artemisia oil [3], Nypa fruticans Wurmb leaves extract [4], Lawsonia extract [5], Telfaria occidentalis extract [6], juice of Prunus cerasus [7], Pennyroyal oil from Mentha oulegium [8], Occimum viridis extract [9], etc. have been reported to be good inhibitors for steel in acid solutions. As noticed, all the previous natural inhibitor was obtained from plant origin while that obtained from animal origin was reported by the author in recent work [10], this was the calm's urine (CU). Calm's urine can be classified as environmentally friendly inhibitor, because drinking of CU for therapeutic purposes was indicated since 14 century in the Moslem Sunna by Prophet Mohammed Peace Upon Him. Moreover, microbiological studies [11] on CU proved its high efficiency against a number of pathogenic microbes when compared with some antibiotics.

In the present work The effect of the untreated camel's urine (UTCU) and treated camel's urine by anion exchanger resin, TCUAE, on the electrochemical behaviour of mild steel in 0.5 M HCl solution is investigated using the electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization (PDP) measurements. The effect of five different temperatures in the range from 30 to70 ^{o}C on the electrochemical behaviour of mild steel in 0.5 M HCl solution in absence and presence of certain concentration of UTCU and TCUAE has also been studied. Hence, Kinetic and activation parameters that govern metal corrosion have been evaluated.

2. Experimental

2.1. Metal specimen

The experiments were performed on mild steel rod with weight percentage composition as follows: = 0.250%, Mn=0.480, Si=0.300, Ni=0.040, Cr=0.060, Mo=0.020, S=0.021, P=0.019 and the rest up to 100% Fe.

2.2. Reagents

A strongly basic anion exchanger resin (Dowex S. B. R.) in the chloride form was used for CU treatment. The aggressive solution (blank solution) of o.5 M HCl was prepared by dilution of analytical grade 97% HCl with de-ionized water.

2.3. Inhibitor

The camel's urine sample is extracted from male camel (one humped) with age around 6 years, early in the evening. Physically, the fresh extracted urine appears clear, amber yellow and watery. The CU

sample was divided into two sections in measuring flask of 250 ml, one of them was kept as plank without any treatment while the other section was treated by anion exchanger resin as follows:

- 250 ml of urine sample was mixed with 10 g of the anion exchanger for 2 hours in round flask with high speed stirring .
- Then the urine sample was separated from the anion exchanger resin particles by filtration and then filled again in a measuring flask of 250 ml. If the volume of urine sample is seemed to be not exactly 250 ml, it should be completed to the mark with de-ionized water.

From these two stocks of CU (UTCU and TCUAE), inhibitor test solutions were prepared in the concentration range 0.5-10 v/v %.

2.4. Electrochemical Measurements

Electrochemical experiments were carried out by using a potentiostate/galvanoatate (ACM Gill AC instrument model 655) and a personal computer were used. ACM Gill software (Version 4) was used for EIS and PDP analysis. A three-electrode arrangement was used for electrochemical studies. Working electrode was prepared from mild steel rod, embedded in Teflon holder using epoxy resin with an exposed area of 0.785 cm^2. The specimen were polished with emery paper no. 400 to 1200 grade. It was cleaned with acetone, washed with de-ionized water, and finally dried at room temperature before being immersed in the tested solution. A saturated calomel electrode (SCE) and a platinum electrode were used as a reference and counter electrodes, respectively. The impedance measurements were carried out in the frequency range of 10 kHz to 0.5 Hz at the open circuit potential, by applying 10 mV sine wave ac voltage. The immersion time before each measurement was 10 min to access an equilibrium potential. The charge transfer resistance (R_{ct}) were calculated from Nyquist plots as described in previous work [10]. On plotting the polarization curves, account was kept of the fact that prolonged anodic polarization might give rise to change at the level of the surface roughness that would imply parallel translation of the Tafel slopes. This can be eliminated by first tracing the cathodic polarization curves and then the anodic ones with potential sweep rate of 1mV sec^{-1}.

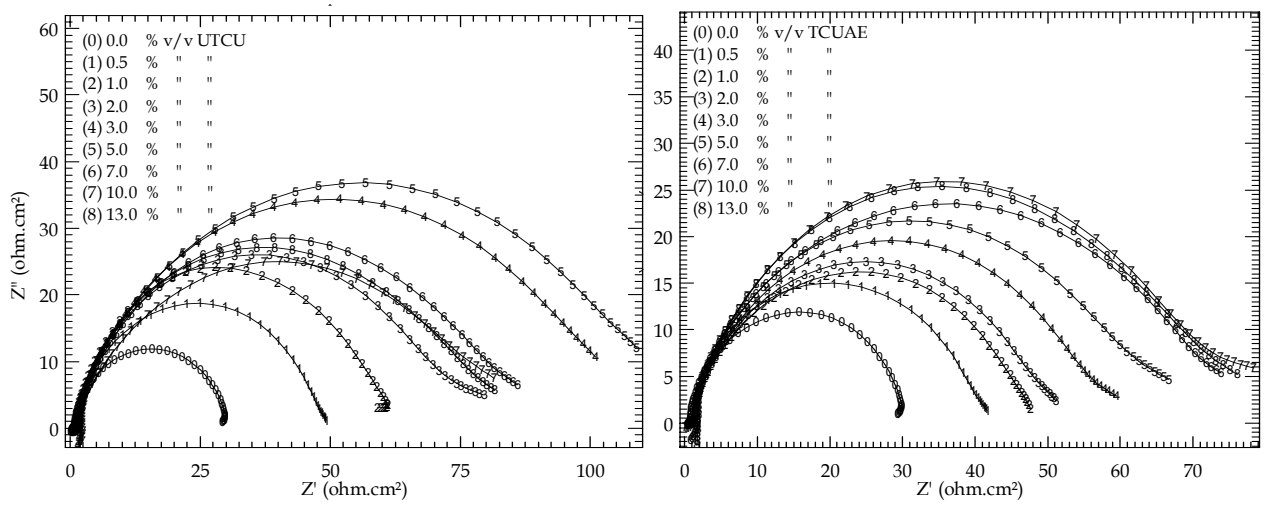
All experiments were performed at 30^o C in aerated solutions. For studying the effect of temperature, EIS measurements for mild steel specimen in absence and presence of certain concentration of inhibitor were done at different temperatures in the range 30^o-70^o C. All experiments were conducted in stagnant, aerated solutions and the temperature of the solutions were controlled by using a thermostat from Cole Parmer (± 0.1^o C).

3. Results and Discussion

3.1. EIS Measurements

Figs. 1 show the effect of the addition of UTCU and TCUAE on the impedance response of mild steel in 0.5 M HCl solution at open circuit potential and 30^o C. As the impedance diagram (Nyquist type) have a semicircle appearance, it indicates that the corrosion of mild steel is controlled by charge transfer process and the presence of inhibitor does not alter the mechanism of the dissolution of steel. This observation was confirmed by the work of Muralidharan *et al.* [12]. While the slightly depressed nature of the semi circle, which has the center below the x-axis, is characteristics for solid electrodes and such frequency dispersion has been attributed to roughness and other inhomogeneties of the solid surfaces [13]. The charge transfer resistance (R_{ct}) and the correspondence corrosion rate (CR) values are estimated and listed in Table 1. Inhibition efficiency ($Inh._R\%$) is obtained by the following equation:

Figure 1: Nyquist plots for mild steel in 0.5 M HCl in absence and presence of different concentrations of UTCU and TCUAE at 30ºC.



$$Inh._R\% = (1 - \frac{R_{ct}^o}{R_{ct}}) \times 100 \quad (1)$$

where R_{ct}^o and R_{ct} are the charge transfer resistance of steel in the absence and presence of inhibitor. The $Inh._R\%$ values are also listed in Table 1.

Table 1: Corrosion parameters for mild steel in 0.5 M HCl in the absence and presence of UTCU and TCUAE from EIS measurements.

Inhibitor concentration v/v %	UTCU			TCUAE		
	R_{ct} **ohm .cm²**	CR **mm.y⁻¹**	$Inh._R$ **%**	R_{ct} **ohm.cm²**	CR **mm.y⁻¹**	$Inh._R$ **%**
0.0	30.18	9.92	-	30.18	9.92	-
0.5	49.06	6.42	38.42	40.96	7.33	26.24
1.0	60.84	5.09	50.34	46.56	6.46	35.11
2.0	76.99	4.08	60.61	52.34	6.18	42.28
3.0	104.76	2.91	71.16	63.64	5.27	52.53
5.0	110.90	2.72	72.73	65.07	4.25	53.57
7.0	84.93	3.57	64.43	75.66	4.03	60.07
10.0	82.05	3.68	63.18	76.60	4.01	60.56
13.0	81.97	3.75	63.14	72.96	4.07	58.59

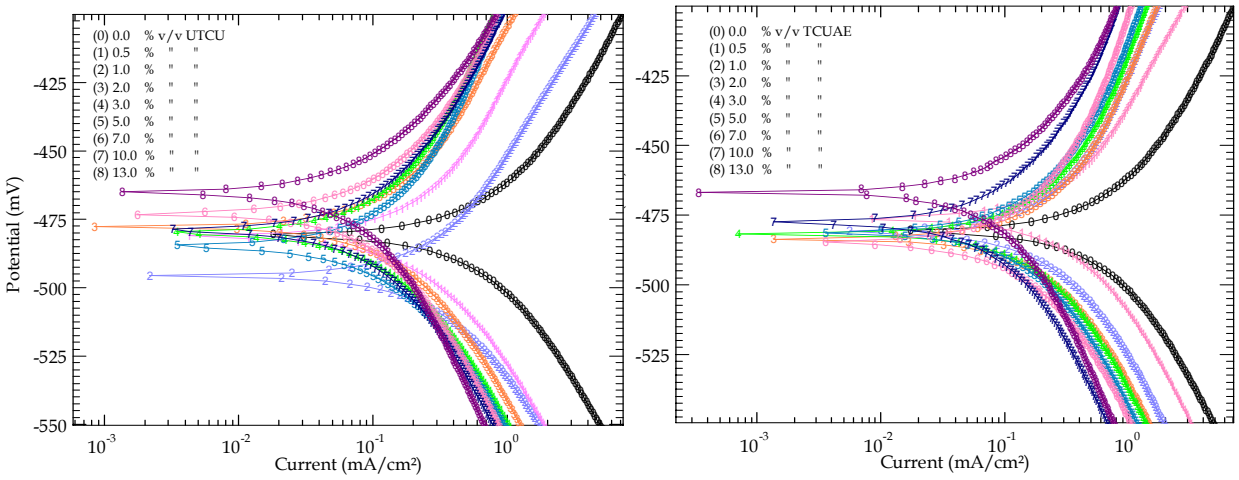
It was clear that the addition of increasing amount of inhibitor concentration increases the R_{ct} value and decreases the CR value and after critical concentration of 5.0% and 10.0% for UTCU and TCUAE, respectively, it was observed a decrease in R_{ct} and an increase in CR with further increase in concentration. However, it was observed that UTCU is more effective than TCUAE.

3.2. PDP Measurements

Figs. 2 show the effect of concentration of UTCU and TCUAE on the anodic and cathodic polarization curves of mild steel in 0.5 M HCl solution. It is clear from these experimental data that both UTCU and TCUAE shift both anodic and cathodic branches of polarization curves to lower values of current density, indicating the inhibition of both the hydrogen evolution and steel dissolution reactions, indicating that both UTCU and TCUAE could be classified as mixed type inhibitors. The corrosion

current density ($i_{corr.}$) was calculated from the intersection of cathodic and anodic Tafel lines. The inhibition efficiency from PDP measurements can be given from the following equation:

Figure 2: PDP curves for mild steel in 0.5 M HCl in absence and presence of different concentrations of UTCU and TCUAE at 30ºC.



$$Inh._{i_{corr.}}(\%) = (1 - \frac{i_{corr.}}{i^{o}_{corr.}}) \times 100 \quad (2)$$

where $i^{o}_{corr.}$ and $i_{corr.}$ are the corrosion current densities of steel in the absence and presence of inhibitor. All values of $E_{corr.}$, $i_{corr.}$ and Inh_i % for mild steel in absence and presence of different concentrations of UTCU and TCUAE were estimated and listed in Table 2. Inspection of Table 2 revealed that no appreciable change in the corrosion potential was observed with the addition of UTCU and TCUAE as it does not exceed ± 15 mV, emphasizing the mixed potential control. As observed, $i_{corr.}$ value has the adverse trend for R_{ct} value obtained from EIS measurements and this behaviour is expected as $i_{corr.}$ and R_{ct} are correlated with the following equation (Stern-Geary equation) [14]:

Table 2: Corrosion parameters for mild steel in 0.5 M HCl in the absence and presence of UTCU and TCUAE from PDP measurements.

Inhibitor concentration v/v %	UTCU			TCUAE		
	$-E_{corr.}$ (mV)	$i_{corr.}$ (mA.cm^{-2})	$Inh._i$ (%)	$-E_{corr.}$ (mV)	$i_{corr.}$ (mA.cm^{-2})	$Inh._i$ (%)
0.0	482	4.89	-	482	4.89	-
0.5	497	3.09	36.81	476	3.32	32.11
1.0	481	2.29	53.17	480	2.67	45.40
2.0	478	1.54	68.51	485	2.02	58.69
3.0	477	1.38	71.78	483	1.80	63.19
5.0	482	1.30	73.42	481	1.69	65.44
7.0	475	1.61	67.08	483	1.65	66.26
10.0	477	1.62	66.87	478	1.63	66.67
13.0	468	1.65	66.26	470	1.67	65.85

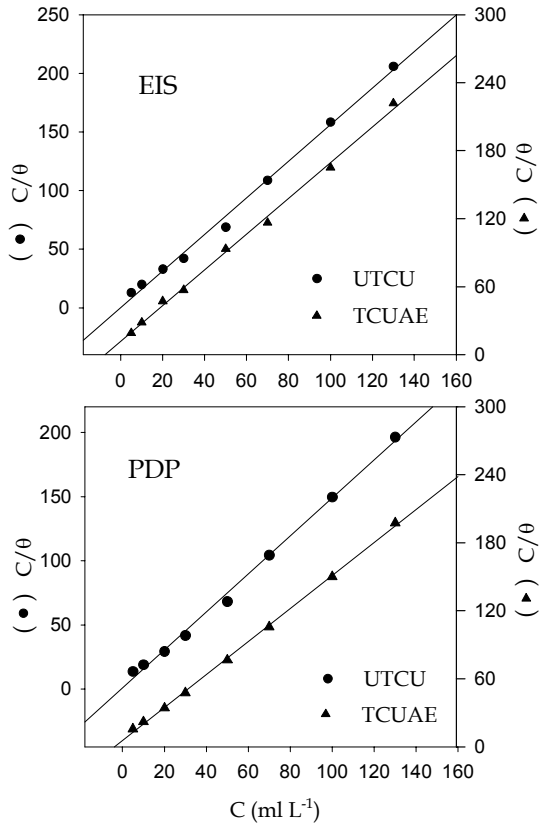
$$i_{corr.} = \frac{\beta_a . \beta_c}{2.303(\beta_a + \beta_c) R_{ct}} \quad (3)$$

Where β_a and β_c are the anodic and cathodic Tafel slopes, respectively.

3.3. Application of Adsorption Isotherms

The values of surface coverage ($\theta = \frac{Inh.\%}{100}$) for different concentrations of UTCU and TCUAE at 30ºC have been used to explain the best adsorption isotherm to determine the adsorption process. Attempts were made to fit θ values to various isotherms. By far the adsorption phenomenon obeys the modified Langmuir adsorption isotherm (Fig. 3) proposed by Villamil *et al.* [15, 16]:

Figure 3: Langmuir adsorption isotherm of UTCU and TCUAE on mild steel in 0.5 M HCl at 30ºC.



$$\frac{C_{inh.}}{\Theta} = \frac{n}{K} + nC_{inh.} \tag{4}$$

where $C_{inh.}$ is the concentration of the inhibitor (converted from v/v % to ml L^{-1}), n is the number of active sites occupied by one inhibitor molecule and K is the equilibrium constant for adsorption process which linked to the free energy of adsorption ($\Delta G_{ads.}$) by the equation:

$$\log K = -\log C_{H_2O} - \frac{\Delta G_{ads.}}{2.303RT} \tag{5}$$

where C_{H_2O} is the concentration of water molecules (converted from mol L^{-1} to mL L^{-1}) at metal/solution interface, R is the universal gas constant and T is the absolute temperature. All n, K and $\Delta G_{ads.}$ values were given in Table 3. The negative values for $\Delta G_{ads.}$ means that the adsorption of UTCU and TCUAE species is a spontaneous process, while the absolute value indicates that the former is more effective than the latter.

Table 3: Langmuir adsorption parameters for UTCU and TCUAE on mild steel surface in 0.5 M HCl from EIS and PDP measurements.

Inhibitor concentration v/v %	n		K (mL^{-1} L)		$-\Delta G_{ads.}$ (kJ mol^{-1})	
	EIS	PDP	EIS	PDP	EIS	PDP
UTCU	1.56	1.48	4.470	1.657	21.18	18.68
TCUAE	1.58	1.45	0.134	0.256	12.34	13.97

3.4. Effect of Temperature

To investigate the mechanism of inhibition and to determine the activation energies of the corrosion process, Nyquist plots of mild steel in 0.5 M HCl were determined at different temperatures (30-70ºC) in the absence and presence of 5.0 % of UTCU and TCUAE (the figures are not shown). The effect of temperature on R_{ct} and $Inh._R\%$ was illustrated in Fig. 4. It is seen that the increase of temperature leads to an essential decreased in R_{ct} value which may attributed to the corrosion rate increase. It was reported that the rate for corroding iron in HCl solutions is approximately doubles for every 10ºC rise in temperature [17]. On the other hand, the adsorption behaviour of UTCU and TCUAE species becomes more favorable with increasing temperature, this can be concluded from the variation of Inh_R % with temperature (see Fig 4-b). The fact that $Inh.$% increases with temperature is explained as the likely specific interaction between the steel surface and the inhibitor species [18]. Ivanov [19] considers the increase of $Inh.$% with temperature increase as the change in the nature of the adsorption mode, the inhibitor being physically adsorbed at lower temperatures, while chemisorption is favoured as temperature increases.

Figure 4: Variation of (a) R_{ct} and (b) $Inh._R\%$ for mild steel in 0.5 M HCl in absence and presence of UTCU and TCUAE with temperature

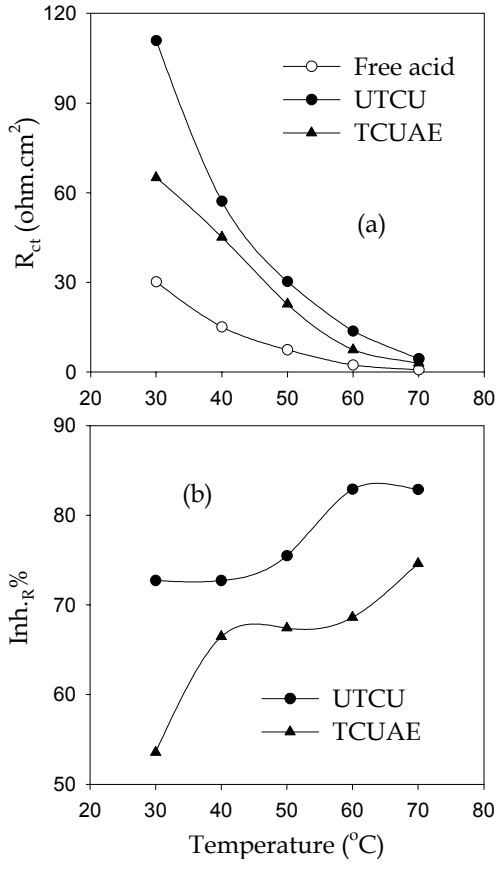
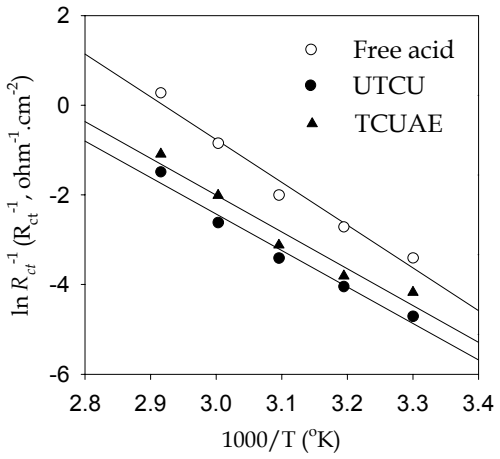


Figure 5 presents the Arrhenius plots of the natural logarithm of the R_{ct}^{-1} versus $\frac{1}{T}$, for mild steel in 0.5 M HCl in absence and presence of 5.0% of UTCU and TCUAE. Straight lines are obtained and the values of the slopes of these lines permit the calculation of the apparent activation energy, $E_a^{\#}$, according to the following equation:

Figure 5: The relationship of $\ln R_{ct}^{-1}$ versus $\frac{1}{T}$ (Arrhenius plots) for mild steel in 0.5 M HCl in absence and presence of 5.0 % of UTCU and TCUAE.



$$\ln R_{ct}^{-1} = -\frac{E_a^{\#}}{RT} + \ln A \tag{6}$$

where A is the Arrhenius frequency factor. The estimated values of $\ln A$ and $E_a^{\#}$ for the studied systems are listed in Table 3. Inspection the data shows that the activation energy is lower in the presence of UTCU and TCUAE than in their absence, indicating that there is an improvement in their inhibition efficiency with an increase in temperature as mentioned before. It is worth noting that the variation in the Arrhenius frequency factor is similar to the variation in the activation energy. This result is the same as some studies [20, 21]. It is obvious that the value of $E_a^{\#}$ obtained for UTCU is somewhat lower than that obtained for TCUAE and this result confirms the result that the inhibitor efficiency of UTCU is slightly higher than that of TCUAE. Similar result was obtained by Bentiss et al [22]. However, the lower value of $E_a^{\#}$ of the process in an inhibitor's presence when compared to that in its absence is attributed to chemisorption process, while the opposite is the case with physical adsorption process [18]. To confirm this result, heat of adsorption for UTCU and TCUAE must be evaluated. An approximation estimate for the heat of adsorption ($Q_{ads.}$) can be obtained from the trend of surface coverage with temperature as follows [6, 23, 24]:

$$Q_{ads.} = 2.303R\left[\log\left(\frac{\theta_2}{1-\theta_2}\right) - \log\left(\frac{\theta_1}{1-\theta_1}\right)\right]\frac{T_1T_2}{T_2 - T_1} \tag{7}$$

where θ_1 and θ_2 are the surface coverage at temperature T_1 (30^o+273) and T_2 (70^o+237). The calculated values are given in Table 4. The positive values of $Q_{ads.}$ indicate that the adsorption of UTCU and TCUAE species is an endothermic process and once again signify that the degree of surface coverage increased with rise in temperature, i.e. chemisorption process [22, 25]. The value of $Q_{ads.}$ for UTCU is somewhat higher than that for TCUAE indicates that the adsorption of UTCU species on the steel surface is slightly more stronger than that of TCUAE species.

Table 4: Corrosion kinetic parameters for mild steel in 0.5 M HCl in absence and presence of UTCU and TCUAE and their heat of adsorption on mild steel surface.

The system	$\ln A$ **(*A*, ohm^{-1}.cm^{-2})**	$E^{\#}_{app.}$ **(kJ mol^{-1})**	$Q_{ads.}$ **(kJ mol^{-1})**
Free acid	27.86	79.35	-
UTCU	21.98	67.65	11.7
TCUAE	22.34	69.59	9.76

3.5. Camel's Urine constituents and Its inhibitive characteristics

The average concentration level of urea, uric acid, creatinine, chlorides, sulphate and phosphate has been determined in twenty urine sample of twenty male camels in Saudi Arabia by Amer and Alhendi [26] and given in Table 5. The low concentration of urea in CU may be referred to the kidney function in camels and the presence of micro-organism in the rumen of herbivores by which urea is partially incorporated into microbial proteins in order to form amino acids [27]. However microscopic examination of urine showed that there were some chemical deposits such as calcium oxalate, calcium hydrogen phosphate, ammonium urate and triple phosphate [26]. Fortunately, urea, uric acid, phosphate, oxalate and sulphate species were reported in the corrosion literature as follows:

Table 5: The average concentration level and the chemical formula of some Camel's urine constituents.

The constituent	**Urea**	**Uric acid**	**Creatinine**	**Chloride**	**Phosphate**	**Sulphate**
The concentration (g L^{-1})	0.195	6.041	0.052	0.450	0.171	7.760
The chemical formula	CN_2H_4O	$C_5H_4N_5O_3$	$C_4H_7N_3O$	Cl^-	PO_4^{3-}	SO_4^{2-}

- Ebenso *et al* [28] reported the dual action of urea as corrosion inhibitor and corrosion accelerator, depending on the studied range of its concentration. It was found that the inhibition efficiency decreases with increasing the concentration of urea and at higher level of concentration it loses its inhibition ability and tends to act as corrosion accelerator.
- Norio [29] studied the inhibitory effects of uric acid on cathodic reaction of steel in saturated Ca(OH)2 solution to simulate the environment in pores in concrete. It was found that uric acid acts as an cathodic inhibitor for macro-cell corrosion. Uric acid was suggested to be adsorbed onto cathodic areas of the steel through coordination of nitrogen atoms and oxygen in the carbonyl group to the iron cations on the steel surface.
- Vatankhah *et al.* [30] studied the electrochemical behavior of iron in aqueous phosphate solutions (0.005–0.1M) of pH ~8 at room temperature. It has been shown that phosphate ions are very effective inhibitors against localized attack, and in the presence of sulfate ions still show an effect very similar to that of phosphate ions.
- Giacomelli *et al* [31] reported that oxalic acid is a good corrosion inhibitor for carbon steel in sulphoric acid solutions.
- Recently, the synergistic inhibition between some of the N-containing organic compounds and chloride ion for steel corrosion in acidic solution has been investigated [21, 32, 33]. It was found that the inhibition efficiency increases with increasing Cl- ion concentration in the presence of certain concentration of the investigated compounds.

In view of the above picture for the constituent of CU and its inhibitive action, one can conclude that camel's urine may act as a package of inhibitors in which each constituent may play a role in its inhibitive characteristics as follows:

- The variation of $Inh.\%$ with concentration of UTCU and TCUAE indicated the contribution of urea in the corrosion inhibition but with no observations for corrosion acceleration behaviour at higher level of studied concentrations.

- The data obtained from the temperature dependence of the inhibition process suggest a chemical type of adsorption. Accordingly, the inhibitive action of the CU, seems to be more likely due to the contribution of specific adsorption (chemisorption) of the molecular species of organic matter (i.e. urea, uric acid and creatinine), than to specific adsorption of cationic species. However, the coordination may be occurred by the lone pairs of electrons on N and/or O and the vacant d-orbitals of Fe atoms on the steel surface.
- Finally, the synergistic effect of anions constituents in CU on its inhibitive action can be evaluated by comparing the $Inh.\%$ obtained in the case of UTCU with that obtained in the case of TCUAE. It was found that the former is somewhat more effective than the latter even after the critical concentration.

4. Conclusions

UTCU and TCUAE inhibited mild steel corrosion in 0.5 M HCl. Inhibition efficiency obtained from EIS and PDP measurements increased with inhibitor concentration up to critical one then it tend to decrease with further increase in concentration. It was found that both of them acted as mixed type of inhibitors without altering the mechanism of steel dissolution. Adsorption of inhibitor species for both UTCU and TCUAE was found to follow the modified form of Lngmuir adsorption isotherm. The trend of inhibitor adsorption with temperature suggest chemisorption of the organic matter (i.e. urea, uric acid and/or creatinine) on the metal surface in 0.5 M HCl. Results showed that the performance of UTCU is somewhat better than of TCUAE.

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Russian Diaspora Politics: Regional Security and the Russian Diaspora in Post-Soviet Space

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Abstract

This essay examines the conceptualization of Russian Diaspora minorities in the post-Soviet republics, the transformation of *russkii* living Ukraine and their subsequent inter-ethnic relationships. Socio-political orientations between Russian living in the 'near abroad' and ethnic majorities is an issue that is very much alive in Russian politics as well as those of the former Soviet Republics. The most acute problem that arose from the collapse of the Soviet Union was determining the nature of the relationship that ethnic Russians would share with their ethnic counterparts, the new Russian nation as well as the Russian state. Since the dissolution of Soviet Communism, social and political polarization is evident in the former UkrSSR; since late 1991 much attention has been given to minorities abroad in Russian foreign policy. Since the time of Russian military intervention in Moldova, a surge of Russian patriotism and identity has taken place in post-Soviet space, which may lead to a greater sense of duty to "protect" Russian 'compatriots abroad'.

Keywords: Diaspora, political homeland, *russkii*, *Rossiia*, multi-ethnic empire, 'near abroad', identity 'transformation', minorities, displaced, foreign policy, 'sovereignization', ethnic polarization, 'compatriots abroad'; *otechestvo, vykhodtsy*; Russians.

Introduction

From the moment that the republics of the Soviet Union proclaimed their sovereignty in 1991, the face of the Soviet ethno-cultural demographic changed significantly. Soviet dissolution was the primary expedient for the creation of the Russian Diaspora as twenty-five million Russians found themselves located in freshly created states that were immediately re-designed as their new political homeland.[1] In due course, displaced Russians were forced to either return to the newly created Russian Federation, or assume a fresh political identity that ultimately distinguished them as the new Russian Diaspora of the former Soviet Socialist Republics. The most acute problem that arose from Soviet dissolution was to determine the nature of the relationship that ethnic Russians would share with their new ethno-cultural counterparts in the former republics as well as with the new Russian nation and the post-Communist Russian state.

This essay focuses its representation from four angles: those of the identity 'transformation' of millions of ethnic Russians and the historical context behind Russian self-expression, the framework for conceptualizing diasporas and ethnic minorities, the inter-ethnic relationship between Russians and indigenes of Ukraine, Russians and Russia, and how Russians are viewed and view themselves; how

[1] Graham Smith. "Transnational Politics and the Politics of the Russian Diaspora," Ethnic and Racial Studies, vol. 22, issue 3 (May 1999), 500. <http://www.library.ualberta.ca/subject/politicalscience/index.cfm> (accessed 29 January 2007).

socio-political orientations of displaced Russian minorities and secessionism have presented themselves as issues of regional security.

An exploration of the relationship between Russians and non-Russian residents in Ukraine will observe the boundaries of minority identity in post-Soviet space. Additionally, I will discuss the fluidity of the Russian Diaspora, presenting models of cultural, ethnic and linguistic over-lap between Russians and Ukrainians in parts of the former UkrSSR. Does the protection of the Russian community within the Russian federation presage a protectionist attitude toward Russian communities living in post-Soviet space? Do less-defined Russian ethnic minorities create contention between the Russian state and states where Russian minorities currently reside? Has the ambiguous linkage between Russian 'settler' (*russkii*) and 'Russian' (*Rossiia*) been settled or has it remained a central element in Russian politics and foreign policy? How does the traditional understanding and nuance of nationalism and nationhood relate to the principles and assumption behind the re-emergence of ethnocratic state? The former have created the basis of a renewed sense of Russian chauvinism that since the break-up of the Soviet Union illustrates the Russian Federation's search for re-newed power and prestige both regionally and internationally.

My contention is that since the collapse of the Soviet Union, the issue of *russkii* and *Rossiia* has not been reconciled and provides a crucible that has been given political significance within the Russian state and among neighbouring states in the Russian periphery. Integration of Russian minorities into the 'near abroad' following the fall of Communism has been unsuccessful and serves as an expedient to renewed polarization within the former Soviet Socialist Republics of Ukraine. Ultimately Russian foreign policy serves as poignant exemplification that the Russian Federation has assumed the responsibility of protecting displaced Russian minorities in contiguous regions, and uses Russian 'compatriots abroad' as a mechanism with which it can re-exert political influence and power throughout Eurasia. As the Soviet Union dissolved, Ukraine exemplified one of the largest concentrations of Russian migrants of all the former republics.

To accommodate the scope of this paper, a focus will be maintained on Russian minorities within the former Ukraine; but issues of Russian ethnic minority in Moldova will supplement the aforementioned queries. I will showcase the events that center on this state in the early 1990s as a model for issues of regional security and ethnic protectionism.

Historical Context

The multi-ethnic nationalities of the Soviet Union were groups anchored in historically defined territories but they still adhered to the general identity as "Soviet." Exploring the relationship between creating a Russian Diaspora and the disintegration of the USSR invariably entangles itself with elements of state expansion and the idea of Russian migration yet the term "Soviet" remained absolutely vital in conglomerating the multi-ethnic empire.[2]

With the break-up of the Soviet Union came the moving idea of "sovereignization" that challenged the old idea of ethnic bonding under the guise of "Sovietization", and led to the discovery and recognition of new political identities in an entirely fresh dimension.[3] Russian historian Vasilii Kliuchevskii drew upon the close inter-relationship between state expansion and migration as a major feature that Russia simply colonized itself.[4] Explaining that the scope for colonization expanded simultaneously with the expansion of state territory invariably implies a fundamental linkage between Russians and the people living in the Russian colonies. Conversely, Richard Pipes asserts that Kliuchevskii ignored the fact that the areas being colonized were already inhabited; thus, Russia was merely colonizing the lands of others and in doing so, Russians were being incorporated into a unique

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[2] *See* Pål Kolstø, "Territorialising Diasporas: The Case of Russians in the Former Soviet Republics," Millennium, vol. 28, issue 3 (1999). <http://www.library.ualberta.ca/subject/politicalscience/index.cfm> (accessed 28 January 2007)

[3] Vladimir Shlapentokh, Munir Sendich and Emil Payin, The New Russian Diaspora, Russian Minorities in the Former Soviet Republics, (Armonk, NY: M. E. Sharpe, 1994), 40 and 41.

[4] Paul Kolstoe, Russians in the Former Soviet Republics, (Bloomington and Indianapolis, IL: Indiana University Press, 1995), 18 and 19.

relationship with imperial minorities in the colonies.[5] What was once perceived as an imperial minority has thence become an ordinary minority; even more so with the collapse of the USSR according to Vladimir Shlapentokh, Muir Sendich and Emil Payin in *The New Russian Diaspora*.[6] The creation of the Soviet Union in 1921, exemplified a continued blending of minorities in the borderlands, whether they were imperial minorities, or not, the policy of "Sovietization" blanketed the recognition of many of the distinct minorities throughout the USSR. Such an effect is best depicted as a process of excessive spread of inter-ethnic contact or relations in the Soviet Union, which largely provoked accusations of assimilation and erosion of the very foundation of the existence of pre-existing ethnos.[7]

The blanketing perspective has come to be seen as a Russian myth, or the Russian perception of an 'imagined community' according to Graham Smith in *Nation-building in the Post-Soviet Borderlands*.[8] In turn, this mythic view resonates in the Russian understanding of present-day Russian state neighbours, especially those that comprise the Commonwealth of Independent States (CIS). Russian elites in Moscow have been heavily influenced by mythic "Sovietization", and sought to prove that there is no sensible alternative to effectively maintaining power and prestige in post-Soviet Russia other than re-enacting the systemic Soviet relationship, except it would be done along Russo-lines as oppose to one of a Soviet nature.

Reification of the systematic relationship is a resolute indication of the political leverage that Russian minorities in the 'near abroad' can play in re-asserting Russian power and prestige in the post-Soviet world. Indeed, Russophile myths have demonstrated their power and persistence, replacing the former "Soviet" identity with the new monolithic Russian identity where the so-called Slavic factor was a very important aspect of the relationship that would develop between Russian and Ukraine especially. It was a factor that was advocated by Russian historian Ruslan Khasbulatov for bringing the former Soviet states closer together in terms of the communities of the nation; the dissipation of the ethnic heterogeneity of the Soviet Union.[9]

Among the many factors that contribute to the current problems of national identity in the former republics, the artificial minority plantation has contributed most to the perception of displaced Russians. Communist cessation simply augmented this problem given how political frame-work of the USSR held the various minorities together under a single Soviet identity, which preserved a distinctiveness of its own. Upon disintegration of the USSR, the Soviet nationality vanished and became obsolete in terms of an intrinsic political identifier. The status of Russians living outside the Russian homeland is explained by Timothy Heleniak accordingly:

> […] Russians became part of a large Diaspora population "without moving an inch or leaving their homes." They went from being members of a privileged majority who arguably saw their homeland as the entire Soviet Union to minority members of 14 newly independent nation states. Some of these states were experiencing sovereignty for the first time in decades and others for the first time in history. All sought to elevate the status of the titular group to some degree, and many were quite hostile to the existence of a Russian minority that ranged from two to 38 percent of their populations.[10]

Soviet identity had lost its ability to bring and hold ethnic groups together while former Soviet territories have become the stage of re-emerging contestation over whether Russians living in the former republics have created the new Russian Diaspora or simply exemplify themselves as an ethnic minority. In the aftermath of Soviet collapse, the Russian Diaspora populations were ultimately confronted with two very difficult choices in such a way that a contentions political massif had

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[5] Richard Pipes, 'Refletions on the Nationality Problems in the Soviet Union', in Nathan Glazer and Daniel P. Moynihan (eds), *Ethnicity: Theory and Experience*, Cambridge, MA, 1975, pp. 453-65, p. 455.

[6] Vladimir Shlapentkh, Munir Sendich and Emil Payin, The New Russian Diaspora, Russian Minorities in the Former Soviet Republics, (Armonk, NY: M. E. Sharpe, 1994), 25.

[7] Ibid., 160 and 161.

[8] Graham Smith, *et al*.. Nation-building in the Post-Soviet Borderlands: The Politics of National Identity. (Cambridge, UK: Cambridge University Press, 2000), 23.

[9] *See* Ruslan Khasbulatov, The Struggle for Russia, Power and Change in the Democratic Revolution. (London, UK: Routledge, 1993).

[10] *See* Timothy Heleniak, "Migration of the Russian Diaspora after the Breakup of the Soviet Union," Journal of International Affairs, vol. 57, issue 2 (Spring 2004): 99-117. <http://www.library.ualberta.ca/subject/politicalscience/index.cfm> (accessed 29 January 2007).

emerged in the centre of Ukrainian society. Russian Diaspora reactions included the options of either remaining in the non-Russian states to form a political opposition minority in order to preserve their minority rights, or simply leaving the non-Russian states.[11] As a result of minority reaction, Russia has sought to fill the void left by the faded "Soviet" identity and the emergence of irredentism has occurred, especially where geographically large concentrations of Russians live in geographical locales contiguous Russia.

Russian Diaspora issue played a less significant role when Boris Yeltsin held office. Since that time, President Vladimir Putin has emphasized restoring Russian power and prestige and Russian nationalism has become a stronger force in domestic affairs and foreign policy, and with it, the issue of Russians abroad has played a more central role as well.

Terry Martin's *Affirmative Action Empire*, offers an historical anchor for Russia's re-affirming identity in the former Soviet Union.[12] Parallels may be drawn between the matters presiding over Russian concentrations in Ukraine and irredentist concerns that surfaced in late 1991. Re-emergence of Russian dominance in the 1930s is comparable to the re-assertion of Russians' right to national self-expression vis-à-vis Russian ethnic minorities spread through former Soviet republics. Further comparisons may be drawn between Russia's present-day position on Russian self-awareness and the period between 1933 and 1938 as well as the status of the Russian Soviet Federated Socialist Republic (RSFSR or Росси́йская Сове́тская Федерати́вная Социалисти́ческая Респу́блика, РСФСР).

Developments from 1933-1938 threatened the foundations of the Affirmative Action Empire because they demanded that the significance of Russian national self-expression be minimized in order to avoid provoking so-called defensive nationalism by the formerly oppressed non-Russian communities.[13] Now the non-Russian communities are stigmatized and perceived as potential oppressors of Russian minorities. Such minorities have been used as a mechanism by which Russian expression in terms of power and prestige can be made in the post-Soviet era.

Conceptualizing Diasporas

Traditional approaches to Diaspora/minority binaries have been concerned with discussing the subject along a 'majority/minority' axis where any minority population is subsequently treated as a foreign Diaspora that saw its transposition take place at a specific point in history. This binary precipitates an over-simplification in the understanding of which groups are dominant and which merely fall among the minority, especially along quantitative lines.[14] Thus, demographics should not authoritatively determine which community is diasporic and which is not. Rather, there is a considerable breadth to the nature of relations between the majority and minority communities, and poses several critical questions that need to be addressed before the nature of the Diaspora can be fully understood

The first question is how the minority community came into existence in the host nation–was it a migratory policy of the homeland, a voluntary movement or a result of past colonization? The second question should address the relationship between the diasporic community and the homeland as well as the host nation. The third question considers the relationship between the host country and the homeland and should gauge whether or not these two are on friendly terms or if the relationship is characterized by historical enmity or hostility that has surfaced more recently. The third question serves as a springboard to exploring a mutual history between the homeland and host nation, the roots of hostility if it hostility does has or does exist, and whether there is any real need for the home nation to "protect" or "defend" the minority population living in the host nation.

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[11] Timothy Heleniak, "Migration of the Russian Diaspora after the Breakup of the Soviet Union," Journal of International Affairs, vol. 57, issue 2 (Spring 2004): 99 and 100. <http://www.library.ualberta.ca/subject/politicalscience/index.cfm> (accessed 29 January 2007).

[12] *See* Terry Martin. The Affirmative Action Empire: Nations and Nationalism in the Soviet Union, 1923-1939. (London, UK: Cornell University Press, 2001).

[13] Terry Martin. The Affirmative Action Empire: Nations and Nationalism in the Soviet Union, 1923-1939. (London, UK: Cornell University Press, 2001), 394.

[14] *See* Avtar Brah, Cartographies of Disapora, Contesting Identities, (London, UK: Routledge, 1996).

While substantial limitations exist in understanding Diaspora communities along previous models, Avtar Brah presents a methodological approach to diasporic climates whereby he refers to the 'diasporic space' as follows:

> "the point at which boundaries of inclusion and exclusion, of belonging and otherness, of 'us' and 'them' are contested". Diaspora space is thus envisaged as 'inhabited' not only by those migrants and their descendents who have settled in a 'foreign' homeland but equally by those who are viewed as indigenous.[15]

This model largely helps to identify the diasporic space itself, but fails to help understand the special relationship that is created in this space between the "us" and "them." Accordingly, Brah explains the diasporic space called 'England' where African, Caribbean, Irish, Asian, Jewish and other diasporas intersect among themselves as well as with the entity constructed as 'Englishness.'[16]

Brah's example of England helps to explain how the various Diaspora communities come together under the unifying identity of "English" just as the various ethnic groups of the Soviet Union become unified under the political identity of "Soviet." In Ukraine, both Russian migrants and indigenous Ukrainians experienced the effects of "Sovietization", whether they were negative effects of not, but in 1991, this political characterization ceased to exist. The departure of Sovietism left stranded communities that are yet to be understood as minority groups or Diaspora Russians.

Precarious dynamics of the stranded Diaspora is echoed by Neil Melvin where the creation of independent states from the Soviet Union fostered the misleading impression that the inter-ethnic relations, especially those between Russians and indegens, were largely harmonious.[17] This harmony disguised a series of sharp conflict that existed since Soviet dissolution; conflict continues to have a toxic effect on ethnic relations in the 'near abroad' to the present day. The toxic effect that has taken hold of Ukrainian society has facilitated the re-emergence of the ethnocratic state, and is a focus in many other former Soviet Republics, most notably Ukraine.

Boundaries of Russian Identity in Ukraine

One of the strongest issues that facilitated the societal rift within Ukraine since the break-up of the Soviet Union is the three-way socio-cultural division that includes Ukrainophone Ukrainians, Russofone Ukrainians and ethnic Russians.[18] Such a division has mitigated Ukrainian national agenda, foreign policy and has impacted international affairs.[19] This section will briefly explore the socio-cultural issues as national elements of Ukraine that have contributed to ethnic stratification since the advent of the Communist era in terms of the three-way socio-cultural division in the former UkrSSR.

A particularly deterministic attempt to sort the ambiguous nature of these divisional classifications has been to approach each group in terms of 'native tongue' as an ancestral anchor. In sociological survey conducted in 1989, sixty-four per-cent of the Ukrainian population classified as 'native tongue' Ukrainians, nine per-cent as of ethnic Ukrainians identifying Russian as their 'native tongue' and twenty-two per-cent as Russian in terms of both ethnicity and language.[20] Challenging the ancestral methodology is the reality of ethnic boundaries in Ukraine still being extremely fluid and retaining deep historical roots. Ukraine has undergone nearly seventy years of linguistic and ethnic merging during the Soviet era alone–a period in which Russians and Ukrainians mingled in every-day life. Many individuals in Ukrainian society accepted and utilized both Russian and Ukrainian as their native languages; since, many Russians have certainly considered Ukraine as their primary homeland,

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[15] Avtar Brah, Cartographies of Disapora, Contesting Identities, (London, UK: Routledge, 1996), 208 and 209.
[16] Ibid., 208 and 209.
[17] *See* Neil Melvin, Russians Beyond Russia, The Politics of National Identity, (London, UK: Chatham House Papers, 1995).
[18] Graham Smith, *et al*.. Nation-building in the Post-Soviet Borderlands: The Politics of National Identity. (Cambridge, UK: Cambridge University Press, 2000), 119.
[19] *See* Dawisha, Karen and Parrott, Bruce. Russia and the New States of Eurasia, the Politics of Upheaval. (New York, NY: Cambridge University Press, 1994).
[20] Graham Smith, *et al*. Nation-building in the Post-Soviet Borderlands: The Politics of National Identity. (Cambridge, UK: Cambridge University Press, 2000), 119.

if not, then there only homeland.[21] Therefore, an even greater ambiguity has been created by way of the very evident ethnic fluidity in Ukraine. For the Russian Diaspora living there, according to Evgenii Golovakha, Natalie Panina and Nikolai Churilov, they are a national minority whose language, culture and socio-political status are being continually shifted toward the periphery of national and state interests.[22]

Ukrainophone Ukrainians

This is the focal group of Ukraine whose ethno-political discourse focuses on their unique and genuine rights as indigenes of Ukraine, and creates a political precedent for what has been termed Ukrainian 'space'.[23] The Ukrainophone Ukrainians exude a dismissive attitude toward Russofone Ukrainians and Ethnic Russians, and advocates a profound discourse of indigenous rights. As the main structural language of Ukrainophones often centers on such concepts as 'indigenous', 'colonialism', and 'Russification', that this group will always stand behind a nationalist argument for the rights as a distinguished people who are set aside from the Russians through their traditional European distinctiveness has become a solid principle in Ukrainian national discourse.[24]

Russofone Ukrainians

Russofone Ukrainians are the unique group in Ukraine, because they split commonalities with their Ukrainophone counterparts. The share many of their characteristics and principles with Ukrainophone Ukrainians yet deny them any dominant nationalist assertions. Moreover, this group facilitates the principles behind "sovereignization", which emerged after the break-up of the Soviet Union, precipitating an expression of neo-political identity.[25]

However, the Russofones claim their territorial rights in Ukraine in terms of traditional Russian 'space' that was brought about by forcible *Russification*, especially that which occurred in the late 1920s via Stalin's rigid censorship and Brezhnev's projects of Russification.[26] Thus, while Russofone's do not deny the nationalist vision of Ukrainians, or the existence of the Ukrainian 'self', their own autonomist apparitions run parallel to those of Ukrainophones, claiming that theirs is also a genuine indigenous tradition with deep and firm historical roots.[27]

Ethnic Russians

The situation in Ukraine is peculiar due to differing policies of Russia and Ukraine concerning the rate of social transformation within each country.[28] Both have formed social objectives and expectations that do not necessarily line in congruency with each others'. Ukrainophone Ukrainians maintain a distinct ethnopolitical discourse that focuses their perceived rights as a so-called 'indigenous' people, which subsequently portrays Russians as outsiders, or in a more traditionally colonial perspective, as 'settlers'. The effects of this ethnopolitical discourse is two-fold, first it de-legitmizes the Russian Diaspora's long-term moral claim to the rights what were officially granted to them by the Ukrainian government in 1991; second, it implies the potentiality of Ukrainian reclamation of those territorial

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[21] Susanne Michel Birgerson, After the Breakup of Multi-Ethnic Empire: Russia, Successor States, and Eurasian Security. (Westport, CT: Praeger, 2002), 102-104.
[22] Vladimir Shlapentokh, Munir Sendich and Emil Payin, The New Russian Diaspora, Russian Minorities in the Former Soviet Republics, (Armonk, NY: M. E. Sharpe, 1994), 59.
[23] *See* Stephen White, Political Culture and Soviet Politics. (London, UK: Macmillan, 1979).
[24] Graham Smith, *et al*. Nation-building in the Post-Soviet Borderlands: The Politics of National Identity. (Cambridge, UK: Cambridge University Press, 2000), 122.
[25] Nadia Diuk and Adrian Karatnycky, New Nations Rising: The Fall of the Soviets and the Challenge of Independence. (New York, NY: John Wiley & Sonse, Inc., 1993), 73, 74 and 75.
[26] Ibid., 73.
[27] Graham Smith, *et al*.. Nation-building in the Post-Soviet Borderlands: The Politics of National Identity. (Cambridge, UK: Cambridge University Press, 2000), 121 and 122.
[28] Vladimir Shlapentokh, Munir Sendich and Emil Payin, The New Russian Diaspora, Russian Minorities in the Former Soviet Republics, (Armonk, NY: M. E. Sharpe, 1994), 59.

sections of Ukraine that are inhabited by ethnic Russians. The second effect is a sub-set of the first, and operates on a potentially dangerous premise of re-emerging ethnocratic reproach.

In fact a Russo-centric counter claim may attempt to point-out that any nationalist Ukrainophone who supports these discourses are in fact themselves the ethnopolitical 'aliens' of Ukraine–the product of Habsburg, Polish or even German ruse, and an artificial implant into Ukrainian society preventing Ukrainians and Russians from living in a natural state of harmony.[29] Present-day discourse on the ethnic issues of Ukraine often center on 'group identity', 'national revival' and 'Ukrainian people' with the clear understanding that these terms refer to those [people] from Ukraine, but could it refer to people merely living in Ukraine? Ukraine is a complex ethnic structure, representing a single piece that once played a role in the breadth of Russia before Soviet collapse, often presented as a model civic state after the in the post-Soviet era.[30] Particular ethnic groups within Ukraine have recently demonstrated signs of trying to turn Ukraine into a ostensible 'ethnic democracy' where political rights should be confined to people believed to be or perceive themselves to be true Ukrainians.[31] If so, then does the previously discusses ethno-social confrontation as well as the alienation of minorities within Ukraine, particularly the Russian ethnic Diaspora, simultaneously promulgate Russian claim to Diaspora "protection"? How dangerous is the president that is set by the conceptualization of such a professed 'ethnic democracy' and how strongly does it impact regional relations and security?

Ultimately, the current relationship between the Ukrainophones and Russofones is one of contesting ideals that retain a repressionist undercurrent; in which Russofones still perceive Ukraine as a mere appendage of the Russian state, inextricably linked through what has historically been viewed as a common faith and language. Therefore, therein rests a potential threat in gauging the interrelation of Ukrainians and Ethnic Russians living in Ukraine as members of an 'ethnic Democracy' because it represents elements of ethnic-repressionism. Nadia Diuk and Adrian Karatnycky describe the historic system of totalitarian repression as one that "combined with widespread national oppression [that] kept the abiding force of Ukrainian national identity hidden for more than six decades, creating a burden that made the Ukrainians a quintessentially hidden nation."[32] Investigating the ethnic climate of Ukraine shows that hidden sub-divisions not only exist, especially in regions that are geographically contiguous with Russia, but both defined and lesser defined Russian ethnic minorities create contention between the Russian homeland and ethnocratic states where Russian minorities reside.

The Russian Homeland and the Ethnocratic State

With an increased reference to Russians living outside of the Russian state, an important change has occurred in Moscow's perception on citizenship.[33] An inclusion of such terms as 'compatriots abroad', Russian minorities, Diaspora communities and 'near abroad' Russians, a shift has also occurred in Russia's perceived role as an ethnocratic *protecteur*.[34] In the midst of Russian identity being re-defined, there has been no formal agreement among Russians whether Russia's future should include formal and/or in-formal control Russians living in the former republics in the post-Soviet periphery.[35] National identity therefore finds a place in the confusion regarding the relationship between Russia and Russians abroad, and is an element described as seldom a perfect "fit" between nation and state by

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[29] Graham Smith, *et al.*. Nation-building in the Post-Soviet Borderlands: The Politics of National Identity. (Cambridge, UK: Cambridge University Press, 2000), 120 and 121.
[30] *See* James H. Billington, Russian Transformed: Breakthrough to Hope. New York, NY: The Free Press, 1992.
[31] Graham Smith, *et al.*. Nation-building in the Post-Soviet Borderlands: The Politics of National Identity. (Cambridge, UK: Cambridge University Press, 2000), 120, 121 and 122.
[32] Nadia Diuk and Adrian Karatnycky, New Nations Rising: The Fall of the Soviets and the Challenge of Independence. (New York, NY: John Wiley & Sonse, Inc., 1993), 78.
[33] Graham Smith, The Post-Soviet States, Mapping the Politics of Transition. (New York, NY: Oxford University Press Inc., 1999), 67.
[34] Ibid., 67.
[35] *See* Susanne Michel Birgerson, After the Breakup of Multi-Ethnic Empire: Russia, Successor States, and Eurasian Security. (Westport, CT: Praeger, 2002).

Susanne Michele Birgerson in *After the Breakup of a Multi-Ethnic Empire*.[36] For those who left Russia (*vykhodtsy*), Russia was a natural 'homeland' (*otechestvo*). Acknowledging the significance of vykhodtsy brings about a focus on the implications of *otechestvo* for those who do not fall into any of the three categories of minority existence–migratory policy, voluntary movement or colonization. So how does the re-definition of homeland affect Russians who were either born into any of the borderlands or resided outside of Russia long enough to identify with a new homeland?

Since the early 1990s, Russia has expressed concern that among the former Soviet Republics, we are observing a restoration of ethnocracy as well as a move, or at least increased political dialogue over the re-emergence of ethnocratic states.[37] The sentiment is being spearheaded by two parties, those of the Russian government and the various Diaspora communities throughout the former Soviet republics–Ukraine in this case.[38] However, this ethnocratic tendency is evident throughout post-Soviet territory, from the Baltic States to those of Central Asia.[39]

In recent years Russians in Ukraine have been calling for Moscow to play a more direct and effectual role in "supporting" Russians who may perceive themselves as having essentially been abandoned by Moscow.[40] Further, Russian foreign policy makers have increasingly thought about their perceived ethnic brethren living outside the Russian state, and concern for Russians in the 'near abroad' has become integral in contemporary Russian politics.[41] Currently, it appears as though Russian politics is being influenced by the implications of state break-up, or that of the Soviet Union in late 1991. In this regard it is important to give attention to how the Soviet Union was constructed and who dominated it.

The term ethnocratic is used to exemplify a situation where a state acts as the authoritative agency of the ethnic majority. State agency acts as authoritative ideologues, policy maker and resource distributor, all three of which were historic roles for the Russian state within the Soviet Union and perceptually, the Russian people as direct derivatives of the Russian state. Sub-dimensions of ethnocratic agency exist in the following three ways. First, the ethnocratic states exhibits a disproportionate recruitment to elite posts and civil service and government that is overwhelmingly in favour of the majority ethnic group, or in this case Russians. Second, the ethnocratic state asserts its cultural qualities on all other ethnic segments as the core ideals of national ideology, hence former policies of Russification. David Brown explains that "…the national identity which is employed to define the ethnic society is neither ethnically neutral nor -ethnic, but rather it is mono-ethnic...clothed in the language of universalism…" which is evident through "Sovietization".[42] The third attribute of the ethnocratic state is the unequivocal maintenance of the monopolization of power by the ethnic majority. These arguments are very useful for the concern of the Soviet Union, but are equally applicable to post-Soviet space as well.

Limitations typically associate with the concept of ethnocracy is that it is more easily perceived external to the state in question; therefore internal domination patterns are difficult to recognize. The possibility exists that Russia still sees its actions and "protection" of Russians in the post-Soviet states as representative or "good" for the country. In turn, the central question that arises from the discussion of re-emerging ethnocracy is that if Russian ethnocratic politics led to state break-up, can the same political cleavage lead to Russian Diaspora mergence?

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[36] Susanne Michel Birgerson, After the Breakup of Multi-Ethnic Empire: Russia, Successor States, and Eurasian Security. (Westport, CT: Praeger, 2002), 45 and 62.
[37] Graham Smith, The Post-Soviet States, Mapping the Politics of Transition. (New York, NY: Oxford University Press Inc., 1999), 66 and 67.
[38] Ibid., 67.
[39] Ibid., 67.
[40] Graham Smith, The Post-Soviet States, Mapping the Politics of Transition. (New York, NY: Oxford University Press Inc., 1999), 67.
[41] Ibid., 67.
[42] *See* David Brown, The State and Ethnic Politics in South-East Asia, (New York, NY: Routledge, 1996).

The Political Crucible

The multi-dimensional nature of ethnicity in Ukraine makes the issue of Russian community integration problematic, especially since the break-up of the Soviet Union. Since 1991, the implications of Russian ethnic distribution in Ukraine are far more significant and political in dimension than prior to Soviet dissolution. The concentration of Russians in Ukraine illustrates an even gradation of Russians towards eastern Ukraine. The highest concentration of Russian minorities exists in the territory furthest east and is strongest in the immediate vicinity of Crimea, Kharkiv and Donetsk.

An internal perspective of Russian minorities shows that in addition to Russians reinforcing their traditional dominance in industry, administration and education in the urban areas, of roughly eleven million Russians living in Ukraine, three-quarters, and the following Russian populations as a per-cent of the national total are concentrated in the five industrially developed regions of Ukraine: Donetsk (43.6%), Luhansk (44.8%), Kharkiv (33.2%), Dnipropetrovsk (24.2%), Zaporozhzhia (32%), and Odessa (27.4%).[43] Overall, Russians made-up 17.3% of significant ethnic groups in Ukraine in 2001, and Russian settlement in Ukraine has created a complex set of overlapping identities in the Russian communities.[44] Does this overlap pose a threat to the identity of Russians in Ukraine? If Russian state prestige and power increasingly identifies with Russian populations in the 'near abroad' how might Russia be expected to "protect" or "defend" these minorities? Bearing in mind that in the Southern regions of Ukraine, including Nikolaev, Odessa and Kherson, the concentration of Russians is potent, certain political circles in Russia considers the Crimea and the Eastern regions of Ukraine as the subject of territorial claims.[45] Russian advocates of the neo-imperial idea also support the restoration of *Novorossiia*, or 'New Russia' within the borders that existed before the 1917 Revolution.[46]

Russian Intervention in Moldova

Heightened Russian sense of identity was an integral component in pressuring the Russian government to "defend" Russians abroad; but in practical terms, this was observed in the western periphery of Ukraine. Russia enacted protectionist measures by undertaking full-scale military operations in the 1990s in the breakaway Russian-speaking enclave of Trans Dniestria, which declared its secession from Moldova in 1991.[47] Through a renewed sense of Russian chauvinism, Russia adopted a special relationship with its own ethnic minorities in this region that saw Russia accepting responsibility for the geo-political security of its own Diaspora abroad.

As a cease-fire maintains the peace in the region to the present day, Russian forces maintain a security presence exceeding 2,500 troops and large-scale ammunition stockpiles.[48] As recently as December, 2002, the Russian military launched the creation of the Transdniester military force to maintain control of stockpiles of ammunition and to ensure the security of the Russian Diaspora community in the region.[49]

Difficulty in managing multi-cultural space has been apparent since the early 1990s and Trans-Dniestrian secessionism is one of two examples of secessionist demands by ethnoregional groups, and the political leverage they have obtained through Russian foreign policy. Since 1990, over fifteen major occurrences and present status acts of inter-ethnic violence have been initiated in post-Soviet space.[50] Both Trans Dniestria and Chechnya, where Russian forces fought for two long years to keep the region within Russian political space, exemplify extreme measures assumed by Moscow to manage and protect Russians in the 'near abroad'. As Barnett Rubin concludes from his analysis of inter-

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[43] Neil Melvin, Russians Beyond Russia, The Politics of National Identity, (London, UK: Chatham House Papers, 1995), 86 and 87.
[44] Ibid., 86 and 87.
[45] Vladimir Shlapentokh, Munir Sendich and Emil Payin, The New Russian Diaspora, Russian Minorities in the Former Soviet Republics, (Armonk, NY: M. E. Sharpe, 1994), 59.
[46] Ibid., 59.
[47] Graham Smith, The Post-Soviet States, Mapping the Politics of Transition. (New York, NY: Oxford University Press Inc., 1999), 67.
[48] Vladimir Socor, September 11 and the Geopolitical Revolution of our Time. (Bucharest, Romania: SNSPA, 2003), 242.
[49] Ibid., 243.
[50] Smith, Graham Smith, The Post-Soviet States, Mapping the Politics of Transition. (New York, NY: Oxford University Press Inc., 1999), 228 and 229.

communal tensions in the post-Soviet space, "…while most of the conflicts of the post-Soviet transition are no longer violent, few have actually been resolved to the satisfaction of the parties [involved], and tensions could reignite."[51] Since the Russian minority populations in both Trans-Dniestria and Chechnya represented less than ten per-cent of the total population, how might Russia orchestrate ethnic minority management in such regions Eastern and Southern Ukraine and Crimea?

Security issues were the most acute reasons for Moscow's military intervention in Moldova, but issues of security were not the only reasons for Moscow to assume a more active role in relation to the post-Soviet republics. As early as 1992–immediately following the disintegration of the Soviet Union, the security of the twenty-five million Russians living in the borderlands has become a major feeling of anxiety for political elites in Moscow who were concerned about the territorial losses incurred from dissolution.

Following Soviet collapse, the preservation of the territorial integrity of Russia was a vital element in Russia's position as a great power in international affairs; yet this position was seriously threatened when Chechnya declared its independence from the Federation. Russia's re-assertion of power and prestige are fundamentally linked with Diaspora communities in the borderlands, and therefore these communities have come to play an increasingly significant role in Russian foreign policy and international relations. Soviet dissolution and Chechnya both represented a severe challenge to Russia's territorial integrity; the existence of sizeable Russian minorities represents a tangible constituent that may compel Moscow to "protect" them, especially since Russian prestige and power are as closely connected to population as they are with territory. In 1980, fifty years after the formation of the Soviet Union, Viacheslav Molotov professed to a great failing of the Soviet government, that the Communist Party had never effectively resolved the Russian national question: the problem of what status the massive RSFSR and the Russian nation should have within the Soviet Union.[52]

Although Russia still retained the largest area of land in the 1990s, its post-Soviet population of roughly 148 million, barely half of the population of the former Soviet Union, ranked well behind China, India, United States, Indonesia and Brazil.[53] Since tension within the Russian elites has been directed to fears that culminate over the loss of the borderlands and its subsequent effect on territorial capacity, equitable focus should be given to its consequent mitigation of Russian ethnic representation, which directly equates the loss of Russian prestige and power. As Molotov explained in 1980, there was never really any place for the Russian nation. The central for Russia sixty years ago was that there nationality was the USSR's awkward nationality. The size of the Russian population made it too large to ignore while simultaneously, it was too important to be given equal status as the Soviet Union's other nationalities.[54] We have seen that the same issue is mirrored in post-Soviet space today, but this issue is augmented by Russia's attempts to re-affirm its prestige and power through territory and population management.

Conclusions

This essay has explored some of the basic theorization behind Diaspora communities and the politics that are inter-connected with them. Additionally, this essay has examined specific cases in which Diaspora politics is reflected in foreign policy and international relations in the space of the former Soviet Union. While nationalizing movements have sought to tackle some of the issues surrounding the integration of Diaspora communities, the existence of such communities, we see, is more regular than is the existence of Diaspora identity. In the case of Ukraine, we find that Diaspora identity is a fluid

[51] Barnett Rubin, 'Managing normal stability', in B. Rubin and J. Snyder, Post-Soviet Political Order. Conflict and State-Building. (London, UK: Routledge, 1998), 170 and 171.
[52] Terry Martin. The Affirmative Action Empire: Nations and Nationalism in the Soviet Union, 1923-1939. (London, UK: Cornell University Press, 2001), 395.
[53] *See* Roman Szporluk, Cultures and Nations of Central and Eastern Europe. (Cambridge, MA: Ukrainian Research Institute, Harvard University, 2000).
[54] Terry Martin. The Affirmative Action Empire: Nations and Nationalism in the Soviet Union, 1923-1939. (London, UK: Cornell University Press, 2001), 395.

concept, and one that is readily influenced by socio-cultural and linguistic elements within the host nation.

Initially, characterizing the existence of ethnic minorities in the former republics seemed easy to do along such lines as either a product of a migratory policy of the homeland, a voluntary movement or a result of past colonization, but how Moscow has attempted to characterize, or rather re-characterize these minorities in the borderlands remains a difficult question to address. Have Russian ethnic communities inadvertently become Russian 'compatriots abroad', the vanguard of neo-nationalizing groups that have brought about a re-newed sense of ethnocracy in Eastern Europe? What is further perplexing is with the collapse of Communism and the dissolution of the entire Soviet empire, how the *raison d'être* for Russian Diaspora sentiments in the borderlands has not faded with the empire.

If the present obstacles facing Russia today are those of territorial and population re-acquisition, then it would seem that in the present-day, Russian Diaspora management has become a vehicle by which Moscow seeks to avoid the creation of dual centers of power in Eastern Europe. It is important to understand and remember that the relationship between the Russian Diaspora and Russian foreign policy is one that is tripartital in nature, comprised of the diasporic community, the host nation and the original or national homeland. Within Russian foreign policy, Moscow still sees the Russian Diaspora community in host nations as too important to be given 'b'-class status among other nationalities in the region, or at least too critical a commodity to share 'a'-class status between national forces in Eastern Europe. This was most evident in the Trans Dniestrian space within Moldova and sharp conflict within Chechnya during the 1990s, but these regions represented a fraction of Russian ethnic minorities in comparison to those living in Ukraine. So how might Russia respond to the difficulty in Diaspora identity among Russian ethnic communities in these regions in the future? Will Russia seek to "protect" or "defend" its populations in the 'near abroad' as it has previously, and what does this mean for the ethno-political security of Eastern Europe and post-Soviet territory?

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Stability Study of Historical Buildings Using a Nondestructive Method

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Abstract

The stability of historical buildings under the impact of the surrounding movements is an important issue to restore, to conserve and to safely reuse. Many historical buildings are tested nondestructively using traditional methods, and this paper is presenting the use of a "Quartz Tiltmeter" to analyze the stability of one of these historical buildings. This instrument offers high accuracy and enables to detect very small movements of a structure, which are not detected and measured using other instruments. We present a case study; the analysis of the stability of the Louvre museum in France. We analyzed the effect of the under ground (Metro) movements on the walls of the museum. The tilt measurements of walls demonstrated the effect on the building. Curves are plotted to demonstrate the relation between the wall tilt and the movement under different cases of metro loading. These results of tilt measurements enable: i) the calculation of the Elastic Rock Modulus of the museum foundations nondestructively and, ii) the determination of the restricted areas needed to protect the historical and archaeological monuments from surrounding movements.

Keywords: "Quartz Tiltmeter"- historical buildings – stability - accuracy - Louvre museum - Boussinesq model.

1. Introduction

Many historical buildings are being renovated to be safely reused these days for diverse purposes such as museums, libraries, city halls, etc. These structures need to be nondestructively tested for stability, in case of restructuring or supporting of the week old foundations, or in the development of the

monument site, or in the process of providing the services needed around it. Providing transportation to a historical site is a major issue which will bring tourism, but the movement of a metro for example may shake the foundations continuously and jeopardize the stability of the monument. This is why we decided to study the effect of the metro on the stability of the historical monument. For this purpose a nondestructive testing method is used which is developed for the study of the stability of structures (Berest et al. 1991; Hoffman and Thompson 1982), and based on the use of a quartz tiltmeter developed by Blum and Saleh in 1986 (Saleh et al. 1991). This instrument is tested over many sites in the world and provided reliable measurements (Beauducel 1998; Saleh et al. 1990). This tiltmeter provides tilt measurements of high accuracy and detects very small movements which are undetected using any other surveying instrument and records measurements continuously without any human involvement.

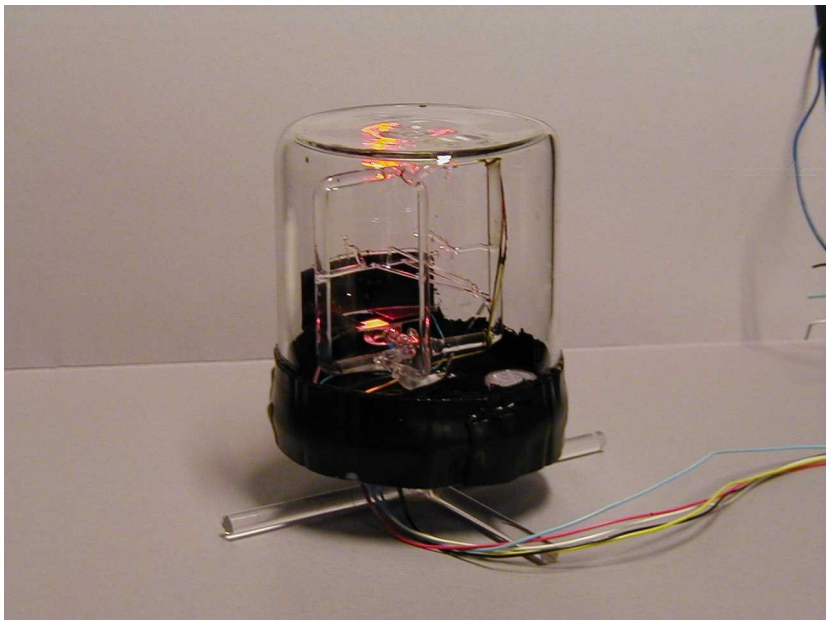
This Paper presents a case study concerning the stability study of a historical building using the quartz tiltmeter. The tilting movements of the Louvre museum in Paris induced by undergoes metro carriages are measured using this instrument. The elastic rock modulus of the Louvre foundations is calculated using tilt measurements.

2. Measurements

Tiltmeter

Many Types of tiltmeters were developed for deformation measurements during the last three decades (D'Oreye 1998; Wyatt and Berger 1980; Goulty 1976). Due to the importance of measuring tilts using accurate devices of low drift and low cost, two tiltmeters of high resolution, in the range of 10^{-8} rad were developed by Blum and Saleh in 1986 (Saleh et Blum 1990; Saleh et al. 1991). The tiltmeter which was used for this case study is the compact quartz tiltmeter (see Fig.1). It is a horizontal pendulum made of melted silica which can operate in vacuum, the rotation of the pendulum mass is transformable into voltage variation using a photoelectric detector. This can be done as follows:

Figure 1: Photograph of silica compact tiltmeter



i) The pendulum mass is lighted by a diode, a spot is formed through the window of the mass on the electrical cell situated behind it.
ii) If a tilt of the ground occurs, the result will be a rotation of the mass and a displacement of the spot on the cell, simultaneously.

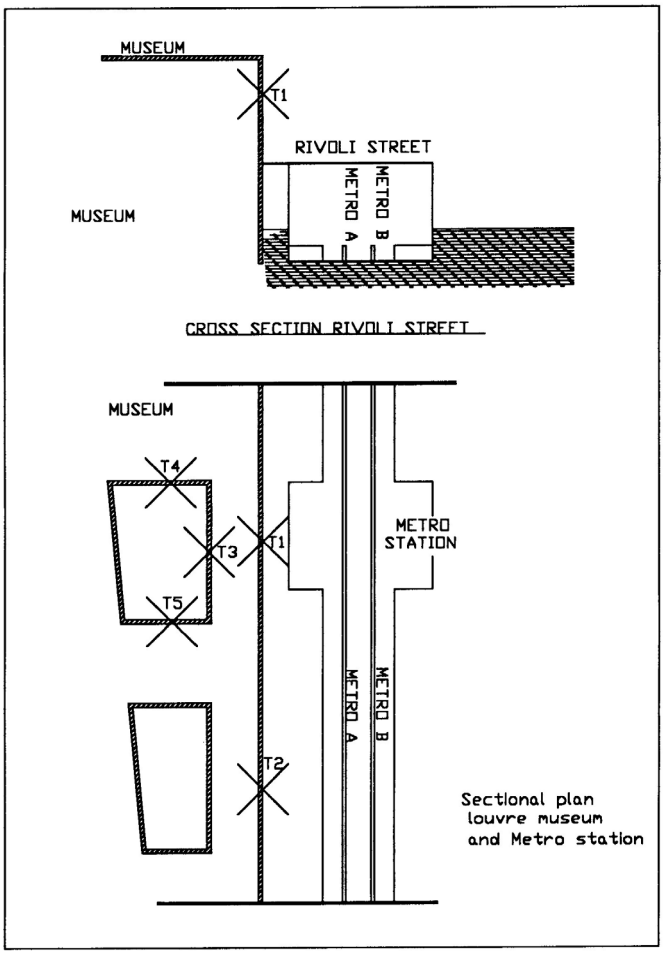
iii) The tilt is proportional to the voltage output induced by the displacement of the spot.

Both the range and the resolution depend on the pr-chosen natural period of the pendulum. In our case study, the period is fixed at 8 sec which gives a resolution of 10^{-7} rad (0° 00' 00.02").

Installation

Five tiltmeters were installed on Louvre museum to study its behavior during a structural work inside it and under the impact of metro movement. Two of the tiltmeters, T1 and T2 were fixed on the exterior wall of the museum while T3, T4 and T5 were fixed on an interior wall (see Fig. 2). The tiltmeters T1, T2 and T3 are oriented to measure the tilt in the direction NE-SW and T4, T5 in the direction SE-NW.

Figure 2: Plan of the walls of the Louvre museum and positions of the tiltmeters



Tilts

The line no.1 of Paris Metro is situated under Rivoli Street and the underground station "Palais Royal" is in front of the Louvre museum. This line is composed of two rails A and B as shown in fig.2. The distance between their axes is 4m.

During the movement of the metro, tilts were recorded by instrument T1, T2 and T3. A typical record from T1 and T2 is shown in Fig.3 and Fig.4 respectively. While no tilts were recorded by instrument T4 and T5 (see Fig. 5). The average tilt measured is 2 x 10^{-7} rad at 10 m distance for an empty metro (130 t) and 3 x 10^{-7} rad for the loaded one (200 t).

Figure 3: Tilt recorded by the tiltmeter T1

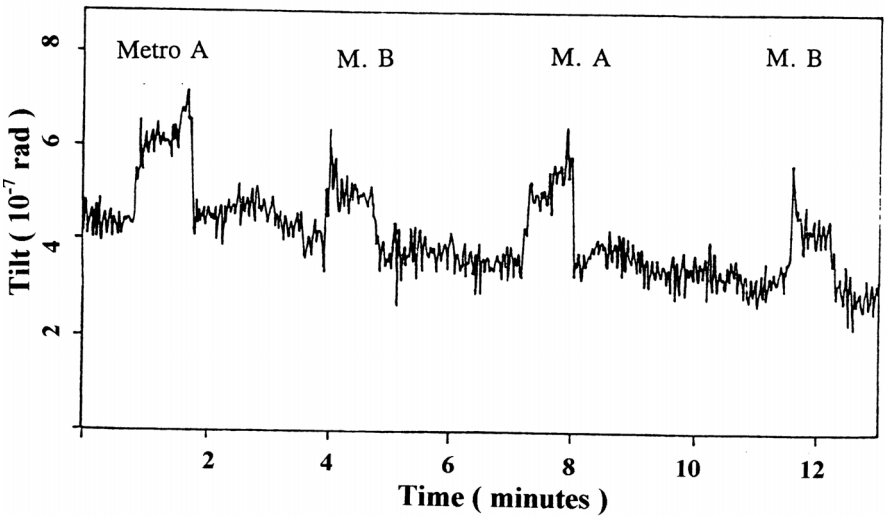


Figure 4: Tilt recorded by the tiltmeter T2

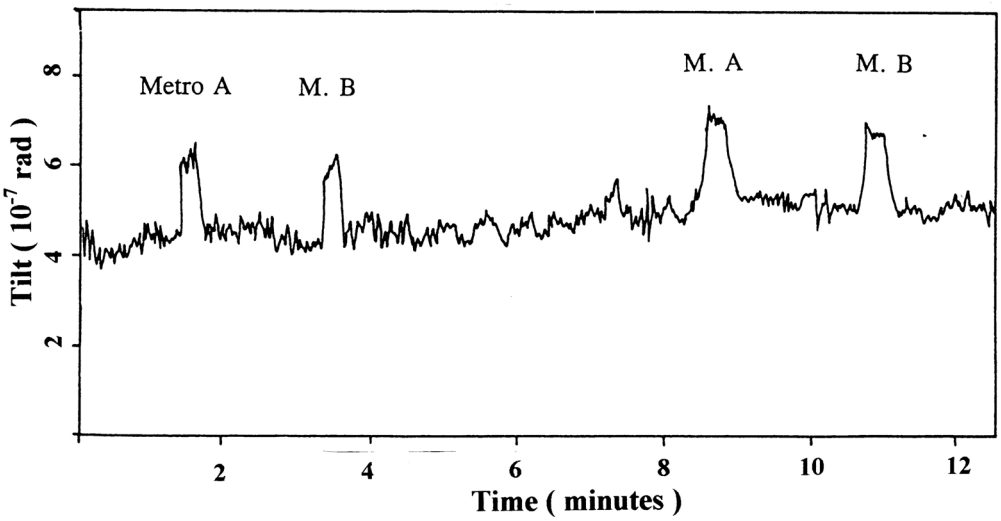
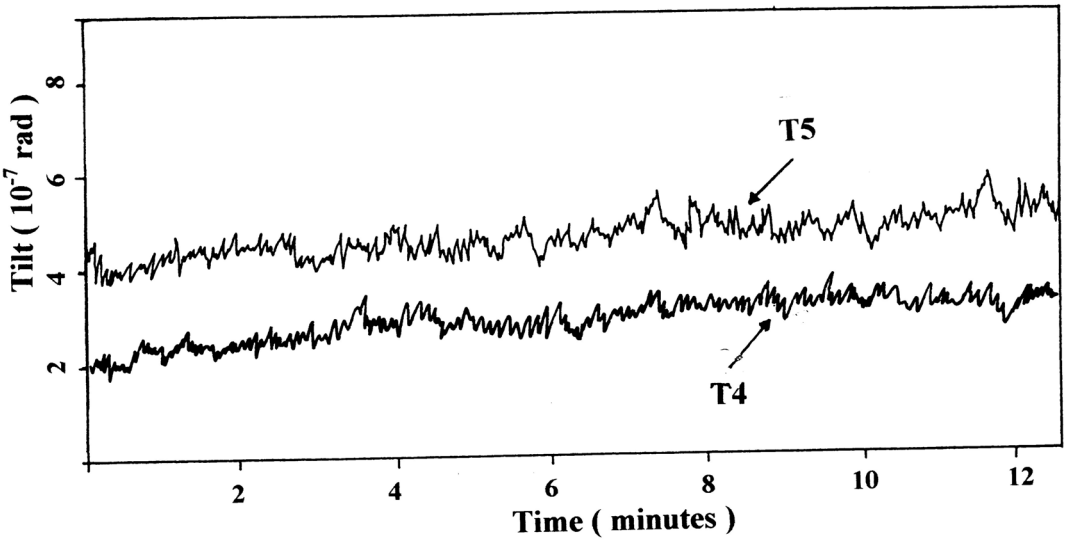


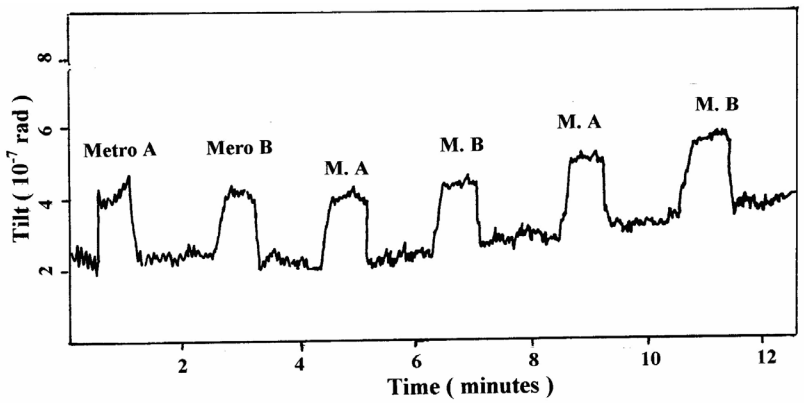
Figure 5: Tilts recorded by the tiltmeters T4 and T5



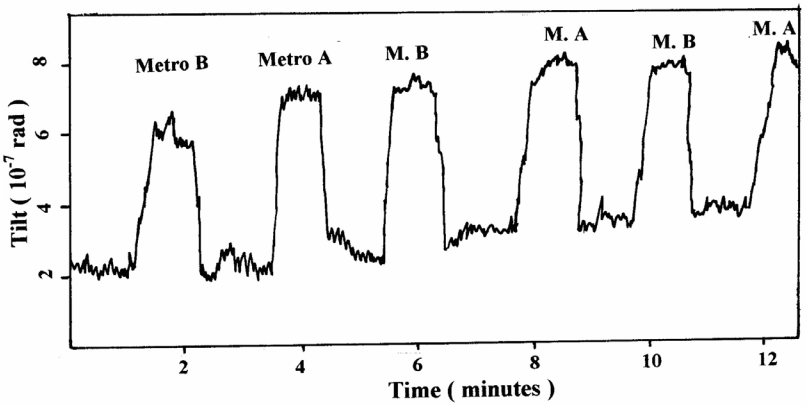
3. Analysis

The tilt measured by tiltmeter T1 takes the form of a large pick, the metro stops in the station for one minute. The tilt recorded by T2 is a sharp pick, the metro is just passing. The tilt observed by T4 and T5 is zero (this direction is parallel to the line load). At 28 m distance from the load, T3 gives the same tilt as T1. This tilt should be very small if T3 is fixed on an independent wall. Four types of tilts are measured by each tiltmeter. Two of them correspond to the position of load; weather the metro is on rail A or B (the tilt is great when the distance is small). The other tilts correspond to different loads, the maximum load of the metro is at rush-hours (200 t) and the tilt becomes greater than that observed at night (see Fig.6). The response of the Louvre walls is elastic under the metro effect and the tilting movement is negligible (the maximum horizontal displacement at the top of the wall is about 3 microns).

Figure 6: Tilts recorded by T3 at different time
(a) Tilt recorded at 10.30 p.m while the metro is empty
(b) Tilt recorded at 5.30 p.m while the metro is full



(a)



(b)

The elastic modulus of the Louvre museum foundations is computed for different observed tilts and many values are obtained using Boussinesq model (Berest 1991):

$$Tilt = \frac{-F}{\pi E}\frac{(1-\nu)}{r^2}$$

Where:

r = Horizontal distance between the tiltmeter and the load
F = Load
E = Elastic modulus
ν = Poisson's ratio

An average value of 50000 kgf/cm2 (5.0 Gpa) is adopted. This value represents a typical elastic modulus of fractured lime stone which is the case of the museum foundations.

4. Conclusions

The following points can be concluded:

- The tiltmeter is suitable for measuring small movements with high accuracy and can be used for historical buildings monitoring.
- The effect of the underground metro is negligible on the Louvre museum.
- This method can be used for the determination of the elastic modulus of foundations nondestructively.
- The method enables the determination of the restricted areas needed to protect the historical and archaeological monuments from surrounding movements.

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Analysis of the Physico-Chemical Characteristics of Groundwater in Proterozoic Land Region of the Tiassale Area (Southern Cote D'Ivoire)

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Abstract

This study focuses on a forest region located in southern Cote d'Ivoire, where fracturing is well developed. It aims at improving knowledge regarding the acquirement of mineralization mechanisms of groundwater in Tiassalé area. The data used within the framework of this study are essentially from physico-chemical analyses of groundwater sampled in boreholes, capturing fractured reservoirs witch depths vary between 40 and 100 m and also from technical sheets information of boreholes. Statistical and multi-dimensional (NCPA) data analysis have been carried out.

Groundwater temperatures vary very little altogether a slightly acidic pH. The mineralization of groundwater from this region is rather good and is similar to that of the fresh water. Analyses show an abundance in some of the ions among which the iron and the manganese in the boreholes investigated. The strong contents of these ions in the water may degrade considerably its drinkability. These two elements have a superficial origin and are driven into the groundwater by the infiltration phenomenon. The NCPA achieved on 14 elements highlights two main phenomena governing the mineralization of groundwater: the stay time period of water in the water-bearing rock and superficial contributions.

Except some points such as that of Morokro who sometimes presents abnormal contents in certain elements, the groundwater of the Tiassalé area is drinkable for human consumption in a general manner. These results contribute to a better knowledge of the properties of groundwater resources in crystalline land of Cote d'Ivoire.

Keywords: Physicochemical analysis, mineralization, NCPA, infiltration, Cote d'Ivoire

Introduction

Les ressources en eau occupent une place de choix dans le développement des différents secteurs de l'économie d'un pays. Elles contribuent à l'amélioration du niveau de vie des populations. Ainsi, au lendemain de l'indépendance, les autorités ivoiriennes, avec l'appui des partenaires au développement, ont réalisé de nombreux projets d'implantation de points d'eau dans plusieurs domaines dont l'agriculture et l'approvisionnement en eaux potables des populations rurales que des grandes agglomérations. Plusieurs structures ont été créées pour le suivi et l'exécution des différents projets, il s'agit de la Direction de l'Hydraulique Humaine du ministère des Infrastructures Economiques et la Direction des Ressources en Eau du Ministère des Eaux et Forêts. Plus treize mille cinq cent forages ont été réalisés sur l'ensemble du territoire ivoirien à l'heure actuelle et de nombreux projets sont encore en cours d'exécution.

Les ressources en eau souterraines de la Côte d'Ivoire sont contenues en grande partie dans les réservoirs formés par le socle fracturé du fait de sa vaste répartition géographique soit 97,5% du territoire national (Lasm, 2000). L'importance des aquifères discontinus se trouve ainsi justifiée. De nombreux études ont été entreprises en vue d'une meilleure connaissance des propriétés géométriques des aquifères fissurés (Lasm, 2000; Lasm & Razack, 2001; Kouame *et al.*, 2005; Razack & Lasm, 2006; Jourda, 2005; Lasm *et al.,* 2008) et des écoulements souterrains dans les fissures (Faillat, 1986; Kouamé & Lasm, 2002; Kouamé *et al.,* 2005). Les eaux des aquifères de fissures sont d'une manière générale potables pour la consommation humaine, en dehors de quelques points d'eau impropres, du fait de la couleur, du goût et de l'abondance en certains éléments chimiques.

Les autorités ivoiriennes ont jadis privilégié la disponibilité de l'eau au détriment de sa qualité. C'est la raison qui justifie les travaux parcellaires et fragmentaires exécutés dans ce domaine dans les milieux sédimentaire (Oga, 1998) et de socle (Biémi, 1992; Oga, 1998; Goné, 2001; Soro, 2002). De plus les analyses ne sont cibler que sur quelques éléments, et ce n'est que lorsque l'eau est trouble ou présente une coloration anormale ou bien même que le goût est inhabituel que certains éléments particuliers sont dosés. A l'heure actuelle, des analyses systématiques sont réalisées en vue de déterminer la potabilité et la qualité des eaux destinées à la consommation. D'après certains travaux (Biémi, 1992; Savavé, 1997), l'on enregistre de plus en plus dans certains forages de diverses localités, de fortes teneurs en certains éléments, dont le fer, le manganèse dans les eaux souterraines.

C'est donc dans l'optique de fournir aux populations des eaux de bonne qualité pour l'usage domestique que cette étude a été entreprise. Elle porte sur une zone située en région de socle où la fracturation est développée.

Les échantillons d'eau étudiés dans le cadre de cette étude ont été prélevés dans les eaux des forages au cours d'une campagne de terrain dans la région de Tiassalé. Ces forages sont repartis dans plusieurs localités en raison d'un forage pour 100 habitants et séparés de quelques kilomètres à plusieurs kilomètres.

La présente étude réalisée dans une région de socle à pour objectifs d'étudier la potabilité des eaux souterraines destinées à la consommation humaine et d'identifier les phénomènes gouvernant l'acquisition de la minéralisation des eaux de la région de Tiassalé.

Cadre d'étude, contextes géologique et hydrogéologique

La région étudiée est localisée dans la région de Tiassalé au sud de la Côte d'Ivoire entre les latitudes 5°32 et 6°24 nord et les longitudes 4°29 et 5°14 ouest. Elle couvre une superficie d'environ 3 370 km^2 (figure 1). L'agriculture occupe une place de choix dans l'économique de cette région. Les principales cultures sont de deux types: les cultures de rente et d'exportation (café, cacao, palmier à huile, hévéas, banane douce et l'ananas) et des cultures vivrières. La région est majoritairement constituée en grande partie de plaines. On y rencontre par endroit des collines qui culminent à 108 m en moyenne et des vallées. Son climat est de type attiéen (tropical).

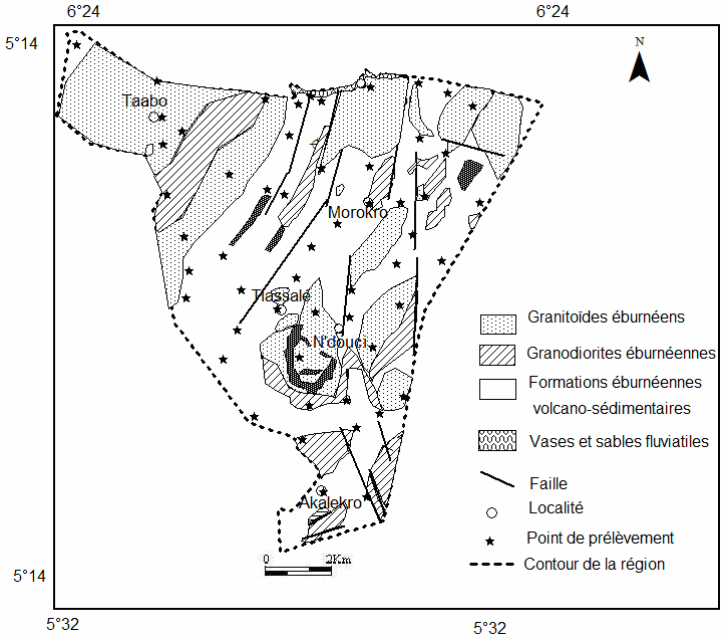
Figure 1: Carte de localisation de la région de Tiassalé

D'un point de vue géologique, la région est localisée dans le domaine Baoulé-Mossi à l'est de l'accident majeur du Sassandra. Son histoire géologique s'inscrit donc dans celle de ce domaine. Plusieurs phases de déformation ont affecté la région dont l'événement tectono-métamorphique majeur est l'orogénèse éburnéenne. Ces déformations ont abouti à la mise en place d'une fracturation développée (Koné, 2005; Baka, 2006). Les formations géologiques de la région ont été structurées au cours de l'orogenèse éburnéenne.

Synthétiquement, ce domaine se présente comme un ensemble de gneiss, constituant le socle des formations supracrustales d'origine volcanique, sub-volcanique et sédimentaire déposées dans des sillons ou bassins intracratoniques dans lesquels se sont mis en place les granites du cycle Eburnéen (Kouamelan, 1996). Ces formations se sont différenciées du manteau vers 2200 à 2300 Ma et caractérisent le birimien. Le birimien regroupe l'ensemble des formations de l'Afrique de l'Ouest dont l'âge varie entre 2400 et 1600 Ma. Le terme birimien a été défini pour la première fois par Junner (1940) dans la vallée de Birim au Ghana.

Elles sont formées d'ensembles volcano-sédimentaires dans lesquelles apparaissent en intrusion des volcanites et des granitoïdes éburnéens (figure 2).

Figure 2: Carte géologique de région de Tiassalé avec localisation des différents forages



Au plan hydrogéologique, on y rencontre les aquifères des altérites et les aquifères de fissures (Faillat & Blavoux, 1989; Biémi, 1992; Savané, 1997; Lasm, 2000). L'alimentation en eau potable des populations se fait au moyen des forages captant les aquifères fissurés. Les aquifères des altérites sont parfois exploités par des puits à grand diamètres mais dans bien des cas les eaux sont polluées (mauvaise protection, état bactériologiques du système d'exhaure, etc.).

Materiels et Methodes

Matériels et données

Les données utilisées dans le cadre de cette étude sont diverses. Ce sont les résultats des mesures in *situ*, celles des analyses chimiques réalisées au Laboratoire Privé d'Analyse (LPA) à Abengourou et au Laboratoire National d'Essai de Qualité, de Métrologie et d'Analyse (LANEMA) à Abidjan. Les données des fiches techniques de forages réalisées au cours des différents programmes d'approvisionnement en eau potable des populations rurales ont été aussi utilisées. Cette étude s'est faite sur 54 forages repartis sur l'ensemble de la zone d'étude. Ces forages ont été retenus du fait de la

qualité de leurs données. Les coordonnées géographiques des forages ont été obtenues à l'aide d'un GPS (GARMIN version 2.0). Nous avons eu recours aux cartes topographiques des degrés carrées de Gagnoa, d'Abidjan et de Dimbokro éditées en 1992 par le Centre de Cartographie et de Télédétection (C.C.T.) et des cartes géologiques réalisées par la Direction de la Géologie en 1996 de ces localités, à l'échelle de 1/200 000. Les diverses cartes ont été scannées puis traitées à l'aide des logiciels Mapinfo, Surfer et Arcview. Les coordonnées initialement exprimées en coordonnées géographiques (longitudes, latitudes) ont été converties en UTM (Universal Transverse Mercator) exprimées en kilomètre, à l'aide du module LNT2UTM du logiciel Rockware Utility. Les coordonnées des forages ont été utilisées pour réaliser la carte de répartition des forages avec les logiciels Mapinfo, Surfer et Arcview (figure 2). Les coordonnées initialement exprimées en coordonnées géographiques (longitudes, latitudes) ont été converties en UTM (Universal Transverse Mercator) exprimées en kilomètre, à l'aide du module LNT2UTM du logiciel Rockware Utility.

Méthodologie

Mesures et dosage

Au cours des campagnes de terrains certaines mesures ont été réalisées sur le terrain et d'autres au laboratoire. Les mesures in situ concernent la température (T°), la conductivité et le pH. Les éléments majeurs et autres ont été dosés en laboratoire par différentes techniques. Les bicarbonates HCO_3^-, chlorure (Cl^-), nitrates (NO_3^-), sulfates (SO_4^{2-}), calcium (Ca^{2+}), Magnésium (Mg^{2+}), sodium (Na^+), fer (Fe^{2+}), Manganèse (Mn^{2+}), phosphates (PO_4^{3-}) etc., ont été dosés au laboratoires une quinzaine de jour au maximum après les prélèvements. Le stockage a été réalisé sous une température de 4°C, à l'abri de la lumière.

Les chlorures et les bicarbonates ont déterminés par titration. Cl- par ajout de nitrate d'argent de molarité 0,016N en présence de 5% de dichromate de potassium comme indicateur et HCO_3^- ont mesurés à l'aide de 0,1 N d'acide chlorhydrique (HCl) en utilisant le méthyle orange comme indicateur. Les sulfates ont été dosés par néphélométrie, nitrates et phosphate par colorimétrie. Tous les cations ont été dosés par spectrophotométrie à flamme. Ces méthodes sont bien décrites en détail dans ouvrages classiques de la chimie.

Paramètres physico-chimiques des eaux

Les résultats du dosage des anions et cations sont utilisés pour la caractérisation chimique des eaux souterraines. Il s'agit du calcium (Ca^{2+}), du magnésium (Mg^{2+}), du potassium (K^+), du sodium (Na^+), du fer (Fe^{2+}) et du manganèse (Mn^{2+}) pour les cations; des bicarbonates (HCO_3^-), des nitrates (NO_3^-), des chlorures (Cl^-), des phosphates (PO_3^{4-}) et des sulfates (SO_4^{2-}) pour les anions. Plusieurs paramètres ont été déterminés notamment:

- **la Minéralisation Totale** (MT) exprimée en $mg.L^{-1}$
  $MT = \Sigma ni\ [A^{ni+}] + \Sigma\ mj\ [B^{mj-}]$ (1)
  avec:
  $[A^{ni+}]$, la concentration en cations majeurs; $[B^{mj-}]$, concentration en ions majeurs;
- **le Titre Hydrométrique Total** (THT) exprimée en degré français (°F)
  Il permet d'apprécier la dureté d'une eau et il est défini par l'expression ci-dessous (2)
  $THT = (Ca^{2++}Mg^{2+}) \times 4{,}985°F$ (2)
  Ca^{2+} et Mg^{2+} sont exprimés en milliéquivalent par litre ($meq.L^{-1}$).

Analyse statistiques des paramètres physico-chimiques et des ions majeurs

Les paramètres physico-chimiques et les ions majeurs dosés à partir des eaux souterraines prélevées dans les forages en milieu cristallin et métamorphique du socle précambrien de la région de Tiassalé ont été analysés d'un point de vue statistique. Il s'agit de l'étude de la distribution des éléments sus-

cités dans un histogramme. Cette approche permet de ressortir quelques caractéristiques des eaux souterraines.

Analyse en Composante Principale normée (ACPN)

L'analyse en composante principale normée ou analyse multidimensionnelle constitue un outil puissant de l'hydrochimie puisque les paramètres chimiques sont généralement soumis à des variations remarquables aussi bien dans le temps que dans l'espace, en outre ces variables sont nombreuses (fréquemment de 10 à 12 pour chaque échantillon). C'est la raison pour laquelle cette méthode a été utilisée pour la caractérisation chimique des eaux souterraines de nombreuses régions à travers divers travaux (Biemi, 1992; Oga, 1998; Soro, 2002. Goné *et al.*, 2004). Elle a été initialement développée par Caillez & Pages (1976). Rappelons que l'ACP, comme tous les types d'analyse factorielle, remplace un tableau de nombres difficiles à lire par une représentation plus facile à lire. Chacun des n échantillons caractérisés par p variables est représenté par un point dans un espace de dimension p. Comme la visualisation du nuage dans un espace à 10 dimensions (pour 10 variables par exemple) n'est pas possible, on projette cet ensemble dans un sous-espace à 2 ou 3 dimensions. La projection du nuage sur l'un des axes de ce sous-ensemble est faite de façon à exprimer le maximum de variance de l'ensemble: c'est le premier axe factoriel. La projection est ensuite poursuivie successivement sur les autres axes, exprimant chacun le maximum de variance inexprimée, jusqu'à ce que les axes factoriels ainsi déterminés rendent compte d'au moins 90 % de la variance totale. L'ensemble des échantillons forme donc un nuage de points aussi fidèle que possible dans cet espace multidimensionnel en matérialisant les principaux axes de la structure; elle permet de limiter les effets de la projection en minimisant les erreurs dues à la déformation. Les calculs permettent de passer à un espace de dimension plus petite par factorisation du tableau des données, avec le minimum de perte d'information (Faillat & Blavoux, 1989). L'usage de l'ACPN permet d'éliminer l'effet de taille et l'hétérogénéité que l'on peut enregistrer au niveau des données. Ce type de représentation d'un échantillon permet de visualiser tous les individus et d'interpréter leur disposition afin de déterminer les principaux facteurs responsables de la structures observée aussi bien par rapport aux variables que par rapport aux u.s.. Dans l'espace des variables, les coordonnées de chaque variable correspondent aux saturations. Une variable contribue d'autant plus à la détermination d'un facteur qu'elle est éloignée du centre de gravité. Dans l'espace des u.s. on recherche la contribution de chaque u.s.; à l'inertie du nuage, puis leurs composantes principales et enfin la contribution de chaque u.s. à la détermination des facteurs. Pour plus de détails, nous renvoyons le lecteur aux travaux de Caillez & Pages (1976), Bouroche & Saporta (1980), Lefebvre (1983). Cette analyse multi-variée permet de mettre en évidence les ressemblances chimiques entre différentes eaux et aussi les différents pôles d'acquisition de la minéralisation (Oga, 1998). L'ACPN synthétise, classe et ordonne les données pour en extraire les facteurs principaux qui influencent l'évolution simultanée des variables en tenant compte de leurs relations réciproques. Pour cette analyse, nous avons eu recours à cinquante-quatre échantillons d'eau de forage et à quatorze variables que sont: pH, Cond., Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Fe^{2+}, Mn^{2+}, HCO_3^{-}, Cl^{-}, NO_3^{-}, SO_4^{2-}, MT, et pCO_2.

Résultats et Discussion

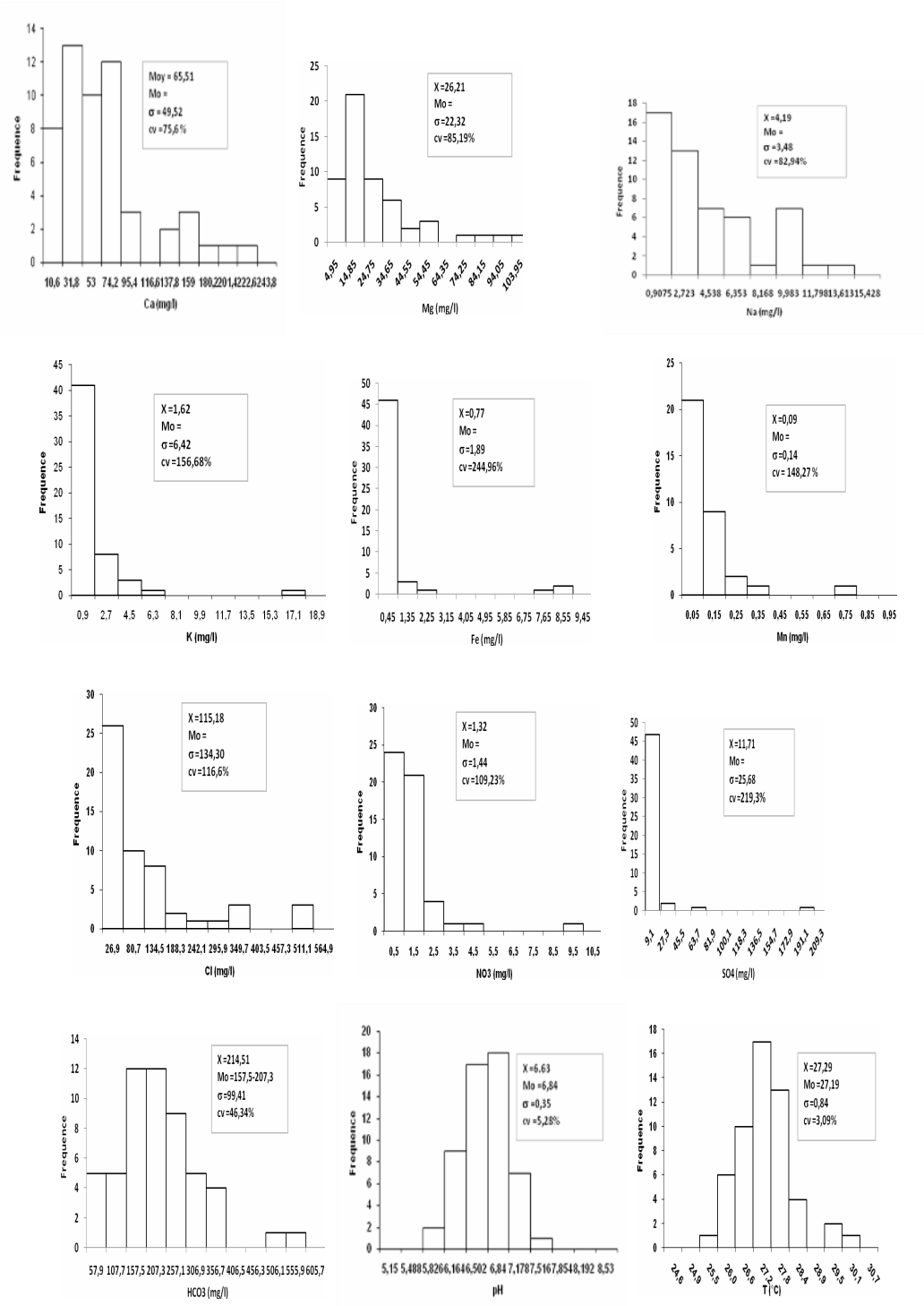
Paramètres physico-chimiques

Paramètres physiques

L'examen des valeurs et la distribution des paramètres physico-chimiques et des ions majeurs de la région de Tiassalé mettent en évidence les principaux points suivants (**figure 3**): Les valeurs de température des eaux souterraines de la région de Tiassalé prélevée dans les forages de profondeurs oscillant entre 31 et 81 m, sont comprises entre 25°C (Akalékro) et 30°C (Affouékro). Le pH de ces eaux est très variable, il oscille entre 5,79 et 7,7. Les eaux légèrement basiques ($7,10 < pH < 7,72$)

représentent environ 11 %, les neutres 48 % (6,5 < pH < 7,1) et les eaux acides (5,9 < pH< 6,50) représentent 31 % des forages étudiés. Les conductivités vont de 113 µs.cm^{-1} à 2 460 µs.cm^{-1}. D'une manière générale, les eaux sont en majorité moyennement minéralisées. Les eaux à forte minéralisation représentent environ 9,3 % des échantillons, elles présentent des conductivités supérieures à 1500 µs.cm^{-1}, la norme admise par l'OMS est comprise entre 500 µs.cm^{-1} et 1500 µs.cm.

Figure 3: Histogrammes et paramètres statistaiques élementaires des 54 analyses



Paramètres chimiques

Cations

Le calcium est le cation le plus abondant dans les eaux souterraines de cette région. Ces teneurs oscillent entre 5,50 $mg.L^{-1}$ et 212,42 $mg.L^{-1}$, plus de 42 % des échantillons présentent des concentrations supérieures à la norme admise (60 $mg.L^{-1}$). Le magnésium présente des teneurs qui varient de 3,20 $mg.L^{-1}$ à 99,63 $mg.L^{-1}$. La norme proposée par l'OMS pour le magnésium est de 30 $mg.L^{-1}$ avec une concentration maximale admissible de 50 $mg.L^{-1}$. Les teneurs en ion potassium sont faibles d'une manière générale, elles varient de 0,11 $mg.L^{-1}$ à 18 $mg.L^{-1}$. Le pic des teneurs en cet ion a été observé dans le forage de Morokro (18 $mg.L^{-1}$), il est nettement supérieur à la valeur préconisé par l'OMS qui est de 12 $mg.L^{-1}$. Cet ion est généralement moins abondant dans les eaux souterraines, car il est absorbé par les plantes et entre dans la composition des minéraux néoformés. De même, les teneurs en sodium sont également faibles, elles sont comprises entre 0,61 $mg.L^{-1}$ et 143 $mg.L^{-1}$ avec toujours le pic dans le forage de Morokro. Cette dernière est une valeur somme toute exceptionnelle (143 $mg.L^{-1}$) dans la région car elle est très éloignée de l'ensemble des autres valeurs et peut être qualifiée de valeur anormale. En effet, plus de 98,15 % des échantillons (soit 53 sur 54) ont des concentrations oscillant entre 0,61 $mg.L^{-1}$ et 14,52 $mg.L^{-1}$. Cet échantillon est donc supprimer de l'ensemble pour conserver une certaine continuité des données étudiées. D'une manière générale, le forage de Morokro présente des valeurs élevées pour certains éléments.

Le fer et le manganèse ont été analysés. Ces deux éléments peuvent se présenter sous plusieurs formes (Fe^{2+}, Fe^{3+} et Mn^{2+}, Mn^{4+}). Les formes Fe^{3+} et Mn^{4+}sont les plus riches mais les formes Fe^{2+} et Mn^{2+}, qui existent sous forme de carbonates ($FeCO_3$; $MnCO_3$), sont à l'origine de la présence de fer et manganèse dans l'eau. Les normes OMS de ces éléments sont respectivement de 0,3 $mg.L^{-1}$ et 0,05 $mg.L^{-1}$. Les ions fer et manganèse sont présents dans les eaux de la région avec des concentrations variant de 0 $mg.L^{-1}$ à 12 $mg.L^{-1}$ et de 0 $mg.L^{-1}$ à 0,86 $mg.L^{-1}$ respectivement. Les concentrations de ces éléments varient fortement d'une localité à une autre. Plusieurs forages ont des teneurs très critiques (valeurs largement supérieures aux normes admises). Il s'agit des campements Adamakro, Pecos, des localités Morokro, Kravesso, Yacoubakro, N'guessankro, Botindé pour le fer et Morokro, Kravesso, Yacoubakro, N'guessankro, Botindé et Béhikro pour le manganèse.

Dans certaines localités, les fortes teneurs en fer sont accompagnées de forte teneur en manganèse, c'est les cas des villages comme Morokro, Kravessou, Yacoubakro, Kouadio N'guessankro et Botindé. En effet, les points d'eau ayant des concentrations en fer et en manganèse supérieures à la norme représentent respectivement 38 % et 43 % de l'effectif total. Ces teneurs élevées ont évidemment des conséquences qui peuvent être évaluées à différents niveaux (turbidité, couleur, gout, etc.). Les fortes teneurs en ces éléments sont favorables à une augmentation la turbidité, l'eau présente une teinte rouge brun et marron noir lorsqu'elle est riche respectivement en fer et en manganèse. De plus, l'eau présente un goût métallique désagréable et provoque des tâches sur la lingerie. Selon la concentration, il peut se produire des précipitations sur les parois des canalisations diminuant considérablement leur diamètre utile et provoquant ainsi un colmatage au niveau de ces canalisations. Il se produit aussi un développement de bactéries ferrugineuses augmentant ainsi la corrosion dans les forages.

Les activités de certains micro-organismes (algobactéries et microbes silicophiles) conduisent à la libération et à la migration de certains éléments comme le fer et le Ca^{2+}, Mg^{2+}, NO_3^-, SO_4^{2-}, Fe^{2+}.

La mise en solution du fer et du manganèse peut se faire suivant les équations suivantes:

$$Fe(OH)_{2(s)} \Leftrightarrow FeOH^+ + OH^- \quad (3)$$

$$FeOH^+ \Leftrightarrow Fe^{2+} + OH^- \quad (4)$$

$$MnCO_{3(s)} + H_3O^+ \Leftrightarrow Mn^{2+} + HCO_3^- + H_2O \quad (5)$$

$$FeCO_3 + CO_2 + H_2O \Leftrightarrow Fe(HCO_3)_2 \quad (6)$$

$$MnCO_3 + CO_2 + H_2 \Leftrightarrow Mn(HCO_3)_2 \quad (7)$$

Anions

Les bicarbonates sont les ions les abondants d'un point du vue quantitatif. Ils constituent de loin, les éléments les plus représentatifs dans les eaux souterraines des régions de socle de Côte d'Ivoire comme c'est le cas à Tiassalé. Ces teneurs sont comprises entre 33,58 $mg.L^{-1}$ au forage F1 de Tiassalé et 530,7 $mg.L^{-1}$ dans la localité de Kassasso. Les teneurs en chlorures des eaux souterraines vont de 4,5 $mg.L^{-1}$ à 538,10 $mg.L^{-1}$, une forte proportion des eaux étudiées présente des teneurs qui dépassent nettement la valeur guide proposée par l'OMS (250 $mg.L^{-1}$). Les nitrates sont moins abondants dans les eaux de la région de Tiassalé. Les concentrations varient de 0 $mg.L^{-1}$ à 10 $mg.L^{-1}$, elles sont largement inférieures à la norme OMS qui est de 50 $mg.L^{-1}$. La teneur en nitrates des eaux recommandée pour la confection des biberons des bébés est fixée à 15 $mg.L^{-1}$. Les teneurs des sulfates oscillent entre 0 $mg.L^{-1}$ et 182 $mg.L^{-1}$ et sont d'une manière générale acceptables pour la consommation humaine.

Sur l'ensemble des forages étudiés, seuls deux forages présentent une minéralisation importante, dépassant les 1000 $mg.L^{-1}$. Il s'agit des forages des localités de Gnanzobli (1 102,63 $mg.L^{-1}$) et de N'zuékro (1 111,23 $mg.L^{-1}$). La majorité des eaux ont une minéralisation totale conforme à celle des eaux douces. Plus de 74 % des ces eaux présentent une MT inférieure à 500 $mg.L^{-1}$.

Titre hydrotimétrique total (THT)

La dureté de l'eau a été déterminée avec le titre hydrotimétrique total (THT). Plus de 22 % des forages présentent des eaux à dureté indésirable, c'est-à-dire que le THT est supérieur à 30°F. C'est le cas des forages de Gnanzobli (92,58°F), d'Amankro (87,2°F), de Génékro (77,23°F) et d'Abeykro (68,2°F). Ces eaux de ces forages sont difficilement moussantes, elles forment des grumeaux (flocons) avec le savon. De plus elles se caractérisent par un dépôt au fond des marmites ou casserole lorsqu'elles sont portées à ébullition.

Analyse en Composantes principales normées (ACPN)

Le table I résume les principaux paramètres statistiques des différents paramètres étudiés. Il s'agit notamment de la moyenne, l'écart type, la variance, le minimum et le maximum.

Table I: Paramètres statistiques

Variables	Moy	σ	σ^2	Min	Max
pH	6,62	0,35	0,12	5,90	7,72
Cond.	792,33	538,34	289804,91	113,00	2460,00
Ca^{2+}	65,50	49,52	2452,71	5,50	212,42
Mg^{2+}	26,21	22,33	498,70	3,20	99,63
Na^{+}	6,76	19,20	369,67	0,61	143,00
K^{+}	1,62	2,53	6,42	0,11	18,00
Fe^{2+}	0,75	1,88	3,54	0,00	8,84
Mn^{2+}	0,11	0,22	0,05	0,00	1,38
HCO_3^{-}	214,52	99,41	9881,97	33,58	530,70
Cl^{-}	115,18	134,30	18072,29	4,50	538,10
NO_3^{-}	1,34	1,43	2,04	0,00	10,00
SO_4^{2-}	11,71	25,68	25,68	0,00	182,00
MT	435,34	258,90	67026,62	725,46	1111,23
pCO_2	0,05	0,03	0,00	0,01	0,15

Le tableau initial contient 54 u.s. et 14 variables (voir paragraphe plus haut). Les trois premiers axes factoriels rendent compte de plus de 72 % de la variance totale dont 37,40 pour le premier, 22 pour le deuxième et 12,20 pour le troisième (**table II**). Dès le 1er facteur le pourcentage n'est pas élevé, ceci implique que de nombreux paramètres doivent intervenir sur la structure des données. Toutefois, déjà pour les facteurs 1 et 2, nous avons 59,40 % de variance exprimée, ce qui permet d'expliquer une bonne partie de l'information contenue dans ces données. La représentation des données dans ce plan

(F1, F2) rend compte de façon satisfaisante de leur structure. Cependant, certains aspects de cette structure seront peut être mal identifiés puisqu'il reste encore 39 % de variance à exprimer. C'est la raison pour laquelle l'analyse a été poursuivi jusqu'au facteur 3. C'est dans le plan des variables que chacun des facteurs sera examiné.

Table II: Matrice de corrélations

Variables	pH	Cond.	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Fe^{2+}	Mn^{2+}	HCO_3^{-}	Cl^{-}	NO_3^{-}	SO_4^{2-}	MT	pCO_2
pH	1,00													
Cond.	0,11	1,00												
Ca^{2+}	0,31	**0,87**	1,00											
Mg^{2+}	-0,02	**0,92**	**0,73**	1,00										
Na^{+}	-0,10	0,31	0,06	0,26	1,00									
K^{+}	-0,14	0,32	0,08	0,31	**0,82**	1,00								
Fe^{2+}	-0,19	0,00	-0,16	-0,01	0,43	0,37	1,00							
Mn^{2+}	-0,14	0,00	-0,12	-0,04	0,36	0,26	**0,50**	1,00						
HCO_3^{-}	0,48	0,49	**0,68**	0,28	0,01	-0,14	-0,17	-0,07	1,00					
Cl^{-}	-0,07	**0,86**	**0,68**	**0,87**	0,27	0,32	0,03	-0,01	0,21	1,00				
NO_3^{-}	-0,02	0,25	0,18	0,25	0,26	0,32	0,09	0,02	-0,01	0,27	1,00			
SO_4^{2-}	-0,09	0,37	0,16	0,28	**0,86**	**0,70**	0,35	0,29	0,08	0,33	0,32	1,00		
MT	0,22	**0,93**	**0,91**	**0,82**	0,29	0,24	-0,04	-0,03	**0,68**	**0,83**	0,23	0,37	1,00	
pCO_2	**-0,72**	0,15	0,06	0,18	0,13	0,09	0,03	0,02	0,08	0,17	0,05	0,14	0,17	1,00

La matrice de corrélations (**table III**) donne les coefficients de corrélations entre les différentes variables, deux à deux. L'analyse de ce tableau souligne que les cations sont bien corrélés avec soit un anion soit deux. Ainsi le Magnésium et le calcium sont bien corrélés avec les chlorures, de même il existe une corrélation entre le calcium et les bicarbonates; entre le sodium, le potassium et les sulfates. On note aussi de bonnes corrélations entre les différents cations: le calcium et le magnésium, le sodium et le potassium, le fer et le manganèse. Au niveau des autres paramètres, le pH et la pCO_2 sont corrélés avec un coefficient négatif. Les phénomènes influençant la conductivité sont les même qui influence la minéralisation totale et sont contraires à ceux qui influencent la pCO_2 et le pH.

Table III: Pourcentages cumulés

Facteurs	Valeurs propres	% Variance propre	% Variance exprimée cumulée
F1	5,23	37,39	37,39
F2	3,08	21,99	59,37
F3	1,71	12,19	71,56

Plan factoriel F1-F2

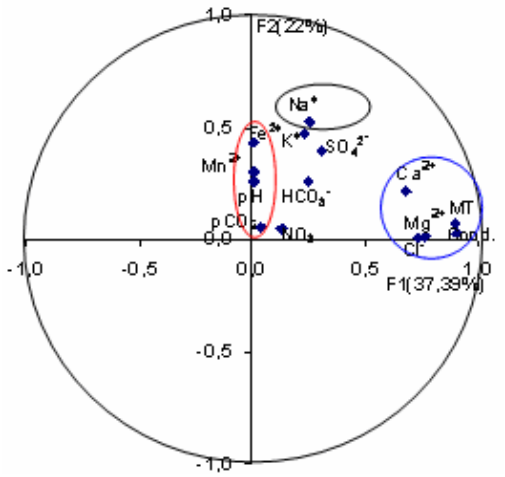
Analyse dans l'espace des variables

Le plan factoriel F1-F2 exprime 59,37 % de la variance totale du nuage de points, mais le facteur 1 est le plus important, car il exprime à lui seul 37,39 % de l'inertie du nuage des points. Le facteur F1 est défini par la conductivité (0,90), la minéralisation totale (0,90), le magnésium (0,77), les chlorures (0,74) et dans une moindre mesure le calcium (0,68). La proximité de la conductivité, de la minéralisation totale, des chlorures et du magnésium, témoigne d'une forte corrélation entre ces différentes variables (figure 4a). Ces observations sont en accord avec la matrice de corrélations (tableau III). Les corrélations entre ces éléments suggéraient une origine commune. Ils proviendraient de l'encaissant dans lequel l'eau y est emmagasinée. Le facteur F1 paraît correspondre à la minéralisation et au temps de séjour de l'eau dans la roche aquifère, temps nécessaire pour l'acquisition d'une minéralisation importante. Le facteur F2 (22 %) présente quelques difficultés d'interprétation dans la mesure où aucune variable ne s'exprime fortement. Cependant, il est défini à un degré moindre par la variable Na^{+}. Dans les sols, les effets de pollution sur les concentrations

anormales en NO_3^- et des échanges de bases produisent des ions K^+ et Na^+. Le facteur F2 peut être interprété comme les apports superficiels.

Figure 4: Analyse en composantes principales des variables des eaux souterraines dans le plan Factoriel F1-F2.

a Espace des variables dans le plan factoriel F1-F2



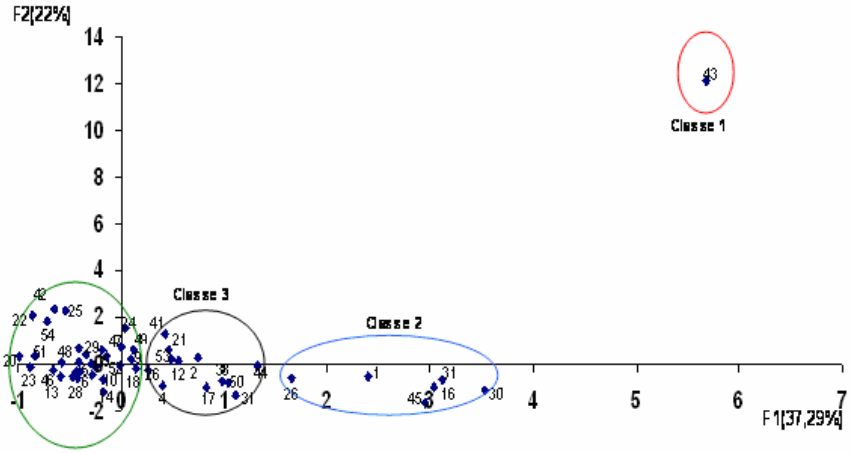
Les variables K^+, HCO_3^- et SO_4^{2-} sont à cheval sur les facteurs F1 et F2, cela dénote que leur présence dans les eaux souterraines est influencée par les phénomènes temps de séjour dans l'encaissant et oxydation. Les oxydations peuvent avoir lieu soit dans les roches réservoir soit au niveau de la matière organique se trouvant à la surface du sol et qui parvient à l'eau souterraine par le phénomène d'infiltration. La présence du Fe^{2+}, du Mn^{2+} de la pCO_2 et sur l'axe F2, justifie qu'ils proviendraient uniquement des couches superficielles et de la surface. Ces éléments sont mal expliqués par ce facteur et partant dans le plan factoriel F1-F2.

Analyse dans l'espace des unités statistiques

La représentation graphique dans l'espace des unités statistiques permet de distinguer les différents groupes qui composent l'échantillon étudié (figure 4b). Ainsi nous distinguons quatre classes dans le plan factoriel F1-F2.

Figure 4: Analyse en composantes principales des variables des eaux souterraines dans le plan Factoriel F1-F2.

b Espace des unités statistiques dans le plan factoriel F1- F2



- La classe 1 caractérise les eaux à forte minéralisation et très riches en ions fer et manganèse. Cette classe comporte un seul point, il s'agit du forage de Morokro. En effet les teneurs en fer et en manganèse sont très critiques, elles sont largement au dessus des normes proposées par l'OMS.
- la classe 2 concerne les eaux à forte minéralisation où les teneurs en chlorure et/ou en bicarbonates sont élevées. Les teneurs en fer et manganèse sont aussi élevées, cependant ces valeurs restent inférieures à celles de la première classe;
- la classe 3 regroupe les eaux pour lesquelles la minéralisation est moyenne avec des teneurs en ions fer et manganèse qui sont plus ou moins élevées;
- la classe 4 représente les eaux à faible minéralisation avec des teneurs en ions de fer et de manganèse qui sont pour la majorité acceptables.

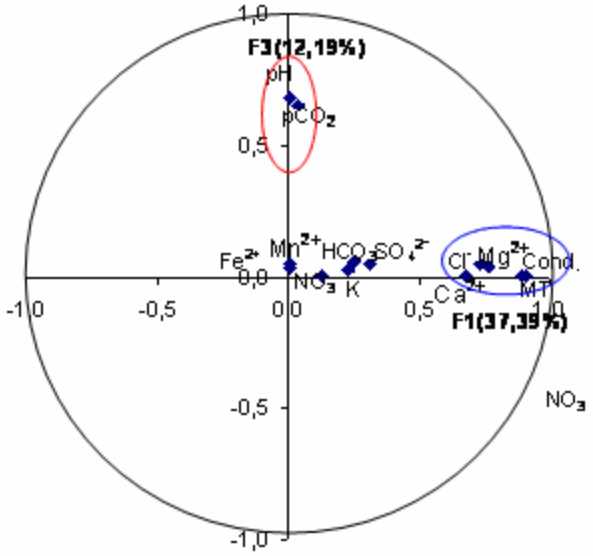
Plan factoriel F1-F3

Analyse dans l'espace des variables

La représentation dans l'espace des variables dans le plan factoriel F1-F3 (figure 5a) montre que le facteur F1est défini par la conductivité, la minéralisation, par Mg^{2+} et Cl^{-}. Le facteur F1 exprime toujours la minéralisation temps de séjour. Le facteur F3 est défini par la pCO_2 et le pH. Ces paramètres étaient mal définis dans la plan factoriel F1 et F2. Ce n'est donc qu'au niveau du facteur 3 que ces sont bien exprimés. La présence de la pCO_2 sur l'axe F3 indique que cet axe est gouverné par les phénomènes d'apports superficiels. Cet apport superficiel peut provenir des activités agricoles (engrais, élevage industriel) ou de la décomposition de la matière organique (déforestation). Ce facteur peut être associé à un indicateur du phénomène d'infiltration superficielle et de pluviolessivage.

Figure 5: Analyse en composantes principales des variables des eaux souterraines dans le plan Factoriel F1-F3

a Espace des variables dans le plan factoriel F1-F3

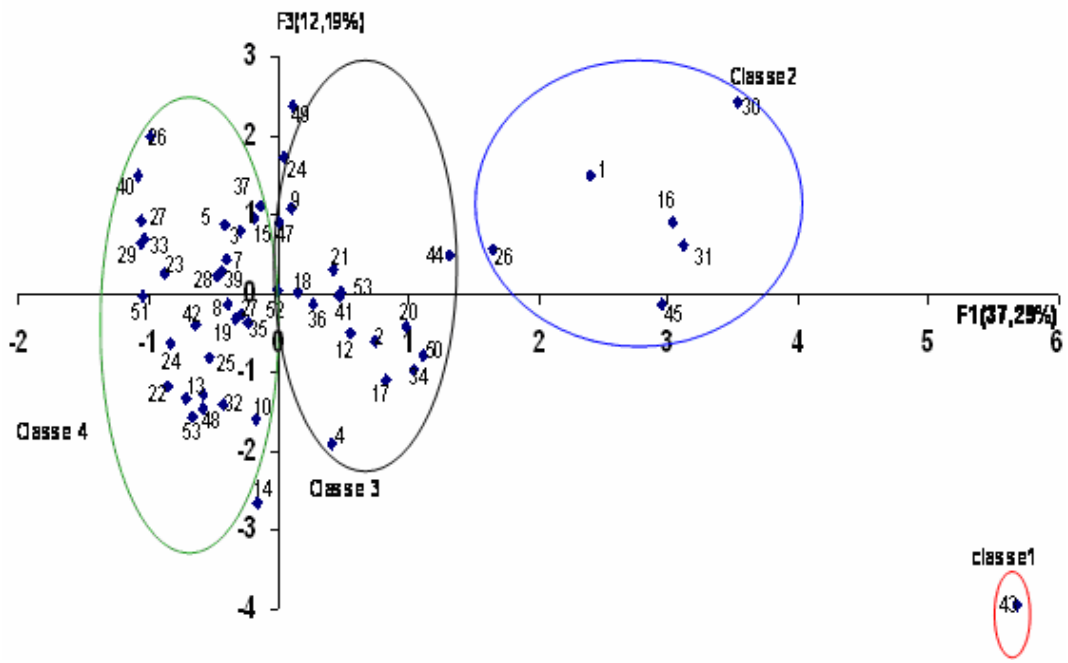


Analyse dans l'espace des unités statistiques

La répartition des unités statistiques dans le plan factoriel F1-F3 (figure 5b) révèle aussi 4 classes d'eau:

Figure 5: Analyse en composantes principales des variables des eaux souterraines dans le plan Factoriel F1-F3

b Espace des unités statistiques dans le plan factoriel F1- F3



- la classe 1, comme précédemment, concerne l'eau fortement minéralisée et très riche en fer et en manganèse de la localité de Morokro;
- la classe 2 regroupe les eaux minéralisées à fortes teneurs en chlorures;
- la classe 3 regroupe les eaux moyennement minéralisées avec des teneurs en Fe^{2+} et Mn^{2+} et Cl^- qui sont plus ou moins élevées;
- la classe 4 regroupe les eaux à faible minéralisation et pauvres en ions fer et manganèse.

Discussion

Les températures des eaux souterraines étudiées varient sur une gamme de 5°C. Le pH des eaux est majoritairement acide à neutre soit 79 % des échantillons. Cette acidité est principalement liée à la production de CO_2 dans les couches superficielles du sol sous l'action des activités biologiques. Des résultats analogues ont été obtenus dans d'autres régions de socle de Côte d'Ivoire (Biémi, 1992; Soro, 2002; Oga, 1998; Savané, 1997; Goné, 2001). La réaction d'hydratation du CO_2 libère de l'acide carbonique qui attaque les roches (Goné *et al.*, 2004). D'une manière générale, les eaux souterraines sont caractérisées par une moyenne minéralisation. A l'exception de quelques forages, les eaux souterraines de Tiassalé respectent les normes de potabilités de l'eau destinée à la consommation humaine. Les ions chlorures (Cl^-) et bicarbonates (HCO_3^-) sont les plus abondants dans les eaux souterraines de la région de Tiassalé, à l'image des autres régions du pays. Les cations dominants qui s'associent à ces ions sont le Ca^{2+} et Mg^{2+}. Ces cations pourraient provenir des roches volcaniques basiques, plus ou moins métamorphisées. Ces roches contiennent fréquemment des minéraux alumino-silicatés les plus facilement hydrolysables (Faillat & Blavoux, 1989).

Le Ca^{2+} et Na^+ constituent également les ions dominants associés aux ions sulfates (SO_4^{2-}). L'oxydation des pyrites pourrait être le processus chimique de mise en solution (Faillat & Blavoux, 1989). L'ion potassium (K^+) est moins abondant dans les eaux souterraines de nos régions d'une manière générale. En effet, il est absorbé non seulement par les plantes mais aussi intervient dans la composition des minéraux néoformés (Savadogo, 1984). Les eaux à forte minéralisation représentent

environ 9,3 % des forages, elles présentent des conductivités supérieures à 1500 $\mu s.cm^{-1}$, la norme admise par l'OMS est comprise entre 500 $\mu s.cm^{-1}$ et 1500 μs.cm (Rodier, 1996).

La minéralisation des eaux souterraines dépendent de plusieurs paramètres dont la nature minéralogique des roches traversées, le temps de contact de l'eau avec les minéraux, la vitesse de circulation de l'eau, le temps de renouvellement de l'eau de l'aquifère, du pluviolessivage de la couverture forestière, du déplacement vers l'intérieur du continent des aérosols marins (Beauchamp, 2007).

Les fortes teneurs en fer et en manganèse enregistrées dans certaines localités constituent un important souci. En effet, ces deux éléments confèrent à l'eau un gout métallique désagréable, un aspect et une couleur (Dore, 1989), qui peuvent amener les populations rurales à se tourner vers d'autres sources d'approvisionnement dont les eaux de surface. D'un autre coté, la qualité de ces eaux est souvent douteuse, et l'état parasitologique et bactériologique est inévitablement désastreux (Lasm, 2000). Les eaux de surface regorgent de bactéries, de faunes, de parasites et de vecteurs de graves maladies (Bilharziose, amibiase etc.) qui sont susceptibles d'affecter sérieusement l'état de santé des populations.

Les précipitations au niveau des parois des canalisations sont fréquentes, celles-ci favorisent la diminution du diamètre utile et partant un colmatage des canalisations. Le développement de bactéries ferrugineuses augmentant ainsi la corrosion dans les forages, les rendant ainsi vulnérable à d'autres sources de pollution qui dégraderaient considérablement la qualité de ces eaux.

Les fortes teneurs enregistrées en certains ions dans les eaux du forage du village de Morokro sont d'une manière générale isolées de l'ensemble des forages étudiés. Ce résultat indique que ce forage capte des eaux d'une fracture isolée, non connectée aux autres fractures. En effet, si tel était le cas, on aurait enregistré également de fortes teneurs en ces éléments dans les forages avoisinants, ce qui est différent des observations.

Les concentrations en ions nitrates de la région de Tiassalé sont largement en deçà des normes internationales à l'instar de la plus part des régions du pays, ce qui est très encourageant. Cependant dans certaines régions des pics de nitrates pourraient être enregistrés dus essentiellement à la déforestation abusive, à l'emploi de fertilisants pour l'agriculture. Ces cas de figures sont vraiment très localisés. L'origine des nitrates dans les eaux souterraines proviendrait du contact eau-roche, favorisant la mise en solution de certains éléments.

Les forages à dureté indésirable (THT > à 30°F) sont caractérisées par des eaux difficilement moussantes, elles forment des flocons avec le savon. Elles sont aussi caractérisées par un dépôt au fond des casserole lorsqu'elles sont portées à ébullition (Tardat *et al.*, 1984).

L'analyse en composante principale permet de mettre en évidence le degré de corrélation entre les différents paramètres. Les trois premiers facteurs rendent compte à plus de 74 % de l'information contenues dans les données. Les informations sont résumées dans le graphe de l'espace des variables (cercle de communauté) et des unités statistique (u.s.). Dans l'espaces des variables toutes les saturations sont positives si bien que sur le graphe tous les éléments sont localisés dans le cadrant supérieur droit du cercle, résultat tout à fait particulier. En effet, dans la plupart des études (Failllat & Blavoux, 1989; Biémi, 1992, Savané, 1997; Goné *et al.*, 2004) les différents paramètres se repartissent sur l'ensemble du cercle de communauté (un groupe d'éléments s'oppose à un autre). Deux principaux groupements de paramètres physico-chimiques se distinguent sur ce graphe. Le premier est composé des éléments comme Ca^{2+}, Cl^{-}, MT et Cond et le second groupement est constitué de Fe^{2+}, pH, pCO_2, Mn^{2+}. Ce second groupement n'est pas mieux exprimé au niveau du facteur F2. Ce qui a conduit à étudier le plan factoriel (F1, F3). Le regroupement de la conductivité et les principaux ions majeurs indiquent que cet axe explique les mécanismes prépondérants d'acquisition de la minéralisation. Le facteur F1 est donc caractérisé par la minéralisation.

La pCO_2 et le pH qui étaient précédemment mal définis dans le plan factoriel (F1, F2) sont mieux expliqués dans le plan factoriel (F1, F3). Le facteur F3 est gouverné par les apports superficiels, il s'agit des phénomènes d'infiltration et de pluviolessivage.

Dans l'espace des unités statistiques 4 classes d'eau ont été identifiés aussi bien dans le plan factoriel (F1, F2) que dans le plan (F1, F3). Les eaux de la classe 1 sont caractérisées par une forte minéralisation et sont très riches en ions fer et manganèse. Il s'agirait sans doute des eaux en contact plus ou moins loin avec des roches riches en minéraux ferromagnésiens. Il se produit alors une oxydation du fer ferreux (fer II) en fer ferrique (Fe III), c'est ce qui explique la couleur rouge des eaux de Morokro (Goné *et al.,* 2004). Les eaux des trois autres classes ont été en contact avec les roches type acide tels que les granites. L'abondance des ions bicarbonates dans les eaux de Tiassalé pourrait s'expliquer par l'hydrolyse des feldspaths que l'on rencontre en abondance dans les roches acides (Goné *et al.,* 2004).

Dans les eaux souterraines des régions africaines et notamment de l'Afrique de l'ouest, les fortes teneurs en fer sont généralement toujours couplées à celle du manganèse. Ces deux éléments proviennent de l'altération des roches de surface. En effet, dans les couches superficielles, l'essentiel des acides secrétés par les micro-organismes (algobactéries et microbes silicophiles) favorise la dissociation des minéraux des roches notamment la silice, les silicates d'alumine, de potassium, de fer et de magnésium, et la matière organique pour libérer les ions comme le Ca^{2+}, le Mg^{2+}, le NO_3^-, les SO_4^{2-}, le Fe^{2+}., etc. A la suite d'un phénomène de pluviolessivage, ces éléments vont être transportés et entraînés vers les aquifères des eaux souterraines (Biémi, 1992). On note dans la région de Tiassalé, de nombreuses intrusions de granitoïdes et de tonalites. La présence de ces formations explique en partie la présence de Fe^{2+} dans les eaux souterraines de Tiassalé. Ces roches sont riches minéraux ferromagnésiens notamment en pyroxènes, amphiboles et en biotites. L'altération de ces roches libère essentiellement des ions comme Mg^{2+}, Ca^{2+} et Fe^{2+}qui sont par la suite entrainés vers les eaux souterraines. La région étant abondamment arrosée, le pluviolessivage des couches superficielles entraîne un départ important de plusieurs cations dont le Mn^{2+} sont entrainés vers les nappes (Biémi, 1992).

Le Fer (II) est un agent complexant moins fort que le fer (III). L'hydroxyde Fe $(OH)_2$ est une base plus forte que le Fe $(OH)_3$ et sa dissociation conduit à la libération du complexe $FeOH^+$ et de Fe^{2+}.

Le manganèse se présente souvent sous forme de carbonate ($MnCO_{3(s)}$). Sa dissolution par l'acide carbonique présent dans l'eau permet la libération du manganèse et du bicarbonate. Les conditions d'anaérobie (milieu réducteur et présence de CO_2) qui règnent dans les fond des retenues d'eau favorisent aussi la mise en solution du fer et du manganèse (Dore, 1989). D'un autre côté, les teneurs élevées de fer et manganèse peuvent être un indicateur du vieillissement des forages.

En effet, les pompes installées sur les forages pour l'exhaure de l'eau sont de constitution métallique et peuvent s'user avec le temps, la vieillesse et le pH; elle peut s'oxyder avec libération de fer dans les eaux. Certaines eaux de forage à pH acide (< 6,5) sont corrélées à de fortes teneurs en fer et sont supérieures à la norme exigée par l'OMS, c'est l'exemple des forages de Morokro, d'Affouvassou et de Goyakro.

Comme les ions fer et manganèse, les chlorures contenus dans les eaux sont d'origine lithologique. Ce qui a été confirmé par les analyses multidimensionnelles (ACPN). Il pourrait ainsi provenir de l'altération des apatites [Ca_5 $(PO_4)_3$ (OH, F, Cl] chlorurés qu'on observe dans les roches métamorphiques et également chloroapatites qu'on trouve dans les roches basiques filoniennes de la région de Tiassalé.

Conclusion

Au terme de cette étude de nombreux résultats ont été obtenus dont les principaux sont résumés ci-dessous:

1. les températures des eaux varient très peu dans l'ensemble avec un pH à dominance légèrement acide;
2. la minéralisation varie sur une large gamme, de faible à forte minéralisation.
3. les eaux souterraines de Tiassalé sont très riches en Fe^{2+}, Mn^{2+}, Ca^{2+}, et Cl^-;

4. en dehors de quelques forages qui présentent des eaux à qualité douteuse tel l'exemple de Morokro, les eaux souterraines de la région de Tiassalé sont potables et aptes pour la consommation humaine;
5. Les eaux du forage de Morokro proviendraient d'une fracture isolée, non connectée aux autres du réseau de fractures.
6. Quatre classes d'eau identifiées d'après leur minéralisation et l'abondance en certains ions.
7. le fer et le manganèse ont une origine superficielle, ils sont entrainés dans les eaux souterraines par le phénomène d'infiltration.
8. Les nitrates dans les eaux souterraines proviendraient essentiellement du contact eau-roche et secondairement des apports superficiels issus de la déforestation abusive, à l'emploi de fertilisants pour l'agriculture.
9. les principaux phénomènes gouvernant l'acquisition de la minéralisation des eaux souterraines sont le temps de séjour de l'eau dans la roche aquifère, et les apports superficiels par infiltration.

Par la suite, nous comptons entreprendre l'étude des ressources en souterraines d'un point de vue isotopique. Cette approche permettra de comprendre le mécanisme de recharge de ces aquifères et de déterminer l'âge des eaux souterraines.

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Modelling and Economic Analysis of Ultrafiltration Units: Case Study of a Full-Scale UF Plant

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Abstract

This paper presents the economic analysis and modelling of ultrafiltration (UF) units with a focus on the development of a model for total operating cost (TOC) as a function of the total output; filtration time and filtration flux. Sensitivity analysis was based on the costs obtained with the assistance of the so –called XIGA^{TM} Projection tool. Sensitivity analysis and the modelling were based on the optimal operating conditions resulting from optimal operation at the full-scale UF plant design conditions and parameters. The developed model used the so-called Response Surface Methodology (RSM) to explain the interactions observed. The sensitivity analysis of the economic data showed that energy cost, chemical cost and waste water disposal cost are sensitive to change in plant output (Q) with waste water disposal cost having the highest sensitivity. Hence, the most influencing cost contributing to the unsteady increase in *TOC* is the cost of wastewater disposal. Also the economic model showed that filtration time has little or no effect on the *TOC* but *TOC* largely depends on the filtration flux and the plant output(permeate). Further economic analysis based on the data generated from the XIGA^{TM} Projection tool showed that the full- scale plant could be operated at J_f =25lmh, and t_f =26mins during the off-peak production period and at J_f =85lmh, and t_f =138mins during the peak production period for minimum *TOC*.

Keywords: Modelling, ultrafiltration, sensitivity, cost, response surface methodology

1.0. Introduction

Internationally, there has been a drive towards the use of membrane filtration (Microfiltration, Ultrafiltration and Nanofiltration) as part of drinking water treatment of non-saline sources, simply because of more stringent drinking water regulations imposed in some part of the world such as Australia, Europe, North America and Japan. Using membranes for cleaning potable water is potentially the largest single application of membrane technology, especially UF and MF. MF and UF are especially beneficial in removing microorganisms that may constitute a health hazard (Cheryan,

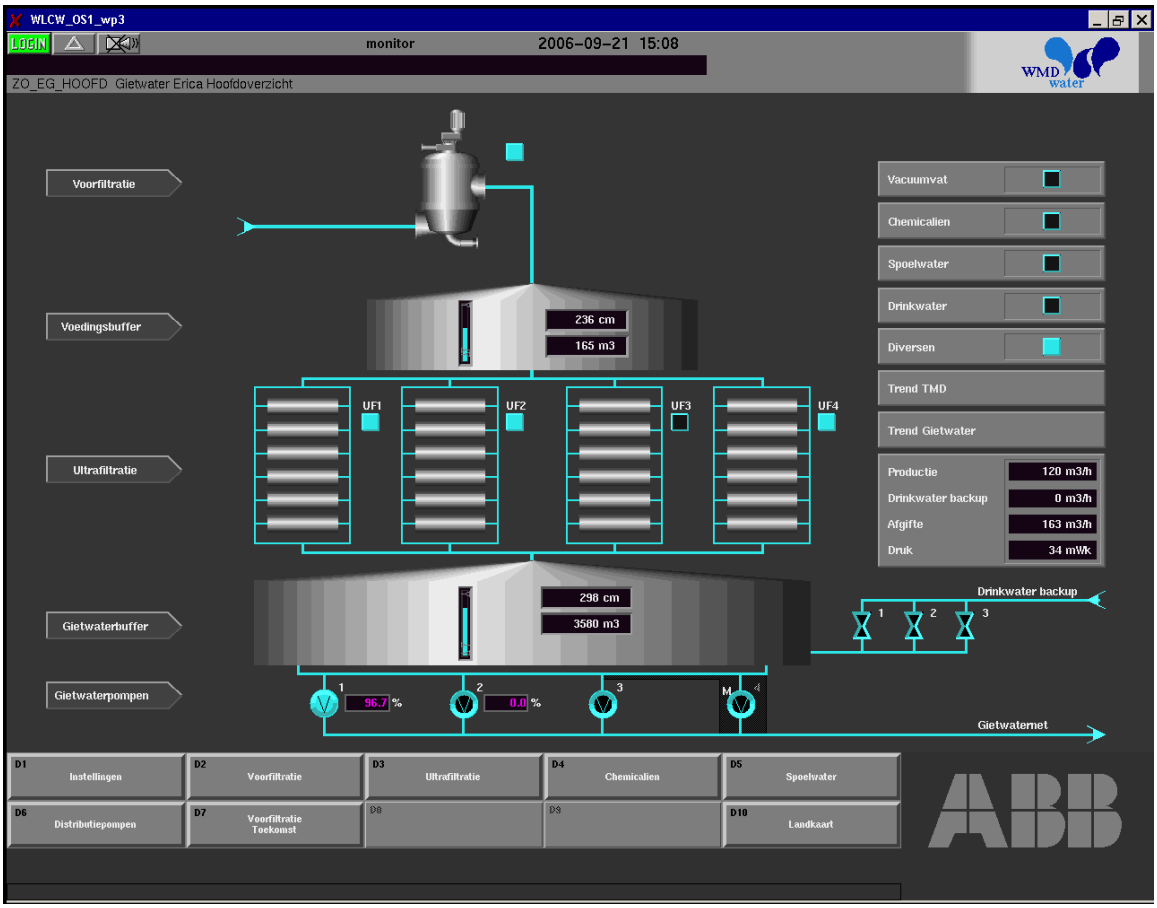
1998). The US 1989 Surface Water Treatment Rule requires a 3-log cycle (99.9%) reduction of *Giardia muris* cysts and a 4-log (99.99%) reduction of *Cryptosporidium parvum oocysts* and *enteric* viruses. The latter are resistant to traditional disinfectants such as chlorine and ozone. MF and UF can meet these standards while avoiding the formation of disinfection by-products (DBP), yet meeting the less then 0.5 nephelometric turbidity unit (*NTU*) rule (Jacangelo *et al,* 1991, 1995). UF membranes may be better than MF in the long run since they can remove viruses more effectively (Cheryan, 1998). Moreover, in the last decade, ultrafiltration applied to drinking water production has demonstrated its reliability and its cost effectiveness (Moll et *al,* 2007).

Actually, ultrafiltration is not as fine a filtration process as nanofiltration or reverse osmosis, but it also does require the same energy to perform the separation operating at lower pressure (Katsikaris *et al,* 2005) It is a kind of low pressure-driven membrane process with applied pressure ranges from 0.1 to 5bar (Norit, 2007) and capable of removing particles, turbidity, bacteria, protozoa and viruses. It has a pore size of about 0.01-0.1μm and will therefore prevent particles, colloids, microorganisms and dissolved solids that are larger in dimension than the pores in the membrane surface from passing. The membrane therefore acts as a physical, size-exclusion barrier, and it is for that reason that ultrafiltration membranes produce such a high quality product.

Ultrafiltration process has been widely applied to a variety of fields. More specifically, in the area of industrial wastewater treatment, UF has been applied to tannery wastewaters in order to recycle trivalent chromium (Fabiani *et al,* 1996; Shaalan *et al,* 2001); or to remove colour from tannery wastewaters (Alves and dePinho, 2000); in textile industry as a pre-treatment step prior to NF or RO for recycling and reuse of textile wastewaters (Marcucci *et al,* 2001); in olive-mill waster waters in combination with centrifugation for the reduction of organic polluting compounds (Turano *et al,* 2002) and even in the artificial kidney mechanisms (Serra *et al,* 1998). As useful this process is, unsteady rise in operating cost is observed in some cases. This unsteady rise in operating costs may be attributed so a lot of factors. However, to minimize and stabilize this instability, it is necessary to identify these influencing factors and possibly optimizing the process by minimizing the operating cost. Optimization of this process in term of operation may lower the operation costs and thereby increasing the profitability. Meanwhile, identifying these factors is possible through economic and sensitivity analysis and proper optimization is subject to existence of accurate model (s), which adequately describes the dependence, or interactions of the identified factors.

Daramola and his co-workers (Daramola *et al,* 2007) recently developed empirical models for backwash processes (both hydraulic and chemically enhanced backwas). The authors showed that change in transmembrane flux during hydraulic backwash is largely influenced by the backwash time and backwash frequency while reversibility of the fouled layer during chemically enhanced backwash largely depends on coagulant concentration dosing and filtration flux. These factors are crucial to achieving optimal operation conditions in ultrafiltration process. However to break-even in any process, minimization of operating cost is very important. Therefore, this paper focuses on the optimization of operating costs in term of cost minimization by investigating the application of UF in the area of irrigation water production for "greenhouses" using real plant process variables of an existing full-scale UF plant (see Fig. 1). However, in the economic analysis of full-scale UF plant, profit definition is not appropriate as revenue data may not be easily available because the installations often produce retentates/concentrates that need further processing to be marketed (Guadix *et al,* 2004). Going by this, this study considers only total operating cost with the assumption that capital cost is a one time investment in the sensitivity analysis. Based on the cost obtained from the so-called XIGA^{TM}, sensitivity analysis was carried out to know the dominant factors and economic model developed to further explain the influence of the operating conditions such filtration time, filtration flux and the plant output on the total operating cost (*TOC*). The model developed utilized *RSM* (Box and Draper, 1987) to explain the interactions among the influencing factors.

Figure 1: Flow sheet for the real full-scale plant for irrigation water production(WMD, 2007)



2.0. Economic Estimation and Analysis

For the economic evaluation, it was assumed that (i) the capital costs are equally distributed during the equipment life;(ii) the cost of each cleaning procedure is a linear relationship of the plant membrane area (Cheryan, 1998) and (iii) the membrane used in the plant is fully retentive membrane. According to previous researcher work (Guadix *et al,* 2004; Owen *et al,* 1995; Kennedy, 2006), variables considered in this study for the modeling and sensitivity analysis are energy cost, chemical cost, wastewater disposal cost and membrane replacement cost.

A software called XIGA^{TM} Projection tool (supplied by Norit Membrane Technology) was used to generate some parameters used in the cost estimation of the aforementioned factors based on the operational specifications (see Table 1) and the design specifications (see Table 2) of the plant (see Fig. 1). Based on the pre-knowledge of this plant, a range of the total plant outputs between 15-85m^3/hr and 110-180m^3/hr were chosen for off-peak (when demand is low) and peak(when demand is high) operation periods, respectively. By playing within this range using the projection the tool, feasible operating conditions with their respective recoveries and plant efficiencies were obtained. The generated data was used to obtain yearly total operating costs (*TOC*) using eqs. (1)- (5).

Table 1: General design specifications of the full-scale plant (WMD/WLN, 2007)

1	Number of unit	4
2	Membrane housings per unit	4
3	Number of feed pump	4
4	Number of backwash pump	1
5	Number of coagulant dosing pumps	4
6	Number of element per unit	16
7	Total membrane area	2240m^2
8	Element membrane area	35m^2
9	Membrane Type	PES, UFC, M5, 0.8mm

Table 2: Operational specifications of the full-scale plant

1	Element resistance	9.6E+11(1/m)
2	Fouling resistance	4.8E+11(1/m)
3	Element life time	7.0years
4	Operation hour per year	8760
5	Feed pump efficiency	60%
6	Backwash pump efficiency	60%
7	Backwash flux	250lmh
8	Backwash duration	40secs
9	Element replacement method	Reservation per year
10	Water source	Surface water
11	Turbidity	Approx. 15NTU

2.1. The energy cost

The energy cost considered the filtration energy cost of the feed water pump, the backwash energy cost for the backwash pump and the chemically enhanced backwash energy cost. For the calculation, it was assumed that the cost of energy is €0.1/kWh (http://www.**nuon**.com, 2007). Thus the energy cost in Euro per year was obtained using

$$C_{energy} = \left(E_{filtr} + E_{HB} + E_{CEB}\right) * C_{energ} \tag{1}$$

where E_{filtr}, energy consumed during filtration; E_{HB}, energy consumed during hydraulic backwashing; E_{CEB}, energy consumed during CEB and C_{energ}, Energy cost per kWh

2.2. The chemical cost

The chemical cost comprises the chemical cleaning cost and the coagulant cost. The amount of the coagulant consumed per day by the plant based on coagulation dosing of 1ppm was obtained from the XIGA^{TM} projection tool. The cost of coagulant in €/year with €180/m^3 of the coagulant was estimated using

$$C_{coagulant} = \frac{M_{coag} * 365 * C_{coag/m^3}}{1000} \tag{2}$$

where C_{coag}, cost of coagulant per m^3; M_{coag}, amount of coagulant consumed (l/day).

The chemical cleaning cost ($C_{chemicalcleaning}$) was generated from the XIGA^{TM} projection tool using the chemicals and the cost/m^3 presented in Table 3.Thus, the yearly chemical cost was obtained from

$$C_{chemical} = C_{coagulant} + C_{chemicalcleaning} \tag{3}$$

Table 3: Costs of chemical used for cleaning

Chemical	Cost in €/m^3
NaOH	60
NaOCl	100
HCl	80
$FeCl_3$(coagulant,14wt%Fe^{3+})	180

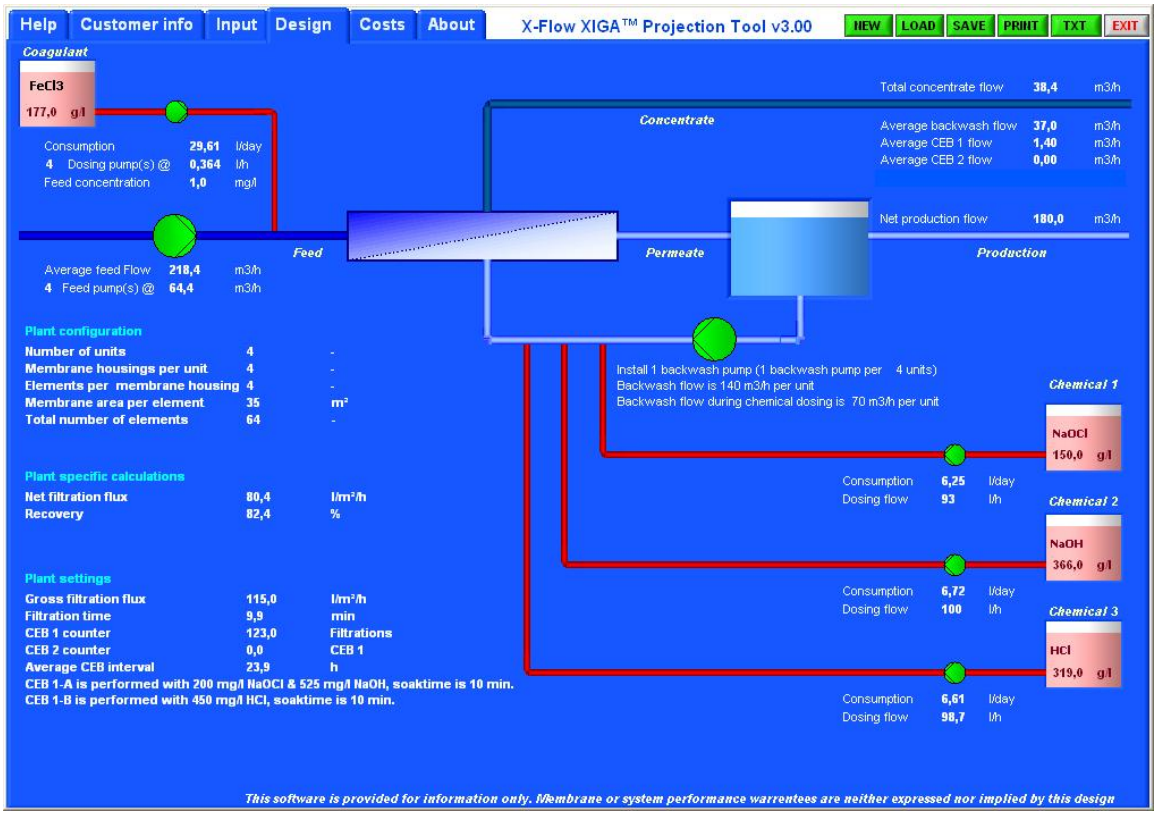
2.3. Membrane replacement cost

The membrane replacement cost (C_{memb}) was generated from the projection tool. However, the generation was based on a reservation per year method of element replacement. This was found to be constant.

2.4. Wastewater disposal cost

The amount of the wastewater (concentrate) generated was obtained from the projection tool (see a sample in Fig. 2) and the cost in €/year was obtained from

Figure 2: Sample of the template generated from the XIGATM projection tool



$$C_{waste} = Q_{concentrate} * \chi_{ref}) * E \quad (4)$$

where $Q_{concentrate}$ = amount of the concentrate produced in m^3 per year; χ_{ref} = disposal reference using by the Netherlands water board based on the location (http://www.nuon.com, 2007). This was assumed to be 0.001(http://www.nuon.com, 2007) for E (the disposal tariff in €/*ve*) which was assumed to be €64.62(year 2005 value)

2.5. Yearly total operating cost (TOC)

The yearly total operating cost in € was obtained using

$$TOC_{yearly} = C_{energy} + C_{chemical} + C_{memb} + C_{waste} \quad (5)$$

3.0. Sensitivity Analysis and Modelling

3.1. Sensitivity analysis

Sensitivity analysis is a general concept, which aims at quantifying the variations of an output parameter of a system with respect to changes imposed to some input parameters (Marshall, 1996; Saltelli *et al,* 2000). In this study, sensitivity of the considered costs to the change in the plant output (permeate) (Q) was obtained using equation (6), which gives the sensitivity coefficients.

$$\frac{d\phi}{d\delta_1} = \frac{\partial\phi}{\partial\delta_1} \approx \frac{\Delta\phi}{\Delta\delta_1} \text{ [Njomo and Daguenet, 2006]} \quad (6)$$

3.2. Modelling

As the sensitivity analysis only gives first impression of the effects of the factors on the costs, we tried to model these effects explicitly taken into account the filtration flux and time as well. Hence an economic model relating yearly TOC to the operating conditions (filtration flux and the filtration time) and the plant output (permeate) (Q) was developed to investigate the effects of these factors on the yearly TOC. Through this, optimal operating conditions may be specified for an economical output. For empirical model formulation, the starting point is the so-called polynomial regression model. Thus the assumed model is of the form

$$TOC = TOC_O + \alpha_1 Q + \alpha_2 t_f + \alpha_3 J_f + \alpha_4 Q^2 + \alpha_5 {t_f}^2 + \alpha_6 {J_f}^2 + \alpha_7 Q t_f + \alpha_8 J_f t_f + \alpha_9 J_f Q \quad (7)$$

where TOC_O, initial yearly operating costs (€/year); Q, total permeate output (m^3/hr); t_f, filtration time (min); $\alpha_1,...,\alpha_9$, the regression coefficients and J_f,filtration flux (lmh or $lm^{-2}hr^{-1}$). The parameters were estimated using the LS estimation method [Norton, 1986]. The most suitable model was obtained based on the comparison among several assumed models by considering their mean square error (MSE).

4.0. Results

4.1. Economic and sensitivity analysis

Tables 4 & 5 present the operating costs and the operating conditions obtained for the peak and off-peak periods at aforementioned plant outputs. The recoveries and efficiencies of the plant at these outputs are also shown in Tables 4 & 5. Comparison among the considered operating costs is shown in Fig. 3 while Fig. 4 shows the considered costs versus plant output. Table 6 presents the sensitivity of C_{energy}, $C_{chemical}$ and C_{waste} to the plant output, Q and Fig. 5 shows a plot of the sensitivity coefficients.

Table 4: Operating costs of the plant at coagulant dosing of 1ppm during the off- peak period using XIGA™ Projection Tool (expressed to the nearest whole euro) Output

Output (m^3/hr)	Operating conditions	C_{energy} (€/year)	$C_{chemical}$ (€/year)	C_{memb} (€/year)	C_{waste} (€/year)	TOC (€/year)
15	J_f =25lmh t_f =11.6min R=30.9% E=26.7%	1269	1000	13714	18963	34946
35	J_f =25lmh t_f =26mins R=67.5% E=62.5%	728	1031	13714	9510	24983
60	J_f =40lmh t_f =19.6min R=73.7% E=67%	1140	1290	13714	12114	28258
85	J_f =60lmh t_f =12.26min R=72.64% E=63.25%	1987	2653	13714	18114	36468

Table 5: Operating costs of the plant at coagulant dosing of 1ppm during the peak period using XIGA™ Projection Tool (expressed to the nearest whole euro)

Output (m^3/hr)	Operating conditions	C_{energy} (€/year)	$C_{chemical}$ (€/year)	C_{memb} (€/year)	C_{waste} (€/year)	TOC (€/year)
135	J_f =65lmh t_f =100.4min R=96% E=92.7%	1396	1813	13714	3210	20134
110	J_f =55lmh t_f =65min R=93.31% E=89.37%	1119	1623	13714	4466	20922
160	J_f =85lmh t_f =26.7min R=90.7% E=84.1%	2527	2138	13714	9284	27663
180	J_f =85lmh t_f =138min R=94.6% E=94.6%	2227	2217	13714	2599	20757

Table 6: Sensitivity coefficients of the considered parameters

$\frac{\Delta C_{energy}}{\Delta Q}$	$\frac{\Delta C_{chemical}}{\Delta Q}$	$\frac{\Delta C_{waste}}{\Delta Q}$
-27	2	-473
16	10	104
-9	5	-245
8	8	-61
11	8	-50
45	13	243
-15	4	-334

Figure 3: Comparison of the operating costs

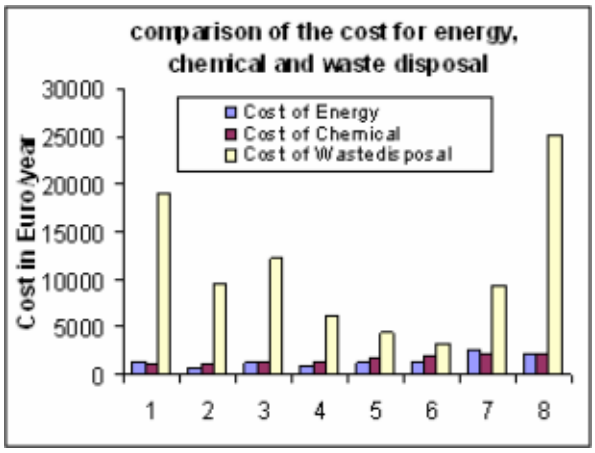


Figure 4: Operating costs vs plant output

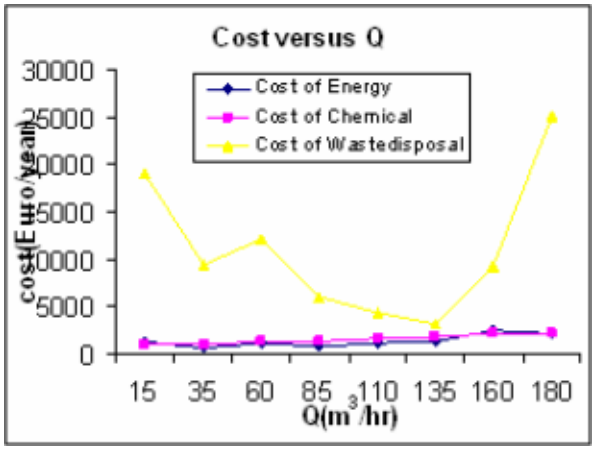
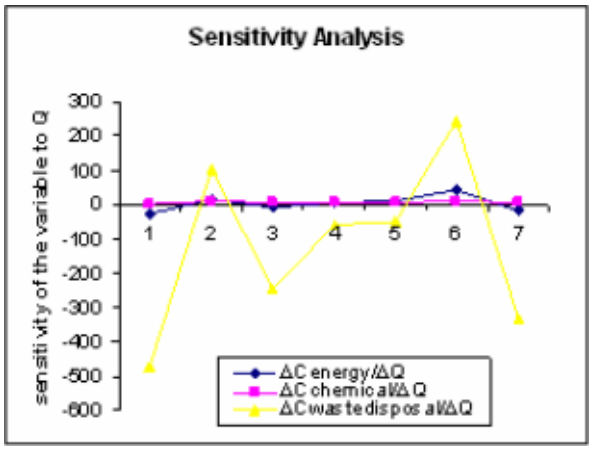


Figure 5: Sensitivity coefficients of the operating costs to the plant outputs



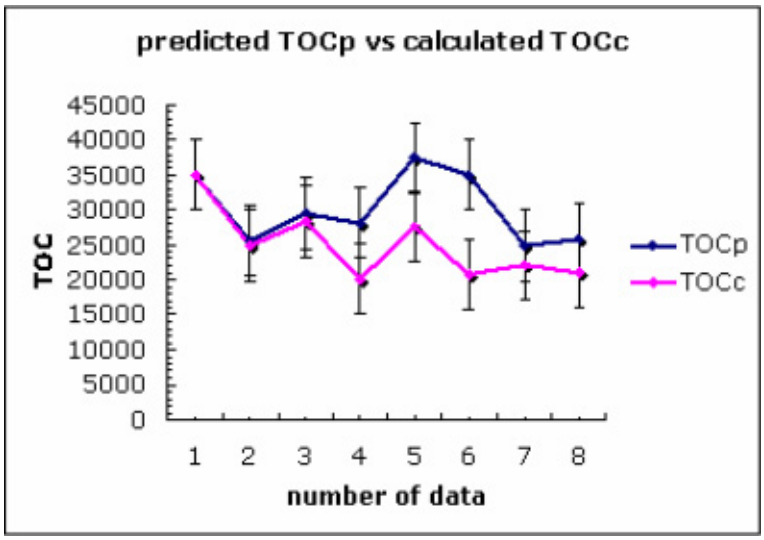
4.2. Modelling

The economic model obtained is of the form

$$TOC = 15515 - 519Q + 25t_f + 1087J_f + Q^2 - J_f Q \quad (8)$$

with the terms J_f^2, t_f^2, Qt_f, $J_f t_f$ (see eq.(7)) being insignificant(as their regression coefficients are negligible). Equation (8) has the lowest MSE of 6,054 and mean residuals of errors of 2.4E-008 among the considered candidate models. To investigate the validity of the model, *TOC* predicted from the model was compared with the calculated *TOC* from the XIGA^{TM} projection tool as shown in Fig. 6.

Figure 6: Comparison of the predicted TOC from the model and XIGA^{TM} TOC



4.2.1. Graphical Interpretation

However to understand the relationship among the influencing factors and for the fact that in industry, the operation is usually at fixed filtration time, t_f, the model was evaluated at a fixed filtration time, t_f, for off-peak and the peak periods (see Fig. 7 & 8 for the response surface and the contours). Also to allow response surface analysis of the full model with three factors, which cannot be done graphically, eq. (8) is written in vector-matrix notation

$$TOC = TOC_O + L^T X + X^T H X \quad (9)$$

where $L = [-519 \quad 25 \quad 1087]$; $H = \begin{bmatrix} 1 & 0 & -0.5 \\ 0 & 0 & 0 \\ -0.5 & 0 & 0 \end{bmatrix}$ and $X = \begin{bmatrix} Q \\ t_f \\ J_f \end{bmatrix}$

Substituting the estimated coefficients of eq. (9) and performing eigenvalue decomposition, i.e. $h=VDV^T$ with $V^TV=VV^T=I$ (identity matrix) and D a diagonal matrix gives

$$eig(H): \lambda = [-0.21 \quad 0 \quad 1.21] \text{ and } V = \begin{bmatrix} -0.38 & 0 & -0.92 \\ 0 & 1 & 0 \\ -0.92 & 0 & 0.38 \end{bmatrix}$$

These matrices indicate the shape and orientation of ellipsoidal contours (Abusam *et al,* 2001). Therefore considering the eigenvalues and eigenvectors associated with Q and J_f at fixed t_f (see the values above), concave and convex shapes are expected. In fact for t_f fixed (which is the usual case in the industrial operation) defines a saddle plane (see Fig. 7 & 8). However, limited data points considered in this analysis does not give a full observation of this plane. These observations are the same for the off-peak and peak operation periods as shown in Fig. 7 & 8, respectively.

Figure 7: Response surface at t_f =26mins and contour plot at t_f =26mins

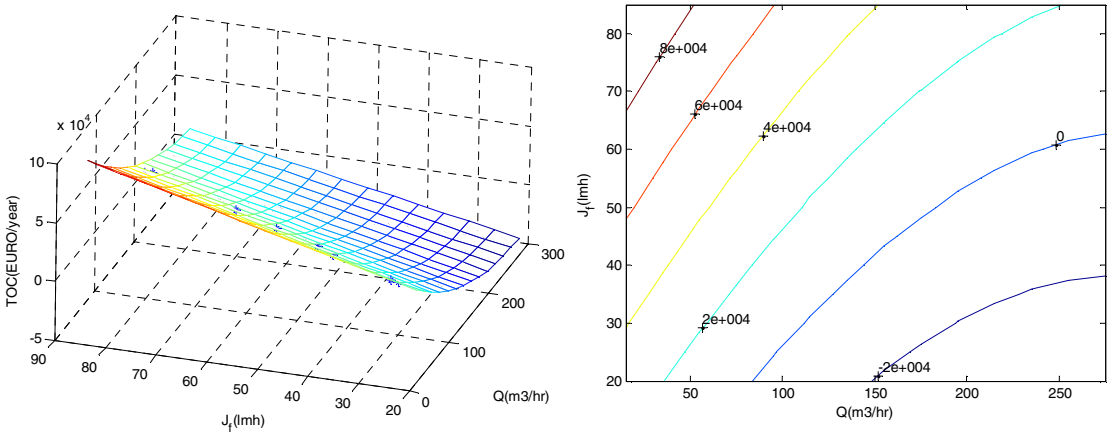
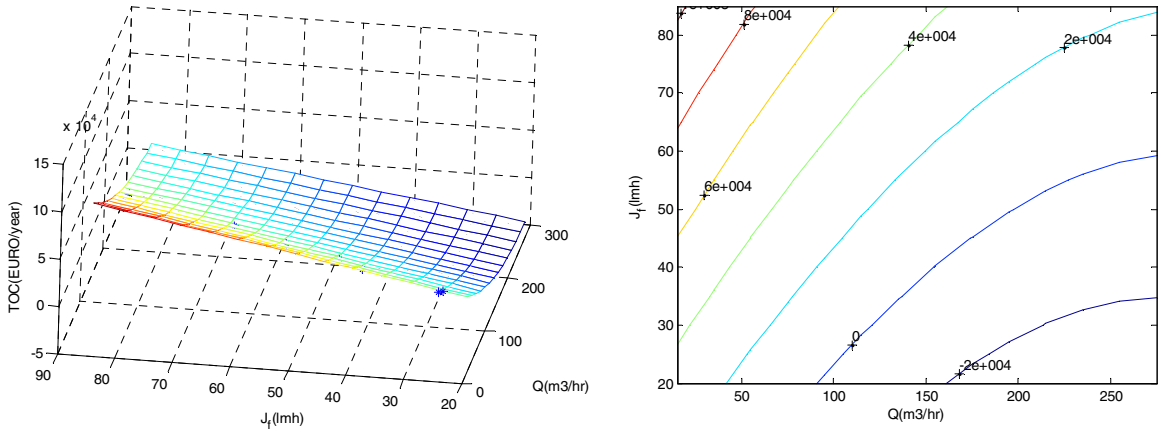


Figure 8: Response surface at t_f =138mins and contour plot at t_f =138mins



5.0. Discussion of results

5.1. Economic analysis

From Table 4 the cost of waste water disposal is relatively high for 15m^3/hr output which eventually results into highest total operating cost (TOC). Also the recovery and efficiency at this production target are poor. 60m^3/hr production target is feasible but has very high cost of wastewater disposal which contributes enormously to the TOC. Notice that the recovery and the efficiency at 60m^3/hr are the highest. During 35m^3/hr production, there is lowest energy cost and moderate cost of waste water disposal. Although the efficiency and recovery are not as high as that of 60m^3/hr production, the operating conditions are still feasible with lowest TOC. Hence for the off-peak production period, it will be advisable to run the plant at J_f of 25lmh for t_f of 26minutes.

From Table 5, the 160m^3/hr output has the highest energy cost and the wastewater disposal cost. These costs invariably increase the TOC. An output of 135m^3/hr has the lowest energy cost and moderate cost of wastewater disposal but lower recovery and plant efficiency compared with 180m^3/hr. 180m^3/hr output has the lowest cost of waste water disposal(which has the highest influence on the TOC), moderate cost of energy with highest plant efficiency and recovery. Therefore, during the peak production period, to meet the demand of the customers and save cost, it will be advisable to operate at J_f of 85lmh for t_f of 138minutes.

Meanwhile, from the XIGA^{TM} Projection tool, the costs for wastewater disposal are the same despite the increase in the amount of coagulant concentration dosing (Table 7). This is true in the sense that the amount of the concentrate produced during UF is independent of the coagulant dosing but dependent on the coagulant concentration present in the concentrate. It means that the coagulant concentration in the concentrate will increase as the coagulant dosing increases. However in this study, unavailability of data that relates the dependence of coagulant concentration to the amount of wastewater produced limits the evaluation of this influence on TOC. Therefore, further research effort is ongoing to address this.

Table 7: Cost of waste disposal at increasing coagulant dosing

Coagulant Dosing(ppm)	$C_{membrane}$ (€/year)	C_{waste} (€/year)
0	13714	18963.38
1	13714	18963.38
2	13714	18963.38
3	13714	18963.38

5.2. Sensitivity analysis

From the plots of C_{energy}, $C_{chemical}$ and C_{waste} against Q (see Fig 4), C_{energy} increases as Q increases. Also, Fig. 4 shows that $C_{chemical}$ increases linearly (almost) as Q increases while C_{waste} decreases as Q increases until Q=35m^3/hr after which it rises. The increase in C_{energy} can be attributed to more consumption of energy to produce more Q while increase in $C_{chemical}$ can be as a result of more chemical needed for cleaning and coagulation as more Q is demanded. Also, decrease in C_{waste} as Q increases may be as a result of less production of waste as a result of increase in recovery of the plant (see Table 4 & 5). However, it is good to note that C_{waste} is independent of the coagulant concentration dosing as projected by the XIGA^{TM} Projection tool. Meanwhile, it is expected that C_{waste} should depend on the coagulant concentration dosing as part of it is among the waste. If this is considered, may be different results could be obtained. But no available relationship that gives the dependence of C_{waste} on the coagulant concentration.

From Fig. 5, the sensitivity of TOC to the C_{energy}, $C_{chemical}$ and C_{waste} is in the order $C_{energy} < C_{chemical} < C_{waste}$ (see Table 6 for their sensitivity coefficients). However, the negative values observed in Fig. 5 may be due to effects of J_f and t_f not explicitly considered in the sensitivity analysis. Also as the membrane replacement cost is the same in all the operating conditions investigated with XIGA^{TM} Projection tool, no logical conclusion could be made about the sensitivity of TOC with respect to the membrane replacement cost.

5.3. Economical model

At fixed t_f =26mins (Figure 5), TOC shows a clear interaction between J_f and Q. The quadratic relationship between TOC and Q can be exploited in determining the minimum TOC for economical Q at optimum J_f. At fixed filtration time, TOC with respect to filtration flux (J_f) and permeate output flow (Q) were found to be concave and convex respectively which is expectedly to result into a saddle plane. Given the constraints on the process conditions, this kind of relationship can be exploited to determine the optimal operating conditions with respect to J_f and Q for minimum TOC.However, the dependence of amount of concentrate on the concentration of coagulant in the concentrate was never considered as this may change the result obtained. The same result was obtained during the peak period of operation. Meanwhile, it is good to notice that the determination of the optimal operating conditions (for both peak and off-peak periods) will always consider the interaction among the influencing factors.

6.0. Conclusion

The economic and sensitivity analysis of an existing full-scale UF plant has been carried out. Based on the result of the economic analysis, an economic model was developed. For operating cost minimization, the analysis has shown that the plant could be run at J_f =85lmh and t_f =138min (per cycle) during peak period while J_f=25lmh and t_f=26min (per cycle) is suitable for off-peak operation period. Also the sensitivity analysis revealed that C_{waste} is the most influencing factor. However accurate estimation of C_{waste} depends on the coagulant concentration in the concentrate. Therefore, a relationship between the coagulant concentration and the amount of concentrate is necessary to adequately draw final conclusion. At fixed t_f (which the usual practice in the industry), TOC responses to J_f and Q were found to be concave and convex respectively which is expectedly to result into a saddle plane. This situation can be exploited to determine the optimal operation conditions. Also Fig. 6 has shown that the model agrees fairly with generated data from XIGA^{TM}

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Notations

CEB	Chemically enhanced backwash
HB	Hydraulic backwash
t_f	Filtration time (hr)
$\alpha_1,...,\alpha_9$	LS estimated parameters (correct symbol should be used)
J_f	Filtration flux (l m^{-1} h^{-1})
t_f	Filtration time (min)
MSE	Mean square error
C_{energy}	Energy cost (€/year)
C_{waste}	Cost of wastewater disposal in €/year
E_{filtr}	Energy consumption for filtration (kWh)
E_{HB}	Energy consumption for hydraulic backwash (kWh)
E_{CEB}	Energy consumption in (€/kWh)
$C_{coagulant}$	Cost of coagulant in (€/year)
C_{coag}	Cost of coagulant per m^3
$C_{chemical}$	Cost of membrane in €/year
C_{memb}	Cost of membrane replacement in €/year
$Q_{concentrate}$	Amount of the concentrate produced in m^3/year
X_{ref}	Disposal reference used by the water board on the location
TOC	Yearly total operating cost (€/year)
Q	Output of the plant (permeate) (m^3/hr)
TOC_o	Initial total operating cost (€/year)

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Performances of Some Estimators of Linear Model when Stochastic Regressors are Correlated with Autocorrelated Error Terms

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Abstract

In linear model with autocorrelated error terms, regressors are not only assumed fixed (non – stochastic) in repeated sampling but also uncorrelated with the error terms. These assumptions are not always tenable especially in business, economics and social sciences. Therefore in this paper, we examined the performances of some estimators of linear model namely; ordinary least square(OLS) and four feasible generalized least estimators which are Cochrane Orcut (CORC), Hidreth – Lu (HILU), Maximum Likelihood (ML), Maximum Likelihood Grid (MLGD) when normally distributed stochastic regressors exhibit various degrees of correlation with the autocorrelated error terms through Monte – Carlo studies. At various levels of autocorrelation (ρ) and correlation between stochastic regressor and autocorrelated error terms (λ), the estimators are compared by examing the finite properties of estimators namely; sum of biases, sum of absolute biases, sum of variances and sum of the mean squared error of the estimated parameter of the model.

Results show that except when $\lambda \to 1$ the best estimator is either ML or MLGD or both; and to a very lesser extent CORC and HILU when autocorrelation level is low $(\rho = 0.4)$ and high $(\rho = 0.8)$. When $\lambda \to 1$, the OLS estimator is best except when the sample size is moderate (n=40) and large (n=80). Furthermore, when the autocorrelation level is very high $(\rho = 0.9)$ or tends to unity ($\rho \to 1$) and $\lambda \le 0.75$ the HILU and the CORC, in that order, are superior to the other estimators. However, when $\lambda > 0.75$, the HILU, ML and to a lesser extent, CORC are best.

Keywords: Stochastic Regressors, Correlation, Linear Model with autocorrelated error, OLS estimator, Feasible GLS Estimators.

Introduction

In linear model with autocorrelated error terms, the regressors are not only assumed fixed (non – stochastic) in repeated sampling but also uncorrelated with the error terms. This assumption of fixed regressors is tenable in experimental design and not in business, economics and social sciences. Neter and Wasserman (1974), Fomby et.al (1984) and many others have not only given situations and

instances where this assumption may be violated but have also discussed its consequences on the ordinary least square (OLS) estimator when used to estimate the model parameters. Graybill (1961), Sampson (1974), Fomby et.al (1984) and others emphasized that if regressors are stochastic and independent of the error terms; the OLS estimator is unbiased and has minimum variance even though it is not Best Linear Unbiased Estimator (BLUE).

Neter and Wasserman (1974), Maddala (2002) attributed a source of correlation between regressors and error terms to measurement errors in the regressors. They noted that if the OLS estimator is applied to regression model of this form, the estimates are not only bias but lack property of consistency. However, Maddala (2002) emphasized that this does not imply that inferences about the model parameters are not possible.

In the presence of autocorrelated error terms, the regression model requires variable transformation for the OLS estimator to be applied and this consequently yields the generalized least square (GLS) method of parameter estimation given by Aitken (1935) as

$$\hat{\beta} = \left(X^1\Omega^{-1}X\right)^{-1}X^1\Omega^{-1}Y \tag{1}$$

with variance – covariance matrix of $\hat{\beta}$ given as

$$V\left(\hat{\beta}\right) = \sigma^2\left(X^1\Omega^{-1}X\right)^{-1} \tag{2}$$

where

$$\Omega^{-1} = \frac{1}{1-\rho^2}\begin{bmatrix} 1 & -\rho & 0 & \ldots & 0 & 0 \\ -\rho & 1+\rho^2 & -\rho & \ldots & 0 & 0 \\ 0 & -\rho & 1+\rho^2 & \ldots & 0 & 0 \\ . & . & . & \ldots & . & . \\ . & . & . & \ldots & . & . \\ . & . & . & \ldots & . & . \\ 0 & 0 & 0 & \ldots & 1+\rho^2 & -\rho \\ 0 & 0 & 0 & \ldots & -\rho & 1 \end{bmatrix}_{n\times n}$$

From (1) and (2), the autocorrelation parameter and hence Ω is required to be known before estimation of the parameters can be done. However, Ω is not always known, it is often estimated by $\hat{\Omega}$ to have what is known as Feasible GLS estimator. Many consistent estimates of $\hat{\Omega}$ can be obtained (Fomby et. al, 1984).

With the first order autocorrelated error terms (AR (1)), two variable transformations observed in literature are those given respectively by Cochrane and Orcutt (1949) and Prais – Winsten (1954) as

$$P = \begin{bmatrix} -\rho & 1 & 0 & \ldots & 0 & 0 \\ 0 & -\rho & 1 & \ldots & 0 & 0 \\ 0 & 0 & -\rho & \ldots & 0 & 0 \\ . & . & . & \ldots & . & . \\ . & . & . & \ldots & . & . \\ . & . & . & \ldots & . & . \\ 0 & 0 & 0 & \ldots & -\rho & 1 \end{bmatrix}_{(n-1)\ \times\ n}$$

which ignores the first observation of the error terms and

$$Q = \begin{bmatrix} (1-\rho^2)^{\frac{1}{2}} & 0 & 0 & \ldots & 0 & 0 \\ -\rho & 1 & 0 & \ldots & 0 & 0 \\ 0 & -\rho & 1 & \ldots & 0 & 0 \\ . & . & . & \ldots & . & . \\ . & . & . & \ldots & . & . \\ . & . & . & \ldots & . & . \\ 0 & 0 & 0 & \ldots & -\rho & 1 \end{bmatrix}_{nxn}$$

which does incorporate the first observation.

Among the Feasible GLS estimators in literature are the Cochrane and Orcutt estimator (1949), Hildreth and Lu estimator (1960), Prais – Winsten estimator (1954), Thornton estimator (1982), Durbin estimator (1960), Theil's estimator (1971), the Maximum Likelihood estimator and the Maximum Likelihood Grid estimator (Beach and Mackinnon, 1978). Some of these estimators have now been incorporated into White's SHAZAM program (White, 1978) and the new version of the time series processor (TSP, 2005). However, all of these estimators are known to be asymptotically equivalent but the question on which is to be preferred in small samples is the worry of researchers (Fomby et. al, 1984).

The efficiency of these estimators has been observed to be affected by the structure of the regressors that are used in the study (Chipman, 1979; Kramer, 1980; Kleiber, 2001). Rao and Griliches (1969) examined the performances of some of these estimators with first-order autoregressive stochastic regressor through a Monte – Carlo study. Their results show that the OLS estimator is only more efficient than any of the GLS estimators considered when $|\rho| < 0.3$; and that the performances of the GLS estimators are not far apart. Park and Mitchell (1980) observed that when regressors are trended, the estimator that retains the first observation (Paris – Winstern) is more efficient than the one that does not (Cochrane – Orcutt); and that the latter is even less efficient than the OLS estimator. Other recent works that are done with different specification of regressors include that of Iyaniwura and Nwabueze (2004a), Iyaniwura and Nwabueze (2004b), Nwabueze (2005), and Olaomi and Iyaniwura (2006).

Consequently since these GLS estimators are meant to correct the error terms' problem in regression analysis, we therefore examine the performances of some of these estimators when a regressor correlated with the error terms with a view of determining the estimators that can be considered best in estimating all the model parameters at various levels of the two correlations i.e autocorrelation (ρ) and correlation between regressor and autocorrelated error terms (λ).

Methodology

Consider a first order autoregressive model with stochastic regressors of the form

$$y_t = \beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + u_t \tag{3}$$

where $u_t = \rho u_{t-1} + \varepsilon_t$, $\varepsilon_t \sim N(0, \sigma^2 I_n)$, $|\rho| < 1$; and x_1 is said to have λ correlation with x_1, $|\lambda| < 1$.

Hence, the variance – covariance matrix of the autocorrelated error terms can be obtained as

$$E(UU') = \sigma_u^2 \begin{bmatrix} 1 & \rho_1 & \rho_1^2 & \dots & \rho_1^{n-2} & \rho_1^{n-1} \\ \rho_1 & 1 & \rho_1 & \dots & \rho_1^{n-3} & \rho_1^{n-2} \\ \rho_1^2 & \rho_1 & 1 & \dots & \rho_1^{n-4} & \rho_1^{n-3} \\ . & . & . & \dots & . & . \\ . & . & . & \dots & . & . \\ . & . & . & \dots & . & . \\ \rho_1^{n-2} & \rho_1^{n-3} & \rho_1^{n-4} & \dots & 1 & \rho_1 \\ \rho_1^{n-1} & \rho_1^{n-2} & \rho_1^{n-3} & \dots & \rho_1 & 1 \end{bmatrix} \quad (4)$$

where $\sigma_u^2 = \dfrac{\sigma_e^2}{(1-\rho_1^2)}$ (the homoscedastic variance)

Now, suppose $W_i \sim N(\mu_i, \sigma_i^2) \quad i = 1,2$. If these variables are correlated, then W_1 and W_2 can be generated with the equations

$$W_1 = \mu_1 + \sigma_1 z_1$$
$$W_2 = \mu_2 + \rho\sigma_2 z_1 + \sigma_2 z_2\sqrt{1-\rho^2} \quad (5)$$

where $Z_i \sim N(0,1) \quad i = 1,2 \quad and \quad |\rho| < 1$ is the value of the correlation between the two variables. This is proved in appendix 1.

Parameter estimation of (3) is done using the OLS and the following (feasible) GLS estimators: CORC, HILU, ML and the MLGD estimators. The CORC and HILU estimators do not retain the first observation while the ML and MLGD estimators do.

Monte Carlo experiments were performed for three sample sizes $(n = 20, 40, 80)$, replicated 120 times at four levels of autocorrelation $(\rho = 0.4, 0.8, 0.9, 0.99)$ and four levels of correlation between stochastic regressor and error terms $(\lambda = 0.25, 0.5, 0.75, 0.99)$ utilizing equation (3), (4) and (5). At a particular choice of $n, \rho \; and \; \lambda$ (a scenario), the first replication was obtained by generating $e_t \sim N(0,1)$ and hence u_t. Assuming the process start from infinite past and continue to operate, the initial value of U (i.e u_1) was thus drawn from a normal population with mean zero and variance $\dfrac{1}{1-\rho^2}$. Hence

$$u_1 = \frac{\varepsilon_1}{\sqrt{1-\rho^2}} \quad (6)$$

$$u_t = \rho u_{t-1} + \varepsilon_t \quad \text{t} = 2, 3, \ldots, 20 \quad (7)$$

Next, $x_{1t} \sim N(0,1)$ was generated using equation (5) having correlation with $\sim N\left(0, \dfrac{1}{1-\rho_1^2}\right)$.

Hence,

$$u_t = \frac{\varepsilon_{1t}}{\sqrt{1-\rho^2}} \quad (8)$$

$$x_{1t} = \lambda\varepsilon_{1t} + z_{2t}\sqrt{1-\lambda^2} \quad (9)$$

Therefore, from (8)

$$\varepsilon_{1t} = u_t\sqrt{1-\rho^2} \quad (10)$$

But the u_t of the model has been obtained in (6) and (7). Thus, replacing the u_t of (10) with the with the u_t of (6) and (7) we obtain ε_{1t} to be used in (9). Therefore,

$$x_{1t} = \lambda u_t \sqrt{1-\rho^2} + z_{2t}\sqrt{1-\lambda^2} \tag{11}$$

where u_t is the u_t of (6) and (7). Thus, the correlation between X_1 and U is affected by autocorrelation.

The values of y_t in equation (1) were also calculated by setting the true regression coefficients as $\beta_0 = \beta_1 = \beta_2 = 1$. This process continued until all replications in this scenario were obtained. Another scenario then started until all the scenarios were completed.

Evaluation and comparison of estimators were examined using the finite sampling properties of estimators which include bias (B), absolute bias (AB), and variance (Var) and the more importantly the root mean squared error (RMSE) criteria. Mathematically, for any estimator $\hat{\beta}_i$ of β_i of model (3)

$$\bar{\hat{\beta}}_i = \frac{1}{120}\sum_{j=1}^{120}\hat{\beta}_{ij} \tag{12}$$

$$B\left(\hat{\beta}_i\right) = \frac{1}{120}\sum_{j=1}^{120}\left(\hat{\beta}_{ij} - \beta_i\right) = \bar{\hat{\beta}}_i - \beta_i \tag{13}$$

$$AB\left(\hat{\beta}_i\right) = \frac{1}{120}\sum_{j=1}^{120}\left|\hat{\beta}_{ij} - \beta_i\right| \tag{14}$$

$$Var\left(\hat{\beta}_i\right) = \frac{1}{120}\sum_{j=1}^{120}\left(\hat{\beta}_{ij} - \bar{\hat{\beta}}_i\right)^2 \tag{15}$$

$$RMSE\left(\hat{\beta}_i\right) = \left[\frac{1}{120}\sum_{j=1}^{120}\left(\hat{\beta}_{ij} - \beta_i\right)^2\right]^{\frac{1}{2}} = \left[Var\left(\hat{\beta}_i\right) + \left[B\left(\hat{\beta}_i\right)\right]^2\right]^{\frac{1}{2}} \tag{16}$$

for i = 0, 1, 2 and j= 1,2,…,120.

For each of the estimators, a computer program was written using TSP software to estimate all the model parameters and to evaluate the criteria. Often times, preference of estimators are based on bias (closest to zero), minimum variance and minimum (root) mean squared error. In this study, we utilized the criteria of sum of bias (SBIAS), sum of absolute bias (SABIAS), sum of variance (SVAR), and the root mean squared error (SRMSE) of the estimated model parameters to compare the performances of the estimators. This approach has also been used by Iyaniwura and Nwabueze (2004a), Iyaniwura and Nwabueze (2004b), Nwabueze (2005), Olaomi and Iyaniwura (2006) and some others.

Consider an estimator $\hat{\beta}(.) = (\hat{\beta}_0, \hat{\beta}_1, \hat{\beta}_2)$, then

$$\text{SBIAS of } \hat{\beta}(.) = |BB0| + |BB1| + |BB2| \tag{17}$$

$$\text{SABIAS of } \hat{\beta}(.) = |ABB0| + |ABB1| + |ABB2| \tag{18}$$

$$\text{SVAR of } \hat{\beta}(.) = VARB0 + VARB1 + VARB2 \tag{19}$$

$$\text{SRMSE of } \hat{\beta}(.) = RMSEB0 + RMSEB1 + RMSEB2 \tag{20}$$

The results based on these evaluated criteria of all the estimators at all the four levels of autocorrelations when $n = 20$ *and* $\lambda = 0.5$ is given in the appendix 2. For other levels of sample size and correlation between regressor and error terms, see Ayinde (2006).

Furthermore at a particular set of the specifications, the estimators are ranked based on their performances in all these criteria. Estimator with the minimum value of the criterion in question is ranked 1; the next minimum is ranked 2; e.t.c. The ranks of each estimator are then added together in all the criteria to determine the best estimator. An estimator is considered best if it has the smallest total rank at that particular set of specifications.

Simulation Results and Discussion

The sum of rank of each estimator is obtained by adding the ranks of each estimator together on the basis of their performances under the criteria at each level of sample sizes, autocorrelation and correlation between regressor and error terms. For example from the appendix, when n = 20 $\rho = 0.8$, $\lambda = 0.5$, the sum of rank of the CORC estimator (SR) = rank of sum of biases + rank of sum of absolute biases + rank of sun of variances + rank of sum of root mean squared error. Therefore, SR = 4 +4 + 5+ 5 = 18. In the same way, that of other estimators was obtained. The summary of the results obtained on the performances of the estimators based on the sum of the rank of all the criteria at each level of sample sizes, autocorrelation and correlation between regressor and error terms are given in table 1.

Table 1: Performances of Estimators based on sum of rank of all criteria at each level of sample sizes, autocorrelation and correlation between regressor and error terms.

$\rho = 0.4$

n	Estimator	$\lambda = 0.25$	$\lambda = 0.5$	$\lambda = 0.75$	$\lambda = 0.99$
20	OLS	14	17	15	08
	CORC	15	18	16	19
	HILU	19	13	13	15
	ML	04	06	10	09
	MLGD	08	06	06	09
40	OLS	20	20	16	06
	CORC	12	11	12	15
	HILU	16	16	16	13
	ML	06	04	09	14
	MLGD	06	09	07	12
80	OLS	20	20	20	06
	CORC	10	13	15	20
	HILU	14	11	12	16
	ML	06	09	04	10
	MLGD	10	07	09	08

$\rho = 0.8$

n	Estimator	$\lambda = 0.25$	$\lambda = 0.5$	$\lambda = 0.75$	$\lambda = 0.99$
20	OLS	17	17	17	09
	CORC	18	18	16	14
	HILU	13	13	11	10
	ML	06	07	12	11
	MLGD	06	05	04	16
40	OLS	20	20	20	10
	CORC	04	04	15	15
	HILU	12	08	04	12
	ML	08	12	13	09
	MLGD	16	16	08	14
80	OLS	20	20	20	10
	CORC	09	09	05	18
	HILU	16	16	14	16
	ML	07	05	08	10
	MLGD	08	10	13	06

$\rho = 0.9$

n	Estimator	$\lambda = 0.25$	$\lambda = 0.5$	$\lambda = 0.75$	$\lambda = 0.99$
20	OLS	17	19	17	09
	CORC	19	15	15	08
	HILU	06	06	05	13
	ML	07	08	14	17
	MLGD	11	12	09	13
40	OLS	20	20	20	12
	CORC	08	08	08	12
	HILU	04	04	04	15
	ML	16	14	16	08
	MLGD	12	14	12	13
80	OLS	20	20	20	16
	CORC	05	05	04	13
	HILU	10	10	09	16
	ML	15	15	12	07
	MLGD	10	10	15	08

$\rho = 0.99$

n	Estimator	$\lambda = 0.25$	$\lambda = 0.5$	$\lambda = 0.75$	$\lambda = 0.99$
20	OLS	19	18	18	14
	CORC	11	05	07	08
	HILU	04	07	07	08
	ML	12	14	13	14
	MLGD	14	16	15	16
40	OLS	18	18	18	16
	CORC	08	08	08	11
	HILU	04	04	04	07
	ML	17	17	17	15
	MLGD	13	13	13	11
80	OLS	20	18	18	16
	CORC	07	07	07	13
	HILU	05	05	05	05
	ML	13	14	14	15
	MLGD	15	16	16	11

From the table when the autocorrelation level is low ($\rho = 0.4$), it is observed that the ML and the MLGD estimators are better at all the levels of correlation between regressor and error terms (λ) except when $\lambda \to 1$ where the OLS estimator is best in all the three sample sizes. This signals that it is at this level of correlation between regressor and the error terms that the corrective measure incorporated into the GLS estimators begin to lose its potency due to the use of the badly behaved regressor.

When the autocorrelation level is high ($\rho = 0.8$) and the sample size is small (n=20), the ML and the MLGD estimators are still better with low ($\lambda = 0.25$) and moderate ($\lambda = 0.5$) correlation between regressor and error terms. However, when the level of correlation between regressor and error terms is high ($\lambda = 0.75$) the ML is best when $\lambda \to 1$ the OLS estimator is best. When the sample size is moderate (n = 40), the CORC estimator is best except when λ is high ($\lambda = 0.75$) where the HILU estimator is best and when $\lambda \to 1$ where the ML estimator is best. With large sample size (n = 80), the best estimator in all the levels of correlation between regressor and error terms is either ML or MLGD or CORC.

When the autocorrelation level is very high ($\rho = 0.9$) and the sample size is small (n=20) and moderate (n=40), the HILU estimator best except when $\lambda \to 1$ where the CORC and OLS are better when the sample size is small (n=20) and the ML estimator is best $\lambda \to 1$ when the sample size is moderate (n = 40). When the sample size is large (n=80), the CORC estimator is best where the ML and MLGD estimators are better.

When the autocorrelation level is very close to unity ($\rho \to 1$), the best estimator in all the sample sizes is either COCR or HILU or both at all the levels of correlation between regressor and error terms. The summary of the best estimator at different levels of autocorrelation,sample size and correlation between regressor and sample size is given in Table 2.

Table 2: Summary of the best estimator at different levels of autocorrelation, sample size and correlation between regressor and sample size.

ρ	n	$\lambda = 0.25$	$\lambda = 0.5$	$\lambda = 0.75$	$\lambda = 0.99$
0.4	20	ML	ML&MLGD	MLGD	OLS
	40	MLGD	ML	MLGD	OLS
	80	ML	MLGD	ML	OLS
0.8	20	ML&MLGD	MLGD	MLGD	OLS
	40	CORC	CORC	HILU	ML
	80	MLGD	ML	CORC	MLGD
0.9	20	HILU	HILU	HILU	CORC
	40	HILU	HILU	HILU	ML
	80	CORC	CORC	CORC	ML
0.99	20	HILU	CORC	CORC&HILU	CORC&HILU
	40	HILU	HILU	HILU	HILU
	80	HILU	HILU	HILU	HILU

Summarily from table 2, it can be observed that except when $\lambda \to 1$ the best estimator in all the sample sizes is either ML or MLGD or both; and to a very lesser extent CORC and HILU when autocorrelation level is low $(\rho = 0.4)$ and high $(\rho = 0.8)$. When $\lambda \to 1$, the OLS estimator is best except when the sample size is moderate where the ML is best and when the sample size is large where the MLGD is the best. Furthermore the autocorrelation level is very high $(\rho = 0.9)$ or tends to unity ($\rho \to 1$) and when $\lambda \leq 0.75$ the HILU and the CORC, in that order are superior to the other estimators. However, when $\lambda > 0.75$, the HILU, ML and to a lesser extent, CORC are best.

Conclusion

The performances of the estimators of linear model with autocorrelated error terms are affected by correlation between regressor and error terms. And so, when both levels of autocorrelation and correlation between regressor and error terms are either low or high, the two GLS estimators ML and MLGD are often better than other estimators. However when the correlation between regressor and error terms tends to unity, the OLS estimator is often superior to the GLS estimators. This signals that it is at this level of correlation between regressor and the error terms that the corrective measure incorporated into the GLS estimators begin to lose its potency due to the use of the badly behaved regressor. Furthermore, with very high level of autocorrelation or autocorrelation very closer to unity the CORC and HILU estimators are often superior to others estimators in all the levels of correlation between regressor and error terms.

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Appendix 1

Theorem

Suppose $W_i \sim N(\mu_i, \sigma_i^2) \quad i = 1,2$. If these variables are correlated, then W_1 and W_2 can be generated with the equations

$$W_1 = \mu_1 + \sigma_1 z_1 \tag{i}$$

$$W_2 = \mu_2 + \rho\sigma_2 z_1 + \sigma_2 z_2 \sqrt{1-\rho^2}$$

where $Z_i \sim N(0,1) \quad i = 1,2 \quad and \quad |\rho| < 1$ is the value of the correlation between the two variables.

In order to prove this theorem, we use this lemma.

Lemma

A matrix **A** is positive definite if and only if there exist a non singular matrix **F** such that **A = FF[1].** A (real) symmetric matrix **A** of rank **r** is semi definite if and only if their exist a matrix **F** of rank **r** such that **A = FF[1]** [30].

This lemma indicates the existence of a matrix **F** such that **A = FF[1]**. To determine a matrix **F**, we use the Cholesky factorization procedure available in Forsythe [31].

Suppose a matrix product may be defined as

$$A = TT^1 = \sum_{i=1}^{n} t_i t_i^1 \tag{ii}$$

so that

$$A - \sum_{i=1}^{n} t_i t_i^1 = 0 \tag{iii}$$

then, the Cholesky or square root factorization procedure constructs t_i^1 in a systematic manner until (iii) is obtained.

Proof

Suppose $\underset{\sim}{Z}_t = \begin{bmatrix} z_{1t} \\ z_{2t} \end{bmatrix} \sim N_2(0, I)$

Then $\underset{\sim}{W}_i = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \Sigma^{\frac{1}{2}} Z_t$ (iv)

Where $\underset{\sim}{W}_i \sim N_2\left(\begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix}, \Sigma\right), \ \Sigma = \begin{bmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{bmatrix}$

Hence from (iv), we need to seek for $\Sigma^{\frac{1}{2}}$. This, we do by applying the lemma and the Cholesky factorization procedure since it is obvious that

$$\Sigma = \Sigma^{\frac{1}{2}}\Sigma^{\frac{1}{2}1} = TT^1 \quad \text{(v)}$$

Using the Cholesky factorization and noting that $\sigma_{12} = \rho_{12}\sigma_1\sigma_2$.

$$\Sigma = \begin{bmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{bmatrix} = \begin{bmatrix} a_1^1 \\ a_2^1 \end{bmatrix}$$

$$t_1^1 = \frac{a_1^1}{\sqrt{a_{11}}} = \frac{1}{\sigma_1}\begin{bmatrix} \sigma_1^2 & \sigma_{12} \end{bmatrix} = \begin{bmatrix} \sigma_1 & \rho_{12}\sigma_2 \end{bmatrix}$$

$$t_1 t_1^1 = \begin{bmatrix} \sigma_1 \\ \rho_{12}\sigma_2 \end{bmatrix} \begin{bmatrix} \sigma_1 & \rho_{12}\sigma_2 \end{bmatrix} = \begin{bmatrix} \sigma_1^2 & \rho_{12}\sigma_1\sigma_2 \\ \rho_{12}\sigma_1\sigma_2 & \rho_{12}^2\sigma_2^2 \end{bmatrix}$$

Thus, $A = \Sigma - t_1 t_1^1 = \begin{bmatrix} 0 & 0 \\ 0 & \sigma_2^2(1-\rho_{12}^2) \end{bmatrix} = \begin{bmatrix} b_1^1 \\ b_2^1 \end{bmatrix}$

Similarly,

$$t_2^1 = \frac{b_2^1}{\sqrt{b_{22}}} = \frac{1}{\sigma_2\sqrt{1-\rho_{12}^2}}\begin{bmatrix} 0 & \sigma_2^2(1-\rho_{12}^2) \end{bmatrix} = \begin{bmatrix} 0 & \sigma_2\sqrt{1-\rho_{12}^2} \end{bmatrix}$$

$$t_2 t_2^1 = \begin{bmatrix} 0 \\ \sigma_2\sqrt{1-\rho_{12}^2} \end{bmatrix} \begin{bmatrix} 0 & \sigma_2\sqrt{1-\rho_{12}^2} \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 0 & \sigma_2^2(1-\rho_{12}^2) \end{bmatrix}$$

Thus, $B = A - t_2 t_2^1 = \begin{bmatrix} 0 & 0 \\ 0 & \sigma_2^2(1-\rho_{12}^2) \end{bmatrix} - \begin{bmatrix} 0 & 0 \\ 0 & \sigma_2^2(1-\rho_{12}^2) \end{bmatrix} = \underset{\sim}{0}$

This has satisfied the Cholesky factorization procedure in (iii)

Therefore,

$$T^1 = \begin{bmatrix} t_1^1 \\ t_2^1 \end{bmatrix} = \begin{bmatrix} \sigma_1 & \rho_{12}\sigma_2 \\ 0 & \sigma_2\sqrt{1-\rho_{12}^2} \end{bmatrix}, \qquad T = \begin{bmatrix} \sigma_1 & 0 \\ \rho_{12}\sigma_2 & \sigma_2\sqrt{1-\rho_{12}^2} \end{bmatrix}$$

Check

It is expected that $TT^1 = \Sigma^{\frac{1}{2}}\Sigma^{\frac{1}{2}1} = \Sigma$.

$$TT^1 = \begin{bmatrix} \sigma_1 & 0 \\ \rho_{12}\sigma_2 & \sigma_2\sqrt{1-\rho_{12}^2} \end{bmatrix}\begin{bmatrix} \sigma_1 & \rho_{12}\sigma_2 \\ 0 & \sigma_2\sqrt{1-\rho_{12}^2} \end{bmatrix} = \begin{bmatrix} \sigma_1^2 & \rho_{12}\sigma_1\sigma_2 \\ \rho_{12}\sigma_1\sigma_2 & \rho_{12}^2\sigma_2^2 + \sigma_2^2(1-\rho_{12}^2) \end{bmatrix}$$

$$= \begin{bmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{bmatrix}$$

Consequently, $T = \Sigma^{\frac{1}{2}}$ and hence (iv) becomes

$$\underset{\sim}{W}_i = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \Sigma^{\frac{1}{2}} Z$$

$$\underset{\sim}{W}_i = \begin{bmatrix} \mu_1 \\ \mu_2 \end{bmatrix} + \begin{bmatrix} \sigma_1 & 0 \\ \rho_{12}\sigma_2 & \sigma_2\sqrt{1-\rho_{12}} \end{bmatrix} \begin{bmatrix} z_{1t} \\ z_{2t} \end{bmatrix} \quad \text{(vi)}$$

Thus, it follows that if $W_i \sim N(\mu_i, \sigma_i^2)$ $i = 1,2$. If these variables are correlated, then W_1 and W_2 can be generated with the equations

$$W_1 = \mu_1 + \sigma_1 z_1$$

$$W_2 = \mu_2 + \rho\sigma_2 z_1 + \sigma_2 z_2\sqrt{1-\rho^2} \quad \text{(vii)}$$

where $Z_i \sim N(0,1)$ $i = 1,2$ *and* $|\rho| < 1$ is the value of the correlation between the two variables.

Appendix 2

Table 3: Bias of β when n = 20 and $\lambda = 0.5$

ρ	Estimator	BB0	BB1	BB2	SBIAS	Rank
0.4	OLS	.002041	.519150	.010325	.531516	5
	CORC	-.012511	.466700	-.012150	.491361	4
	HILU	-.008113	.453230	-.010431	.471774	3
	ML	-.001513	.459430	-.005967	.466910	2
	MLGD	-.001455	.456840	-.005961	.464256	1
0.8	OLS	.015658	.588740	-.004711	.609109	5
	CORC	-.085828	.279600	-.026235	.391663	4
	HILU	-.024841	.256860	-.025770	.307471	3
	ML	.009456	.266240	-.020039	.295735	1
	MLGD	.011025	.268800	-.019280	.299105	2
0.9	OLS	.038166	.556300	-.014049	.608515	5
	CORC	-.075991	.178420	-.026814	.281225	4
	HILU	.054334	.178650	-.027442	.260426	3
	ML	.025641	.185550	-.017772	.228963	1
	MLGD	.026217	.187640	-.017639	.231496	2
0.99	OLS	.081839	.203350	-.016196	.301385	5
	CORC	.022311	.052790	-.022763	.097864	2
	HILU	.010397	.053007	-.022601	.086005	1
	ML	.060635	.054512	-.020897	.136044	4
	MLGD	.057004	.054694	-.021079	.132777	3

Table 4: Absolute bias of β when n = 20 and $\lambda = 0.5$

ρ	Estimator	ABB0	ABB1	ABB2	SABIAS	Rank
0.4	OLS	.094982	.538530	.187070	.820582	5
	CORC	.132940	.476680	.191910	.801530	4
	HILU	.134520	.471210	.192000	.797730	3
	ML	.086257	.470110	.188190	.744557	2
	MLGD	.087456	.467410	.188570	.743436	1
0.8	OLS	.234460	.606960	.241420	1.082840	5
	CORC	.338370	.316010	.173910	.828290	4
	HILU	.307450	.292450	.172630	.772530	3
	ML	.231970	.297840	.169340	.699150	2
	MLGD	.228840	.299690	.169450	.697980	1
0.9	OLS	.571940	.580870	.273580	1.426390	5
	CORC	.546860	.240940	.165200	.953000	2
	HILU	.422420	.241430	.164770	.828620	1
	ML	.580460	.241500	.158720	.980680	3
	MLGD	.584490	.243500	.159680	.987670	4
0.99	OLS	4.272930	.359890	.295810	4.928630	5
	CORC	3.709690	.189340	.151830	4.050860	1
	HILU	3.835430	.188570	.151490	4.175490	2
	ML	4.293160	.183330	.148250	4.624740	3
	MLGD	4.298200	.184060	.148830	4.631090	4

Table 5: Variance of β when n = 20 and $\lambda = 0.5$

ρ	Estimator	VB0	VB1	VB2	SVAR	Rank
0.4	OLS	.015072	.061053	.063761	.139887	3
	CORC	.030759	.060211	.068367	.159338	5
	HILU	.029102	.061783	.067666	.158551	4
	ML	.015987	.053864	.063888	.133739	1
	MLGD	.016397	.054297	.064075	.134770	2
0.8	OLS	.082603	.147685	.102618	.332906	3
	CORC	.488444	.086804	.058335	.633582	5
	HILU	.279493	.052933	.057885	.390311	4
	ML	.091970	.051086	.050564	.193620	2
	MLGD	.085860	.051317	.050956	.188133	1
0.9	OLS	.486643	.213880	.130603	.831126	4
	CORC	1.237165	.050171	.053399	1.340736	5
	HILU	.340648	.050336	.053958	.444942	1
	ML	.543943	.046533	.040588	.631064	2
	MLGD	.552053	.046839	.040897	.639789	3
0.99	OLS	30.286922	.198379	.154098	30.639399	3
	CORC	22.379922	.048274	.038010	22.466206	1
	HILU	24.029292	.047937	.037714	24.114943	2
	ML	30.759363	.045742	.036981	30.842087	4
	MLGD	30.866771	.046076	.037304	30.950150	5

Table 6: Variance of β when n = 20 and $\lambda = 0.5$

ρ	**Estimator**	**RMB0**	**RMB1**	**RMB2**	**SRMSE**	**Rank**
0.4	OLS	.122784	.574952	.252721	.950458	4
	CORC	.175829	.527276	.261754	.964859	5
	HILU	.170786	.516914	.260336	.948037	3
	ML	.126448	.514723	.252832	.894003	1
	MLGD	.128059	.512835	.253202	.894095	2
0.8	OLS	.287833	.703065	.320375	1.311273	4
	CORC	.704138	.406177	.242946	1.353262	5
	HILU	.529254	.344833	.241969	1.116056	3
	ML	.303412	.349242	.225757	.878411	2
	MLGD	.293227	.351525	.226557	.871309	1
0.9	OLS	.698642	.723429	.361663	1.783734	5
	CORC	1.114872	.286365	.232633	1.633870	4
	HILU	.586174	.286796	.233904	1.106874	1
	ML	.737970	.284538	.202247	1.224756	2
	MLGD	.743465	.286440	.202998	1.232903	3
0.99	OLS	5.503964	.489622	.392887	6.386473	5
	CORC	4.730795	.225967	.196286	5.153047	1
	HILU	4.901979	.225271	.195512	5.322762	2
	ML	5.546444	.220712	.193437	5.960594	3
	MLGD	5.556080	.221511	.194288	5.971879	4

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Les Impacts Sur L'environnement du Dessalement de L'eau de Mer

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Abstract

La nécessité de dessaler l'eau de mer se fait de plus en plus pressante dans de nombreuse parties du mondes .Au cours des années 1950-1990, la consommation mondiale d'eau a triplé, tandis que la population de la planète augmentait de 2,3 milliards d'habitants.

Le dessalement de l'eau de mer est une industrie en essor constant .Cette forme de ressource en eau pratiquement illimitée consomme de l'énergie et elle a des impacts sur l'environnement .Ces impacts proviennent principalement de du concentré (saumure) produit au cours du dessalement, mais aussi des rejets de produits chimiques utilisées dans les procédés de dessalement.

Parmi les impacts dus à une usine de dessalement, il y a ceux qui se limitent à la phase de construction et ceux qui sont liés à la phase d'exploitation. les impacts commencent avec la transformation de l'occupation du sol, puit continuent avec des conséquences visuelles et des nuisances sonores pour s'étendre à des émissions dans l'atmosphère et des rejets dans l'eau ainsi qu'à des dommages potentiels pour le milieu récepteur (milieu marin).

Bien que les travaux de recherches consacrés à la question soient restreint, le rejet de concentré dans la mer appelle une vigilance particulière et une évaluation scientifique des impacts possibles sur le milieu marin.

Keywords: Dessalement, rejets, impacts, mer, environnement, pollution.

1. Introduction

La croissance démographique dans le monde s'accompagne d'une augmentation de la demande d'eau potable tandis que l'industrialisation, l'irrigation des sols et l'élévation des niveaux de vie se traduisent par un accroissement supplémentaire de la consommation d'eau douce par habitant .Cette évolution se produit surtout sur une étroite bande de littoral où prés de la moitié de la population de la planète vit, et cette proportion atteindre les trois quarts d'ici à 2020.Dans la région méditerranéennes, comme dans le

monde, la croissance démographique et l'intensité de l'activité socio-économique font de l'eau douce une ressource de plus en plus rare. Selon les estimations la demande totale dans la région, qui était 300 milliards de mètres cubes par an en 1990, augmentera de 32% d'ici à 2010 et de 55% d'ici 2025, pour atteindre plus de 460 milliards de mètres cubes [10].

Pour exploiter l'eau de mer aux de dessalement, il faut au départ une eau brute de bonne qualité, mais les masses d'eau côtières subissent souvent les effets préjudiciables des rejets d'eaux usées provenant de toute une série d'activités menées à terre, y compris les installations de dessalement .Le courant de déchets produits par le dessalement se présente généralement sous la forme d'une saumure dont la salinité peut augmenter avec la température et qui contient des substances chimiques résiduaires du prétraitement, des métaux lourds dus à la corrosion ou des agents chimiques utilisés par intermittence pour le nettoyage. Le rejet dans la mer de ces déchets aux multiples composants, soit directement par les émissaires côtiers soit indirectement par des bateaux, risque donc d'avoir des effets préjudiciables à la qualité de l'eau et des sédiments ou de nuire aux écosystèmes marins. Bien que les impacts soient le plus souvent liés au concentré, les usines de dessalement peuvent aussi être de grandes installations industrielles qui prennent de l'espace, exigent de l'énergie et émettent d'énormes quantités de gaz de combustion, ou peut avoir des effets indirects sur le développement socio-économique.

Donc il faut que les gouvernements concernés prennent en compte, dans la planification et la gestion des nouveaux projets des impacts potentiels environnementaux et socio-économiques qui en résulteront.

2. Les Impacts Sur L'environnement du Dessalement de L'eau de Mer

Parmi les impacts dus à une usine de dessalement, il y a ceux qui se limitent à la phase de construction et ceux qui sont à la phase d'exploitation. Les impacts commencent avec la transformation de l'occupation du sol, puis continuent avec conséquences visuelles et des nuisances sonores pour s'étendre à des émissions dans l'atmosphère et des rejets dans l'eau qui donnent des dommages potentiels pour le milieu récepteur.

Les activités de construction et d'exploitation peuvent se traduire par une série d'impacts sur les zones littorales, affectant notamment la qualité de l'air, la qualité de l'eau, la flore et la faune marines, la perturbation d'écosystèmes (dunes de sable, herbiers marins.

En dépit du fait que des procédés différents ont été mis au point pour le dessalement -osmose inverse, distillation, électrodialyse, congélation sous vide, etc. -, ils ont tous en commun de consister à ôter de l'eau de mer les substances minérales et notamment mais pas exclusivement les sels qui y sont dissoutes. Il en résulte donc, dans tous les cas, un effluent concentré qui a une composition similaire à l'eau de mer d'alimentation mais dont la concentration et de 1,2 à 3 fois plus élevée [19], avec en plus les produits chimiques utilisés au cours des phase de prétraitement et de post-traitement. Toute une série de produits chimiques et additifs servent en effet, lors de dessalement, à prévenir ou combattre l'entartrage ou la prolifération de microorganismes dans le cycle de dessalement.

Les constituants présents dans ces eaux résiduaires rejetées par les usines de dessalement dépendent dans une large mesure de la qualité de l'eau d'alimentation, de la qualité d'eau douce produite et de la technique de dessalement adoptée. Cependant, les rejets des usines de dessalement ne comprennent pas seulement l'effluent de saumure concentrée, les désinfectants et les agents antisalissures [2], mais également des eaux chaudes et des effluents aqueux tels que les distillats et condensas d'éjecteur. L'autre trait marquant des procédés de dessalement est qu'ils nécessitent un apport d'énergie thermique ou mécanique afin de réaliser la séparation de l'eau douce et de l'eau salée d'alimentation. Cet apport d'énergie se traduit par une hausse de la température de la saumure éliminée et par des rejets thermiques et des émissions atmosphériques associées à la production d'électricité.

Figure 1: Décharge sur le rivage par l'intermédiaire d'un canal ou d'un déversoir.

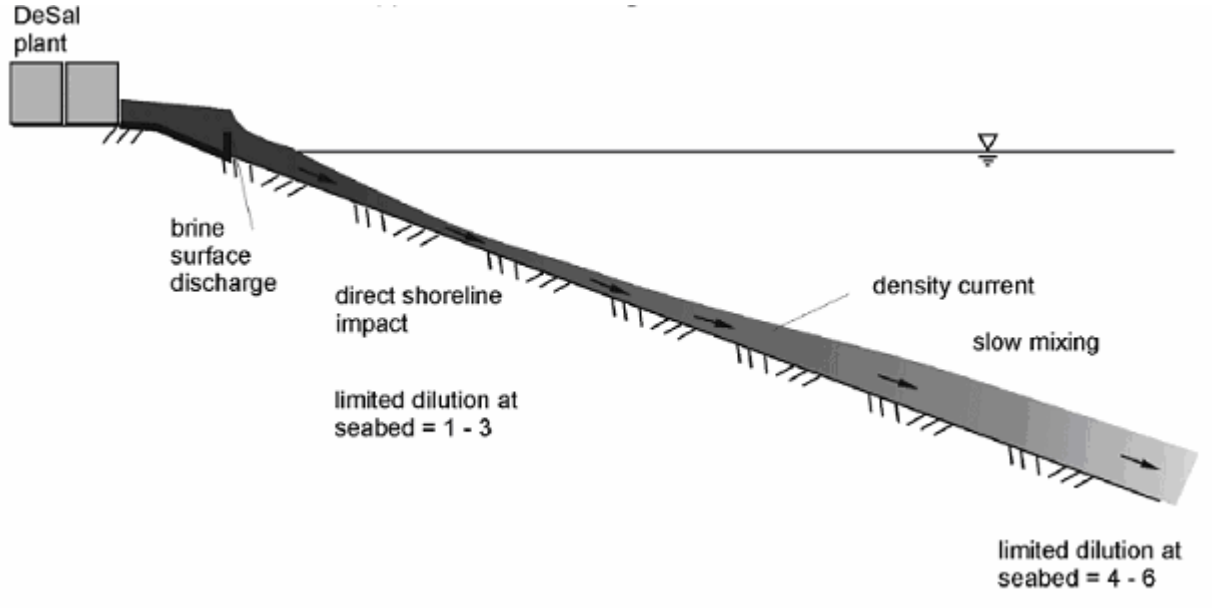
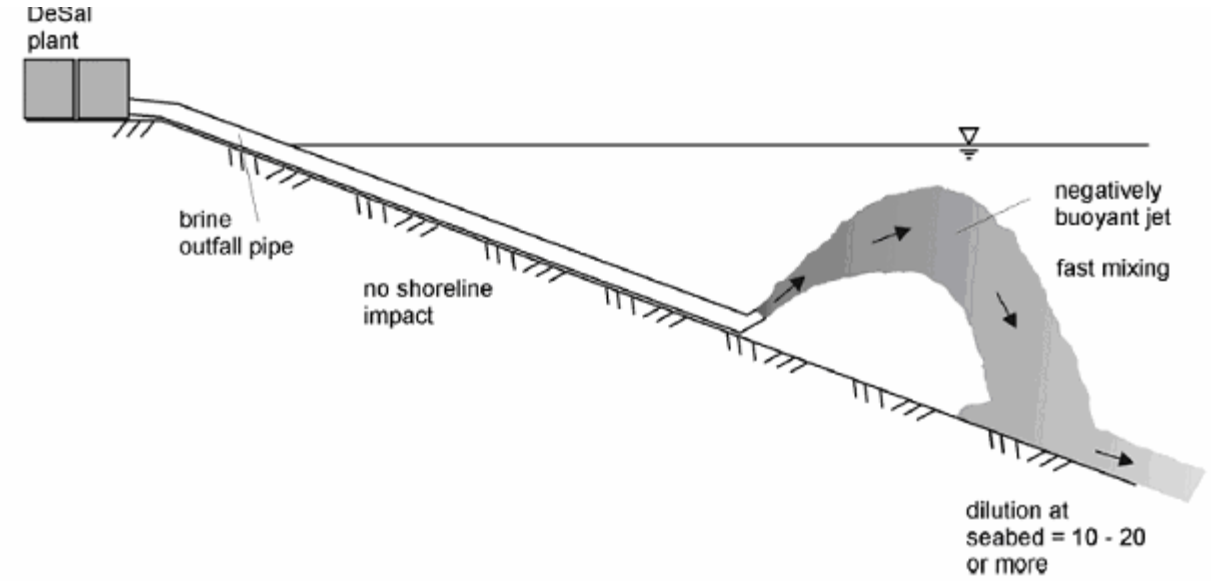


Figure 2: Décharge submergée par l'intermédiaire de canalisation et bec ou diffuseur.



2.1. Origine et type des emissions et rejets

2.1.1. Emissions atmosphériques

En général, les émissions atmosphériques des usines de dessalement consistent seulement en azote et oxygène provenant de distillation qui utilisent des procédés de désaération pour réduire la corrosion, en rejets des éjecteurs (usines MSF) ou des dégazeurs (usines OI).

En outre, la production d'énergie destinée à être dans les usines de dessalement accroît les émissions atmosphériques. Des augmentations substantielles des émissions atmosphériques peuvent également se produire si une centrale thermique ou une installation de production couplée est construite dans le cadre d'un projet de dessalement.

Une méthode permettant d'évaluer l'énergie destinée à une usine de dessalement, avec des apports thermiques par kg d'eau produite, pour des usines types, Wade et Fletcher (1995) (tableau nº1).

Table 1:

Procédé de dessalement		
Centrale associée	**MSF Cycle combiné**	**OI Cycle combiné**
Consommation de chaleur du procédé de dessalement en kJ/kg	282	-
Consommation de l'électricité du procédé de dessalement, en kWh/m^3	3,6	7,5
Energie de combustible pour la production d'eau, kJ/kg	149	75,0

Cette comparaison des besoins respectifs en énergie de ces procédés de dessalement montre que l'OI a une consommation d'équivalents énergie plus réduite que la distillation MSF.

Comme les émissions atmosphériques dues à un procédé de dessalement sont directement en rapport avec ses besoins respectifs en énergie, il va de soi que les émissions dues à l'OI sont moindres que celles dues à la MSF. L'étude d'Afgan et *al.* (1999) qui porte sur des usines de dessalement des pays de Golfe a permis de calculer des indicateurs de durabilité qui ont confirmé ce qui précède.

Table 2: Indicateurs de durabilité pour une usine MSF à production simple

Indicateur de ressources en combustible, kg combustible/m^3	11
Indicateur environnemental pour CO_2, kg CO_2/m^3	37
Indicateur environnemental pour SO_2, kg SO_2/m^3	0,09
Indicateur environnemental pour NO_X, kg NO_X/m^3	0,06

Table 3: Indicateurs de durabilité pour une usine OI avec une source locale de l'énergie électrique

Indicateur de ressources en combustible, kg combustible/m^3	1,8
Indicateur environnemental pour CO_2, kg CO_2/m^3	6
Indicateur environnemental pour SO_2, kg SO_2/m^3	0,005
Indicateur environnemental pour NO_X, kg NO_X/m^3	0,009

2.1.2. Rejets chimiques

Toutes les usines de dessalement utilisent des produits chimiques pour le prétraitement de l'eau d'alimentation ainsi que le post-traitement de l'eau produite. La plupart des produits sont utilisées avant tout comme agents biocides, antitartre, antisalissures et antimousse. La présence de certains métaux, qui sont des produits de la corrosion du circuit, influent aussi sur la composition de la saumure concentrée.

Ces produits chimiques ne sont pas les mêmes pour les principaux procédés de dessalement, à savoir MSF et l'osmose inverse. Les phases de pré- et de post-traitement des procédés de production d'eau potable sont exposées sur le tableau nº4.

Table 4: Résumé des phases de prétraitement et post-traitement au cours de la production d'eau potable par dessalement [11] (Mickley et al, 1993).

Phase de prétraitement	**Objet**	**Produits chimiques ajoutés**	**Devenir des produits**
Ajustement du pH à 7	Diminue la concentration de carbonate (et la précipitation de carbonate).Protège la membrane contre l'hydrolyse	Acide (H_2SO_4)	Modifie le p H de l'eau produite et de la saumure concentrée, le sulfate set retenu dans la saumure concentrée
Antitartre	Prévient la formation de tartre sur les membranes	Agents chélateur et dispersants	Les complexes formés sont retenus dans la saumure concentrée
Coagulation -Filtration	Prévient les salissures et l'encrassement des membranes	Coagulants –floculants	Les agents floculants formés se séparent par décantation et sont éliminés par filtration
Désinfection	Prévient l'encrassement biologique et élimine les microorganismes qui se nourrissent des matières des membranes	Chlore (ou biocide)	Chlore également réparti dans le perméat et la saumure concentrée
Déchloration	Protège les membranes sensibles au chlore	Bisulfate de sodium charbon actif granulaire (CAG)	Réagit avec le chlore pour former du sulfate et du chlorure qui est retenus dans la saumure concentrée
Elimination des gaz dissous	Elimine les gaz nauséabonds, C, le radon et Hs	Aération, Dégazage	Oxyde Hs et nH4 dans l'eau produite et dans la saumure concentrée
Phase de post-traitement	**Objet**	**Produits chimiques ajoutés**	**Devenir des produits**
Ajustement du PH à 7	Prévient la corrosion de la conduite du système de distribution, protège la flore et la faune aquatiques en cas de rejet en surface	Noah, carbonate de sodium anhydre, chaux	Accroît le niveau de sodium dans l'eau produite et dans la saumure concentrée
Désinfection	Prévient la prolifération bactérienne dans le système de distribution, protège la flore et la faune aquatique si nécessaire	Chlore	Le chlore est retenu dans l'eau produite et dans la saumure concentrée
Réduction du niveau de chlore	Elimine le chlore et d'autre oxydants	Bisulfite de sodium ou CAGE	Accroît les niveaux de sulfate et de chlorure dans l'eau produite et dans la saumure concentrée
Oxygénation	Accroît l'oxygène dissous à un niveau concourant au développement de la flore et de la faune aquatique	Aération	Accroît l'oxygène dissous dans la saumure concentrée
Elimination d'autres formes chimiques	Diminue tous les polluants susceptibles d'être présents dans l'eau produite et dans la saumure concentrée	Est en fonction des formes chimiques	

a) Produit de la corrosion

Les usines de dessalement à procédé thermique rejettent du cuivre, du nickel, du fer, du zinc et d'autres métaux lourds en fonction des alliages présents dans la filière de production, comme par ex. le titane [15]. En termes de concentrations, celles du cuivre et du fer sont les plus élevées [9].

b) Agents antitartre

Les dépôts de tartre se forment sur les surfaces du matériel de dessalement. La présence de tartre entraîne immanquablement des difficultés d'exploitation et/ou de perte de rendement. Les additifs antitartre le plus largement utilisés semblent être des polymères de l'acide maléique [17]. Ces polymères empêchent les matières dissoutes de précipiter, décanter et former une croûte sur les surfaces.

c) Agents antisalissures

Les salissures constituent un processus à phase multiples dans lequel interviennent de nombreux groupes d'organismes. Elles commencent par l'adsorption de substances polymères de l'eau non traitée sur les surfaces solides, ce qui permet la formation d'un film précurseur pour la colonisation par des bactéries.

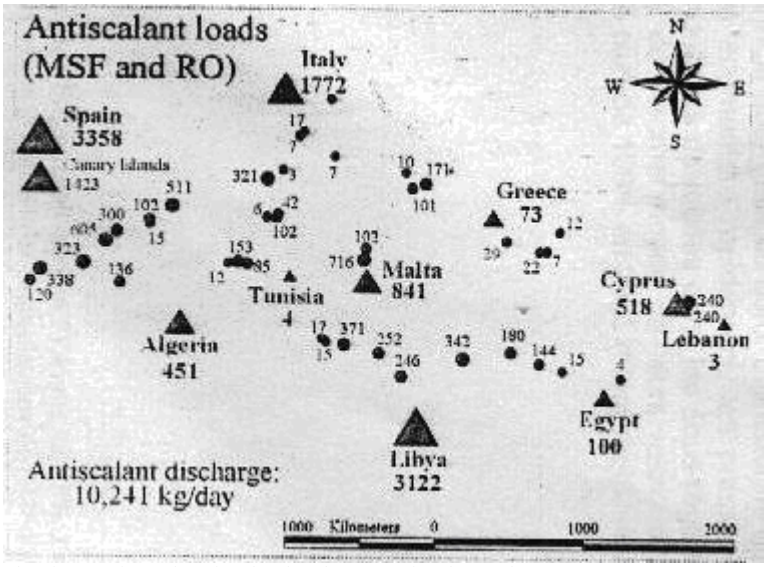
Depuis longtemps, les composés de chlore sont utilisés pour désinfecter les systèmes d'apport d'eau de mer et l'usine située en amont, afin de prévenir les salissures.

d) Agents antimousses

La mousse produite par l'eau de mer aux étages du procédé de distillation multiflash est imprévisible mais a tendance à poser un problème plus grave quand les séparateurs sont proches de la surface du courant de saumure, ce qui ne permet de séparer qu'un volume réduit en phase aqueuse et la phase vapeur.

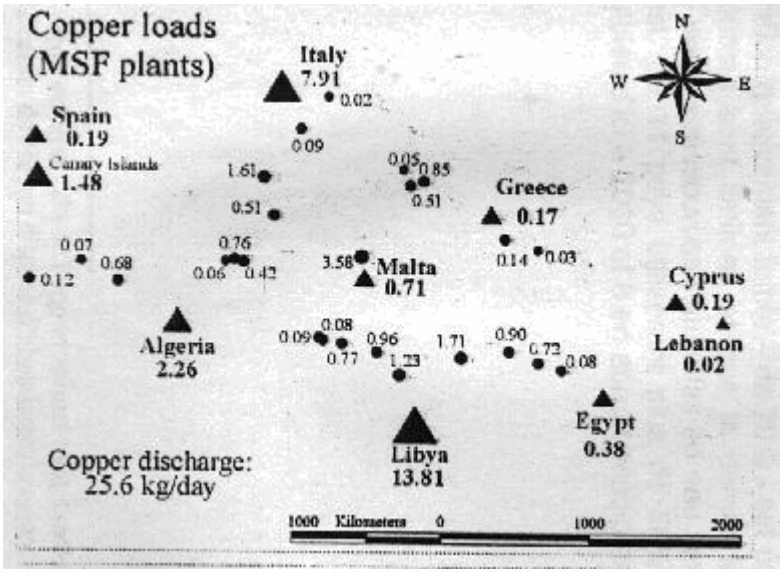
Les agents antimousses sont habituellement des polyglycols alkyles, des acides gras et des esters d'acides gras. Les agents sont tension- actifs à l'interface eau- vapeur et empêchent la formation de mousse. La formation de mousse est une fonction des constituants organiques de l'eau de mer qui sont principalement des produits d'excrétion et de dégradation d'algues planctoniques.

Figure 3: Estimation des rejets des agents Antitartre dans la méditerranée (en kg/jour).



*Les points indiquent les charges de rejet par site, et les triangles, les charges nationales totales [18].

Figure 4: Estimation des rejets de cuivre Dans la méditerranée (en kg/jour)



*Les points indiquent les charges de rejet par site, et les triangles, les charges nationales totales [18].

e) La saumure concentrée

Avec le procédé MSF, un taux de récupération habituel sur la base de l'eau d'alimentation est de 10% et la salinité de la saumure concentrée est donc 1,1 fois plus élevée que celle de l'eau d'alimentation. Le concentré est généralement dilué par deux avec l'eau de refroidissement avant d'être rejeté, et par conséquent le facteur de concentration est de 1,05, ce qui réduit les impacts sur l'environnement.

Avec le procédé OI, le facteur de conversion varie de 30 à 70%. Dans ce cas la salinité du concentré est de 1,3 à 1,7 fois plus élevée que celle de l'eau d'alimentation. Si l'on admet une salinité type de 39 ‰ pour la Méditerranée oriental, cela signifie que la saumure issue des usines OI varie en moyenne d'environ 51 à 66 ‰.

La composition chimique de la saumure rejetée par rapport à celle de l'eau de mer d'alimentation dans le cas des unités de dessalement OI des îles Canaries est reproduite sur le tableau n°5 [22]. La salinité totale de la saumure est de 63,8, contre 38,95 pour l'eau d'alimentation, soit un rapport saumure/eau d'alimentation de 1,64.

Figure 5: Usine d'Al Ghubrah (plus grande en Oman, capacité de production 191,000 m3/j): Décharge de saumure par un canal ouvert au Golf d'Oman (photo: H.H..Al-Barwani).

Figure 6: Rejet de l'usine de dessalement d'eau de mer d'Al-Doha, Koweit. Après le traitement, la saumure concentrée est rejetée en mer où, dessinant l'image d'un monstre tentaculaire [8].

Table 5: Composition chimique de la saumure concentrée par rapport à celle de l'eau de mer (Données analysées dans des échantillons provenant d'usines OI des iles Canaries) [22](D'après Zimmerman, 1999).

Analyse	Eau d'alimentation mg/l	Saumure mg/l	Rapport Saumure/Eau d'alim-
Ca^{++}	962	1.583	1,64
Mg^{++}	1,021	1,09	1,87
Na^{+}	11,781	19,346	1,64
K^{+}	514	830	1,61
NH_4^{+}	0,004	0,005	1,25
HCO_3^{-}	195	256	1,31
CO_3^{-}	/	/	/
SO_4^{-}	3,162	5,548	1,75
Cl^{-}	21,312	43,362	2,03
F^{-}	1,5	1,9	1,26
NO_3^{-}	2,6	4	1,54
PO_4^{-}	0,08	0,4	5
NO_2^{-}	0,03	0,05	1,67
Dureté totale en CaCO	6,600	11,800	1,78
Salinité totale (TSD)	38,951	63,840	1,64
Fe^{***}	0,04	0,05	1,25
Al^{+++}	0,001	0,007	7
PH	6,33	6,26	NA
Conductivité	46,200	75,300	NA

f) Rejet des eaux de lavage à contre-courant des membranes dans les usines OI

Dans les usines OI, le nettoyage des membranes peuvent engendrer des eaux potentiellement dangereuses. Les membranes doivent etre nettoyées à des intervalles de trois à six mois en fonction de la qualité de l'eau d'alimentation et du fonctionnement de l'usine. Les formulation utilisées pour le nettoyage de membranes sont habituellement des solutions alcalines ou acides aqueuses. Ces produits chimiques sont normalement épurés avant leur rejet dans la mer [7].

2.2. Impacts Sur L'environnement

Un grille présentant les impacts néfastes sur l'environnement assocés aux procédés de dessalement est donné sur le tableau nº6. Selon ce tableau, les impacts les plus prononcés sont dus aux produits chimiques qui favorisent les phénomènes d'eutrophisation dans les eaux réceptrices.

Table 6: Grille d'impacts néfastes sur l'environnement associés aux procédés de dessalement [2](D'après Abu Qdais,1999)

Impact	Degré d'impact	Origine de l'impact
Pollution thermique: Réduction de l'oxygène dissous dans les eaux réceptrices Effets nocifs pour les espèces thermorésistantes	 M M	Saumure chaude
Salinité accrue: Effets nocifs pour les espèces résistantes aux sels	 M	Saumure concentrée
Désinfectants	E	Chlore et ses composés Réaction du chlore avec des composés organiques-hydrocarbures principalement
Métaux lourds: Toxicité	 M	Corrosion du materièl de l'usine
Produits chimiques: Eutrophisation des eaux receptrices Toxicité Hausse de PH	 E F F	Adjonction d'agent anticorrosion et antitartre
Pollution atmosphérique: Plus acide Effet de serre Poussières	 F M M	Utilisation de combustibles et activités d'élimination
Sédiments: Turbidité et limitation dela photosynthèse Difficultés de respiration chez les animaux aquatiques	 M M	Perturbation des sables par des activités d'excavation et de dragage
Bruit	F	Activités de construction. Pompes et autres appareils au cours de l'exploitation de l'usine

E- Impact de degré élevé, M- de degré moyen, F- de degré faible.

La réduction de l'oxygène dissous dans les eaux réceptrices par suite du rejet de saumure chaude et les effets nocifs pour les espèces résistantes aux sels sont caractérisés comme étant des impacts de degré moyen. La turbidité accure et la limitation de la photosynthèse par suit de la perturbation des sables due aux activités d'excavation et de dragage sont caractérisées comme des impacts de degrés moyen. La la toxicité due aux produits chimiques est caractérisée comme étant un impact de degré faible.

2.2.1. Effets dus aux produits de la corrosion

Les usines de dessalement par distillation rejettent des métaux tels que le cuivre, le nickel, le chrome et zinc dans le milieu marin.

Ces métaux ne se trouvent pas à l'état d'ions libres mais forment des complexes inorganiques et organiques qui sont adsorbés sur les matières en suspensions et déposent en s'accumulant dans les sédiments. Comme, dans ce cas, le problème ne réside pas dans la concentration effective du métal mais dans sa charge totale atteignant l'environnement, on ne peut pas atténuer les effets endilluant le rejet [18].

2.2.2. Effets dus aux additifs antitartre

Les produits utilisés contre l'entartage sont les phosphates polymères. Dans une zone marine oligotrophe comme la mer méditerranée, le rejet de ces produits peut avoir des effets drastiques tels que des efflorescences algales, des proliférations d'algues macroscopiques, etc. Ces dernières anneés, les agents antitartre les plus utilisés ont été les polymères de l'acide maléique pour empecher l'apparition d'effets eutrophisants.

2.2.3. Effets des additifs antisalissures

Si le chlore est un agent antisalissures à large spectre, il présente aussi des effets étendus sur le milieu marinquand il est rejeté avec la saumure. Il occasionne des effets biologiques par son action stérilisante intrinsèque et des effets chimiques en halogénant les constituants organiques de l'eau de mer [9].

2.2.4. Effets des additifs antimousse

Les agents antimousse sont des détergents. Les détergents ont des effet nocifs sur les organismes en altérant le système membranaire intracellulaire.

2.2.5. Effets du concentré (saumure)

La saumure exerce le plus fort impact sur le milieu marin.Le volume total de saumure libéré dans ce milieu est déterminant pour les dommages qu'il peut induire.

A part le volume proprement dit, les modalités et l'emplacement du rejet sont essentiels pour les impacts qui peuvent en resulter. La longueur de l'émissaire, sa disatnce au rivege, son niveau au-dessus du fond de la mer, l'existance ou non d'un diffuseur, ainsi que la profondeur de l'eau et les caractéristiques hydrodynamiques (courants, vagues,…) peuvent conditionner la dispersion de la saumure et l'efficacité de la dillution au point de erjet et, par voie de conséquence, l'impact potentiel sur l'environnement.

Par exemple, à l'usine de dessalement de Dhekelia (Chypre), qui a une capacité de production de 40 000 m3/jour, la saumure, d'une salinité d'environ 72 ‰, est rejetée dans la mer par un émissaire doté à son extrémité d'un multidiffuseur, à une profondeur d'environ 5 m et une à distance de 250 m du rivage; il en resulte un accroissement de la salinité dans un rayon de 200 m à partir du rejrt. De fait, la plus forte salinité (≈ 54 ‰) a toujours été décelée au point de rejet et était possible de relever une salinité supérieure à celle de l'eau de mer (≈ 39 ‰) jusqu'à 200 m du rejet.

La zone d'impact présentant une forte salinité varie selon la saisaon, l'impact le plus marqué se produisant durant les mois d'été [5].

Le tableau ci-dessous récapitule les effets de solutions sodées hypertoniques sur les organismes marins côtiers [18]:

Table 7:

Survie et éclosabilité	Sans effet ‰	Sensibilité ‰	Salinité létale initiale ‰
Survie de juvéniles de pagel	<45	50: changement de coloration de l'organisme	50
Survie de larves de flet	<50		55
Eclosabilité d'œufs de flet	<40	50-55: léger retard de développement; 60: retard de développement	70
Survie de praires	<50	60-70: pas de protrusion du siphon	60
Juvéniles de pagel	<40	45: apparaît assez souvent 50: ne dure que quelques dizaines de secondes	70

Conclusion

Bien que le dessalement de l'eau de mer soit une industrie en développement dans de nombreux pays du monde, on ne dispose que d'un très petit nombre d'études sur les impacts que cette activité exerce sur le milieu marin. Ces impacts vont du changement de l'occupation du sol, les nuisances sonores aux rejets dans l'eau, émissions dans l'atmosphère et dommages potentiels pour le milieu récepteur. Les principaux procédés de dessalement de l'eau de mer, MSF et OI, diffèrent par le type de leurs impacts. Dans le cas du procédé MSF, les principaux impacts sont la chaleur, les effluents thermiques et le rejet de métaux comme Cu, et Zn, alors qu'avec OI c'est la salinité élevée de la saumure concentrée (1,2 à 3 fois supérieure à la salinité de l'eau d'alimentation).

Un procédé de dessalement nécessite un apport d'énergie thermique ou mécanique, laquelle, à son tour, se traduit par une élévation de la température des effluents de saumure concentrée. Au cours du pré-traitement et du post-traitement qui interviennent lors du processus de dessalement, sont ajoutés un certain nombre de produits chimiques tels qu'agents antitartre, désinfectants, agents anticorrosion et antimousse. Une partie de ces produit ou de leurs dérivés peuvent être rejetés dans la concentré de saumure. Leur ajoit doit être soumis à des conditions bien définies afin d'éviter leurs impacts sur le milieu marin.

L'une des rares études menées à cet égard en Méditerranée a concerné les effets de l'usine de Dhekelia (Chypre) sur la macrobenthos des eaux cotières attenantes. Il en ressort que la saumure, d'une salinité de 72 ‰, entrainait une augmentation de la salinité dans un rayon de 200 m du point de rejet. Des modification notables du macrobenthos ont été relevées à proximité du rejet de la saumure. A proximité de l'usine OI, TIGNE de Malte, des effets ont également été observés sur la croissance des algues.

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Domination in Communication and Knowledge the Problem of Regionalism in Canada

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Abstract

This article is concerned with the direction communication is taken in our times. Specifically, how the communicative techniques and technology have a fundamentally profound influence on our consciousness of the existing reality and the way we perceive the world. It will examine the fact that through our consciousness, communication shapes both our knowledge of the world as content and the systems by which we appropriate knowledge of it as a *form.* That is, the epistemological reality by which we apprehend the world and ourselves as *ideology.* Moreover, the technology of communication has been indirectly responsible for the growth and development of a consciousness and worldview in the Canadian mind, particularly of the specific experience which is expressed as regionalism.

1. Introduction

The imaginary landscape of Canada is probably the most familiar while at the same time the least known to its own citizens. Any enquiry about the historical formations would more than likely produce either bewilderment or faint ennui, signifying unawareness of both what it has been and what it is. It comes as no surprise that any national crisis becomes exacerbated by this very ignorance and results in the utmost reactionary tendencies. Yet this is in spite of the reality of being surrounded continuously by the "simulacrum"[1] of artifices of the imaginary landscape. The base of this landscape is communication, and the technology of the time to communicate.

The more current theoreticians of communication, in particular Mcluhan, promote a cultural approach. However, the study of communication theory is in itself an epistemological activity, while curiously enough both the techniques and the technology of communication tend to shape the specificity of knowledge and epistemology itself. The economic historian Harold Innis noted that Canada was formed as a nation-state precisely because of communication. Without the dialectical tension of center-periphery, of center versus region, and of finance versus resource capital interests the modern state and its attendant national activities would not have been produced.

This paper will contend that communication techniques and technology have a fundamentally profound influence on the way we perceive the world and as such our consciousness of the world. Further, that through our consciousness communication shapes both our knowledge of the world as *content* and the systems by which we appropriate knowledge of it as a *form.* That is, the epistemological reality by which we apprehend the world and ourselves as *ideology.* Moreover, that communication technology has been indirectly responsible for the growth and development of a

[1] Kroker A. *Technology & the Canadian Mind*, New World Perspective, Montreal, 1985, p. 18.

consciousness and worldview in the Canadian mind. Particularized in the specificity of experience for and expressed as regionalism.

2. The Essence of Communication and Domination

Communication is to be found in any activity related to the human interaction. It is an activity most notably connected with language as the basis of all communicative techniques and technologies. Innis suggests "that western civilization has been profoundly influenced by communication and that marked changes in communication have had important implications".[2] It is from these implications that Innis traces the historical developments and influence of various mediums of communication on the shape and scope of knowledge, and the degree to which it was monopolized and oligopolized by specific institutional and class interests.

Innis traces this development through the two most basic language traditions open to human activity, the oral and written traditions. The oral and written traditions carry different orders of communication, and by virtue of the medium of communication different orders and systems of knowledge. In turn, these different systems of knowledge influence the shape of social relations. Hence, our world-view seems to be shaped by and reflected in the system of communication. In other words, it shows that our consciousness is primarily determined by the type of communications and systems of knowledge that form in part, our social and intellectual environment.[3] Innis writes: "an oral tradition implies freshness and elasticity but students of anthropology have pointed to the binding character of custom in primitive cultures. A complex system of writing becomes the procession of a special class and tends to support aristocracies. A simple, flexible system of writing admits of adaptation to the vernacular but slowness of adaptation facilitates monopolies of knowledge and hierarchies".[4]

However, he also comments that a written tradition has deep implications on the *techne* of civilization; that is, both the techniques of structuring knowledge and the technology produced in and from it.[5] The author George Grant, states here the classical ontological assertion that particular technique is our selves. All descriptions or definitions of technique that place it outside our selves hide from us what it is. This applies to the simplest accounts which describe technological advance as new machines and inventions as well as to the more sophisticated which include within their understanding the whole hierarchy of interdependent organizations and their methods. Technique comes forth from and is sustained in our vision of our selves and conquering the chances of an indifferent world. He continuous suggesting that, "reading in contrast with writing implies a passive recognition of the power of writing".[6] The technology of communication imposes its own structural alignment on civilization, and writing in particular imposes a lineated structure and strict logic (i.e. grammar, syntax) on the development of language, and subsequently on the order of knowledge. Historically, Innes contends, the development of monopolies and oligopolies of knowledge have usually experienced destabilization as the skill of writing becomes more accessible and creates interest in learning. However, an interest in learning spreads it "assumes a stable society in which organized force is sufficiently powerful to provide sustained protection. Concentration on learning, "implies a written tradition and introduces monopolistic elements in culture which are followed by rigidities and involve lack of contact with the oral tradition and the vernacular".[7]

Innis goes on to establish a principle that any concentration of communicative *techne*, along with the monopolizing of knowledge, will result in "a weakening of the relations between organized force and the vernacular and collapse in the face of technological change which has taken place in

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[2] Innis H. *The Bias of Communication*, University of Toronto Press, Toronto, 1951, p. 3.
[3] Barnes Barry, *Interests & the Growth of Knowledge*, Routledge & Kegan Paul, 1977, p. 16.
[4] *The Bias of Communication*, op. cit. p. 4.
[5] Grant G. *Technology and Empire*, House of Anansi, 1969, p. 137.
[6] Idid, page 4.
[7] Ibid, p. 4.

marginal regions which have escaped the influence of a monopoly of knowledge".[8] In short, the peripheral regions of knowledge are bound to escape the immediate appropriation from the center. At the center, knowledge becomes bound to a rigid formalism that structures on the bias of ideology. Even the system of compartmentalizing and categorizing reflect ideological priorization and orders knowledge accordingly.

The experience of modernity, Foucault has noted, has structured and restructured knowledge, perception, and interpretation according to systems biased in favor of empirical and rationalist modes of reason (positivism) that tend to dominate epistemological thinking.[9] Knowledge at the margins of civilization, on the other hand, tends to be less rigid, dogmatic, and formalist, reflecting a more open and dynamic exchange and development in both range and content of ideas. Central to the success of a dominant epistemological order, as Innis noted, is the use of force in imposing a dominant ideology. But this success is tied to a depended on an effective combination of the oral tradition and the vernacular in public opinion with technology and science".[10] Any group, totality or society, when effectively dominated, especially within the constellation of a new order of things, "becomes receptive to cultural importation".[11] Innis then notes that language, in particular its written form, develops as a result of changes and developments in the technique of communication,[12] and that any destabilization produced by the medium of communication is bound to result in legal and political orientation and realignment as a response force.

Going back to the fundamental differences between the written and oral traditions, Innis writes that the "oral tradition emphasized memory and training".[13] This implies emphasis on the custom of social respect for older members of society, the accumulated wisdom of their years, and the conventions of knowledge associated with memory and custom. It also implies a common-sense view of the world; that is things were assumed to be self-evident, obvious, given and not to be questioned. With Plato's introduction of critical philosophy,[14] and its main technique of negative dialectics, the oral tradition, experienced the first attack to its epistemological legitimacy. The written tradition added to the process of undermining the validity of the spoken word, questioning the basis of its knowledge foundation, thus questioning the entire order of things associated with the oral tradition. At the same time the community spirit lived within the spoken word was liquidated by the privacy of the written word, and subsequently resulting in the rise of the individual ego.[15] Innis notion here regarding the writing and memory is important. He mentions that following the invention of writing the special form of heightened language characteristic of the oral tradition and collective society gave way to private writing. Records and messages displaced the collective memory.[16]

The written word imposed rigidity of structure and logic, and, to Innis, it forced consensus (i.e. homogeneity of values and beliefs). The printed word completed the process of liquidating the values of the spoken word, at the same time liberating knowledge from the hands of monopolistic and oligarchic structures through the mass production of written material. It is interesting to note that the rise of liberal theories of individualism coincided with the development and spread of moveable type printing. As a result human perceptions experienced change, and consequently the order of knowledge reflects this change.[17]

The other side of the oral-written tradition is language. Language forms the base of all civilizations, and, to the extent that humans are conscious and reach self-consciousness, it forms the centre of all ontological considerations. Language is the vehicle by which technology and technique are transferred and available from one culture- society to another. At the same time it facilitates the pace of

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[8] Ibid, p. 4.
[9] Foucault M. *The Order of Things*, Vintage Books, 1973.
The Archaeology of Knowledge, Pantheon Books, 1972.
[10] The Bias of Communication, op. cit. p. 5.
[11] Ibid, p. 5.
[12] Ibid, pp. 6-7.
[13] Ibid, p. 9.
[14] Laclau Ernesto, Politics and Ideology in Marxist Theory, New Left Books, 1977, p. 7.
[15] Innis H. *Empire and Communications*, Press Porceric, 1986, page 8.
[16] Ibid, pp. 8-9.
[17] Innis H. The Bias of Communication, op. cit. p. 9.

change and adjustments, especially in the onto-epistemological order of things. The author suggests that, "pervasiveness of language becomes a powerful factor in the mobilization of force particularly as a vehicle for the diffusion of opinion among all classes. Language, exposed to major incursions become more flexible, facilitated movement between classes, favored the diffusion of technology, and made for rapid adjustment".[18]

Another major technological consideration of knowledge is the separation of knowledge from the form as he assures further. The weakness of oral based civilization is to be found in the oral tradition. As he puts it appropriately, "richness of the oral tradition made for a flexible civilization but not a civilization which could be disciplined to the point of effective political unity".[19] For example, the incursion of Europeans to North America destabilized the oral traditions of Indian culture and custom since it was flexible but not disciplined enough to withstand the bludgeoning of European culture, organization and institutionalization as rooted in the written tradition. In other words, the separation of knowledge and form has had profound implications in the development of civilization and communication.

Knowledge becomes the activity of knowing purely for itself, as a theory,[20] whereas form commodifies knowledge, transforming it into object for exchange, but exchange as a means to an end. As means it is transformed into information, and as information it is consigned to use value. In other words, that particular object has no meaning outside of its value for the exchange, trade, acquisition and appropriation of other commodities. Hence knowledge is reified. Truth becomes a temporal moment privatized as a subjective experience rather than collectively as an objective reality. In the modern and post/modern epochs information has become an object pursued almost dialectical tensions of centre-periphery and restructuring the epistemological landscape in a totality of what Arthur Kroker perceives as all "peripheralized".[21]

Innis notes that variable rates of development make it difficult to reason out the communicative and technological accomplishments of civilization. "Improvements in communication, he states, make for increased difficulties of understanding. The cable compelled contraction of language and facilitated a rapid widening between English and American languages".[22] As such the rate of change in technology and communication would vary, depending on cultural orientation. The economic application of communicative techniques and technology in the early stages of the Industrial Revolution "hastened the spread of compulsory education and the rise of the newspaper, and intensified interest in vernaculars, in nationalism, and in romanticism".[23]

The Industrial Revolution introduced more and more complex technology that increasingly required a more educated labor force to run the machinery, thus promoting the necessity for mass public education. With an educated labor force there is a massive increase in the percentage of the population that is literature, and with literacy is the increased viability to market products, hence the need for newspapers as the medium to advertise. Newspapers originated as broadsides and with advertising became ventures for legitimating specific class interests (both economic and political).

In terms of interests newspapers were no doubt responsible for the spread of nationalist sentiments and imperialist desires, and in the expressed laments of bourgeois sentiments for simpler age found in communion with nature. The rise of romanticism indicated to Innis that mechanized 'communication divided reason and emotion and emphasized the latter'.[24] This division isolated and neutralized reason as an academic preoccupation and made emotions the dominant connective of industrialized social relations. With a population that is literature but ruled by their emotions it leaves them open to the machinations of manipulation and deception. Once again knowledge is reified

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[18] Ibid, p. 11.
[19] Ibid, page 10.
[20] Habermas J. Knowledge and Human Interests, Beacon Press, 1971, p.310.
[21] Kroker A. Technology and the Canadian Mind, New World Perspectives, Montreal, 1985, p. 129.
[22] Innis H. op. cit. p.28.
[23] Ibid, p. 30.
[24] Ibid, p. 30.

through the use of industrialization, at the same time it becomes peripheralized. The centre becomes power, and the sole object to life becomes the materialist ideal of the 'will to power'.

Printing facilitated the transmission of information concerning technological innovation. Innis states, that "printing marked the first stage in the spread of the Industrial Revolution".[25] He sums this up very succinctly: "The Industrial Revolution and mechanized knowledge have all but destroyed the scholar's influence. Force is no longer concerned with his protection and is actively engaged in schemes for his destruction. Enormous improvements in communication have made understanding more difficult. Even science, mathematics, and music as the last refuge of the Western mind have come under the spell of the mechanized vernacular. Commercialism has required the creation of new monopolies of language and new difficulties in understanding".[26]

At each historical stage of development the communicative calculus differentiates into new and still newer and more complex arrays of technology and technique. The pressures of change reify knowledge and form, and reason and emotion even further, yet demands its very contradiction, that of integration. At the same time the rate of change increases exponentially while it also processes knowledge as prepackaged information, subject to the fashions of immediacy (instant) and obsolescence (taste). As the technology of communication changed there was also a corresponding change in the techniques. The mediums of communication reflected this change. The change from papyrus to parchment and then to paper, carries with it fundamental implications. The techniques in the production of papyrus, parchment and paper reflect the change in technology, and vice versa. The change in one leads to a change in the other. Further, the type of medium determines the availability of knowledge.

Paper, for example, was an essential technology for the creation of moveable type and the spread of the printed word. The medium prejudices both the availability (dissemination) and structure of knowledge.[27] Innis correctly states, "our knowledge of other civilizations depends in large part on the character of the media used by each civilization in so far as it is capable of being preserved or of being made accessible by discovery as in the case of the results of archaeological expeditions".[28]

To summarize, knowledge becomes dependent on the type of medium of communication used by civilizations, and in turn this influences the consciousness of a civilization. Consciousness will evaluate the world and social formation from the standpoint of the dominant communicative techne; that is, the values and beliefs operating within the context of a society. As such, the world according knowledge systems current to it, knowledge systems will be determined according to the communications medium, the communications medium as the product of technology and technique, which is shaped and developed by consciousness and attendant knowledge systems. However, Innis study of bias in communication observes disturbing developments of technological influences on culture and the psychology of society/civilization.

His main concern is with the change in "attitudes toward time preceding the modern obsession with present mindedness, which suggests that the balance between time and space has been seriously disturbed with disastrous consequences to Western civilization. Lack of interest in problems of duration in Western civilization suggests that the bias of paper and printing has persisted in a concern with space. The state has been interested in the enlargement of territories and the imposition of cultural uniformity on its problems, and, losing touch with the problems of time, has been willing to engage in wars to carry out immediate objectives. Printing emphasized vernaculars and divisions between states based on language without implying a concern with time. The effects of division have been evident in development of the book, the pamphlet, and the newspaper and in the growth of regionalism, as new monopolies have been built up".[29]

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[25] Ibid, p. 30.
[26] Ibid, pp. 30-31.
[27] Ibid, page 33.
[28] Ibid, page 33.
[29] Ibid, pp. 76-77.

Innis noted that communication created spatial divisions where it became difficult to establish political stability.[30] Instead, increased communication, (for example newspapers), organized into monopolies of biased value dissemination, and largely "based on the eye hastened the development of a competitive type of communication based on the ear, in the radio and in the linking of sound to the cinema and to television. Printed material gave way in effectiveness to the broadcast and to the loudspeaker".[31] This implies several features. As a result of sound and visual communications geopolitical boundaries became largely irrelevant.

Political appeal can be made directly through new mediums of communication, such as radio and television, reaching larger numbers of people, and threatening politics based on literacy (i.e. the printed word) since audiovisual means of communication did not require literacy. As Innis comments at this point, "political boundaries related to the printing industry disappeared with the new instrument of communication. The spoken language provided a new base for the exploitation of nationalism and a far more effective device for appealing to larger numbers. Illiteracy was no longer a serious barrier".[32] Hence the re-emergence of the spoken word, the diminishing of the printed word as the **logos** of organizational and institutional thinking.

Illiteracy and the spoken word open the conundrum of propaganda and deception. In short, the manipulation of values, beliefs, attitudes, and perceptions. In turn this influences the order of knowledge and memory. If knowledge is open to manipulation, then, reality becomes of a 'will to power'. Modern communicative techne has begun the move toward a post-literate society, and has raised the possibilities of delusion".[33] How the study of technology and communication open serious venues into ways of understanding the Canadian mind, and the way this influences regionalism, will be examined in the next section.

3. Theory of Regionalism in Canada

The "Canadian imagination, Kroker A. states, is situated midway between the future of the new world and the past of European culture, between the rapid unfolding of the 'technological imperative' in America empire and the classical origins of the technological dynamo in European history".[34] In short, the Canadian mind is "in-between" the superficiality of American empirio/cultural encroachments[35] and the indifference of the dead weight of European memory.

The dilemma of the Canadian mind faces an unalterable situation. He contends that, "it is our fate by virtue of historical circumstance and geographical accident to the forever marginal to the 'present-mindedness' of American culture (a society which specializing as it does in the public ethic of 'instrumental activism' does not enjoy the recriminations of historical remembrance); and to be incapable of being more than ambivalent on the cultural legacy of our European past. At work in the Canadian mind is, in fact, a great and dynamic polarity between technology and culture, between economy and landscape. And this dialectical movement between the power of American empire and our bitter historical knowledge that the crisis has its origins much deeper in European culture is the gamble of the Canadian discourse on technology".[36]

It is in this dialectical tension that meaning and difference are formed as the means of establishing identity. Canada faces the high anxiety over the illusive belief (self-delusive) in a national identity. The great accomplishments of this nation have been glossed over for want of an ontological myth. Yet our identity is rooted in our duality, of difference and understanding [37]as they work themselves out through techniques of survival. These differences express themselves in topographical terms, namely regionalism.

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[30] Ibid, page 78.
[31] Ibid, page 81.
[32] Ibid, page 81.
[33] Ibid, page 82.
[34] Kroker, op. cit. page 7.
[35] Innis H. op. cit. page 82.
[36] Kroker A. op. cit. page 8.
[37] Habermas J. Communication and the Evolution of Society, Beacon Press, 1979, page 3.

Janine Brodie has mentioned that, "regionalism is a socio-psychological factor that involves the identification with and commitment to a territorial unit. Regionalism also contains concrete political and social dimensions that are deeply embedded in collective historical experience".[38] According to Gibbons R. regionalism implies the 'spatial organization of values or behavior' more so than explicitly along geographic orientation.[39] The author takes the behavioral approach to regionalism; contending early community development has been seriously eroded by the post-war experience of rapid 'social change', namely modernization. He asserts that, "in the contemporary society social change, much of it technological in character, has eroded the previous isolation and has fostered the spread of a more homogeneous national culture largely oblivious to regional distinctions".[40]

Indeed, there is L. Armour's interpretation that regionalism is largely a state or condition of consciousness rather than of place. It is more a product of an imaginary landscape, derived from what he suggests are transcendental experiences, which in turn are etched into the Canadian consciousness. Moreover, that as a nation Canada consists of a multiplicity of communities, each with their own unique conditions and experiences that shape their particular community and regional consciousness. Armour's interpretation incorporates some aspects of both Brodie's and Gibbins approaches. Like Gibbins, Armour notes the postwar influence of multinational and transnational corporation that of no community allegiance and a homogenizing affect on culture.

This homogenization produces alienation, and as consequence "compels a search for meaning"[41] that ends with the locus of regional identification invested in geopolitical institutions. Hence, modern regionalism is largely understood as provincial in identification, with some variation played out with regard to the Maritime-Atlantic and Prairie provinces sometimes acting collectively. In the case of regionalism a consciousness has developed around its geopolitical institutions that can be appropriately described as ideological in scope. As mentioned earlier, Innis saw communication as largely responsible for the political divisions that lead to regionalism, but the effect has been cumulative. From his famous study of the fur trade Innis came to the conclusion that the "economic history of Canada has been dominated by the discrepancy between the centre and the margin of Western civilization".[42]

It is, as he interprets, a dialectical tension from the interplay of stables region and manufacturing centre that influences the geopolitical configuration of Canada. As Innis noted, "it is no mere accident that the present Dominion coincides roughly with the fur-trading areas of northern America".[43] And that the basic stables industries were largely responsible for the centralized organization, which in turn gave Canada the necessary institutional framework to expand territorially.[44]

However, from the regional standpoint, expansion brought technology, which has had both positive and negative impacts upon the regional consciousness. The experience of modernity has produced a series of paradoxical circumstances which Arthur Kroker views as transforming the imaginary landscape of our desires and fears, For example, prison cells and pleasure places, of secrets and anxieties as those experiences both Orwellian and hopelessly utopian.[45] In other words, paradoxical circumstances as of a society with twenty-first century engineering, but nineteenth century perception'.[46] It may be this incongruous tension that produces the ideological contradictions of regionalism, or even ethno-cultural homogeneity that accounts for the social and political elements of intolerance for difference.

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[38] Brodie Janine, *The Political Economy of Regionalism*, in the book Wallace Clement & Glen Williams, The New Canadian Political Economy, McGill-Queens University Press, 1989, page 139.
[39] Gibbins Roger, Prairie Politics and Society: Regionalism and Decline, Butterworth, 1980, Page 6.
[40] Ibid, pp. 7-8.
[41] Leslie Armour, The Idea of Canada and the Crisis of Community, Steel Rail Publishing, 1981, page 33.
[42] Innis H. *The Fur Trade in Canada*, University of Toronto Press, Toronto, 1956, page 385.
[43] Ibid, page 392.
[44] Ibid, page 396.
[45] Kroker A. op. cit. page 125.
[46] Ibid, page 127.

4. Conclusion

As an inference, it is possible for someone to think and take regionalism as a reaction. But reaction at a level that is responsive to the reasonless ness and emotionalism of its audience. This is certainly true for most regions in Canada when it comes to criticizing the federal government. If anything can be noted it is that regionalism at its best answers the needs of communities through the use technology, and at its worst exploits community fears, anxieties, and ignorance for the sake oligarchic political ambitions. Communications has put the ideas of Canada into everyday language, and has brought regions and communities together with more self-assured identities.

However, those very communicative links have recently experienced a curtailment that threatens to fragment and alienate communities and regions. If the Canadian mind is to grow, there must be a continuous advancement of communicative links toward the maintenance and growth of a place with 'no centers and no margins', just a technological society of where everyone is 'peripheralized'.[47] Instead, the decent red centre has decided to turn away from effective communicative links and attempt to conjure-up a pre-war world of nightmarish proportions. Such a vision can only lead to political tragedy and result in breaking the already fragile positive and constructive links between regions.

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[8] Habermas Jurgen, *Knowledge and Human Interests*, Beacon Press, Boston, 1971.
[9] Innis H. *Empire and Communication*, Press Porcepic, Toronto, 1986.
[10] Innis H. *The Fur Trade in Canada*, University of Toronto Press, Toronto, 1956.
[11] Innis H. *The Bias of Communication*, University of Toronto Press, Toronto, 1951.
[12] Kroker Arthur, *Technology and the Canadian Mind*, New World Perspectives, Montreal, 1985.
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[47] Ibid, page 129.

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Heavy Metals in Alkaline and Zinc-Carbon Dry Cells as Pollution Indicators of Spent Batteries

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Abstract

Alkaline and zinc-carbon batteries readily available in Nigeria were collected, dismantled, and separated into the anode and cathode and analyzed for lead, cadmium and copper by flame atomic absorption spectroscopy after acid digestion with 1:1 HNO_3/H_2O_2. The mean values for, Pb, Cd & Cu obtained in the anode; 2698mg/kg (range <10-6600mg/kg), 166mg/kg (range <5-518 mg/kg) and 133 mg/kg (range 13.3-423 mg/kg) respectively were higher than the corresponding values for the cathode; 570mg/kg (<10-2300 mg/kg), 17mg/kg (<5-42.3 mg/kg) and 121mg/kg (<5 -306 mg/kg). The metal levels in the anode samples for all sizes of the zinc-carbon cells were higher than the corresponding values for the cathodes except in size AAA and the alkaline cells. About 31% of the dry cells contained ≥ 0.025% Cd (wt) whereas 20% contained ≥ 0.4 Pb in their anode, which are the current European Union Directive (EU Directive 91/157/EEC) specifying special disposal or recycling for batteries. The results indicate that the zinc-carbon cells are more polluting as they contain more of the toxic metals Pb and Cd: the mean values being approximately 2 to 4-fold for lead and approximately 6-folds the mean value for alkaline cells in the cathode samples, and about 7-14-folds the mean lead level of the alkaline cell for anode samples. The alkaline cells are less polluting as they contained less Pb and Cd compared to the zinc-carbon cells.

Keywords: Dry cell, battery, pollution, heavy metals, Nigeria.

Introduction

A battery is a device, which enables the energy liberated in a chemical reaction to be converted directly into electricity. The battery most commonly known is the dry cell, which are used in radio sets, torches, etc. They are purchased in their charged state and discharged through use and then discarded.

Many battery types can pose serious problems when disposed of with municipal waste; their toxic constituents can be released into the environment from municipal landfills, incinerators or from the open dumps, thereby causing damage to the environment and human health (Malloy 1994, Nnorom and Osibanjo 2006a; 2006b; Xara, 1999).

The technological advances which are occurring in various countries though desirable for socio-economic reasons, are taking place at the expense of environmental quality (Osibanjo, 1982). Whereas the nature and magnitude of pollution problems vary from country to country, every country faces some common environmental pollution problem of which battery (primary and secondary) and electronic waste (e-waste) is increasingly becoming of great concern. For example, the phenomenal advances in electronics and ICT have resulted in the development of many consumer electrical and electronic products. Due to inadequate grid electric power supply in Nigeria and other developing countries, a greater proportion of these consumer products are powered by batteries - primary or secondary (rechargeable) (Dell, 2000;Wamukonya and Davis; 2001).

Over the past fifty years, there has been a significant improvement in the design of Leclanche cells (Zn-carbon) and their materials of construction. The metallurgy of the zinc can has been improved through alloying additions to facilitate deep drawing. Better designs of seals have been developed. The use of Hg to increase the over-potential for hydrogen evolution at the zinc electrode has been largely phased out for environmental reasons. The cardboard jacket is now replaced by a steel container coated with polymer and is insulated from the zinc can. The insulating cell cap is made of a hard polymer rather than board. These improvements greatly reduce the tendency of the cells to leak electrolyte when fully discharged, which used to be a serious problem. (Dell, 2000).

As a result of continual innovation in the design and manufacture of Leclanche cell, variants based on the zinc anode and manganese dioxide cathode represent one of the strongest sectors of the portable energy market. The favorable position of this cell is due to various factors including low cost of raw materials, ease of manufacture, and performance characteristics that satisfy a wide range of portable devices. (Smith and Vincent, 2002).The alkaline cells have many acknowledged advantages over zinc-carbon cells, including a higher energy density, longer shelf life and superior leakage resistance. Its lower internal resistance allows it to operate at higher discharge rates over a wide temperature range (Castillo, et al, 2004).

The disposal of spent dry cell batteries represents an increasing environmental problem in terms of the heavy metals they contain, especially when these devices are disposed of in an inappropriate way (Ferella et al, 2006). Several types of household batteries have or still utilize heavy metals as electrode or to increase the life span (DEHNR, 1996; Xara et al, 1999). The composition of the common types of household batteries is given in Table 1.

Table 1: Composition of common types of household batteries

Battery Type	Cathode	Anode	Electrolyte
Zinc/Carbon	MnO_2	Zn	NH_4Cl and/orZnC_{l2}
Alkaline	MnO_2	Zn	KOH
Mercury	HgO	Zn	KOH or NaOH
Silver	Ag_2O	Zn	KOH or NaOH
Zinc Air	O_2 taken from air	Zn	KOH
Lithium	Various metal oxides	Li/MnO_2	Organic solvent/Li salt
Ni-Cd	NiO	Cd	KOH or NaOH
Ni-MH	Mm-Ni-Co*	$Ni/Ni(OH)_2$	KOH or NaOH

*Mm = Misch metal Source: Gega and Walkowiak, 2001

Because environmental legislations are non-existent or lax in the developing countries, consumer products such as batteries and e-waste that contains hazardous materials are not appropriately managed at their end-of-life (EoL). They are disposed with municipal solid waste, burned in open dumps and disposed at unlined landfills. A greater proportion of wastes are also disposed into surface water bodies. Land-filling of batteries containing hazardous substances appears

to be rather safe in the short term, but it may cause negative environmental effects in mid to long term when battery casing corrode and the interior is exposed (Scholl and Raumann, 1997). Leaching tests of Zn-MnO_2 batteries have shown that these batteries should be considered as hazardous wastes (Panero et al, 1995). Similarly, corrosion tests of household batteries have shown that Zn and Mn could be found at elevated concentration, while only a small proportion Hg, Cd, Ni, and Ag present in the batteries was dissolved by the leachate (Jones et al, 1978).

In continuation of our assessment of the heavy metal contents of EoL consumer products and consumption emission of such toxic metals from the inappropriate management of discarded consumer products we report here the result of our study of the heavy metal content of some dry cells readily consumed in Nigeria. In this paper, a comparative analysis of the Pb, Cd and Cu content of the anode and cathode constituents of zinc-carbon and alkaline dry cells was carried out in order to assess their contributions to heavy metal pollution from discarded spent dry cells.

Materials and Methods

Zinc carbon and alkaline battery of different brands and sizes were collected in Ibadan Southwestern Nigeria and used in this study. Three cells of the same brand, and size were selected and used to make a composite sample in other to avoid variation in composition that may arise from batch-to-batch inconsistencies. The selected samples were carefully dismantled using pliers, scissor and screw driver and dried to constant weight. Twenty-nine (29) different brands of dry cell battery were studied. Details of the battery samples used in this study are given in Table 2. Battery brands of the same specification (e.g. AA or R6C etc) were used to avoid possible variation in composition from differences in battery specification/size as battery composition may vary significantly for the different sizes/formats (Xara et al, 1999). It was observed that some dry cells had outer metal casing as well as inner metal zinc anode whereas others had polymeric outer cover. Other components of the dry cell such as the kraft paper and plastic/polymeric materials were not used in this study. The cathode (zinc can) and other metallic components were separated from the system and properly cleared. The metallic components of the dry cells were chipped into tiny bits using clean pliers and scissors. This was subsequently mixed thoroughly and a representative sample collected for analysis. The battery anode, carbon rod and cathode mix (MnO_2 + carbon + electrolyte) were ground into a fine particle 'black mix' using an agate mortar. The anode and cathode sample were dried to constant weight in a moisture-extractor oven and the moisture content determined. Approximately 1g of the anode and 1.5g of the cathode were digested with 10mL of 1:1 conc. HNO_3/H_2O_2. After the initial violent reaction (very pronounced in the digestion of the cathode) with evolution of brown fumes had subsided the digestion flask was heated up to 120ºC to near dryness and then cooled. The sample digests were then resolubilized using deionized water; thereafter the digests were filtered into a calibrated 25ml standard volumetric flask and made up to volume with deionized water. Glasswares were appropriately cleaned using a washing solution, rinsed with clean water, soaked in dilute nitric acid for a minimum of 6 hours and subsequently rinsed with deionized water three times before use. The digests were analyzed for Pb, Cd and Cu using flame atomic absorption spectrophotometer (Buck Scientific Model 200A). Blanks were included at 10% insertion rate. Re-tests of Pb, Cd and Cu standards was used as internal quality control check. The moisture content of the samples ranged from 7.5% to 20.3%. More than 80% of the samples had moisture content >10%. Andrade-Tacca and Duarte (2005) reported a water content of 12.6% in spent alkaline batteries of size D. Reagents used were of analytical grade. Calibration standards were made by dilution of the high purity commercial BDH (Poole, England) metal standards for atomic absorption analysis. A replicate analysis was carried out using one of the brands of the Zn-C battery samples studied. The precision calculated as the coefficient of variation gave 6.5% for Pb and 9.0% for Cd.

Table 2: Details of battery samples used in the study

Battery Type	Class/Size	Brand
Zinc carbon	Size D (R20)	Flash, Yarico, Toku, ABC, Rocket, Golden, Nulec, Diamon, Ace, Tudor
	Size C (R14C)	Sonic, Champion
	Size AAA (RO3)	Super Power, Poweer, Solar Energy, Xiong Jian
	Size AA (R6)	Everyday, GetReady, Tunar, Royal, Mega Watt, Toshiba, Tiger, Sunrise, Supower
Alkaline	6F, AM3, LR6	Panasonic plus, Hi-Watt, Alkaline Duracell, Panasonic Alkaline Plus

Results and Discussion

The mean and ranges of the heavy metal concentration in the cathode and anode samples grouped according to battery size/format are shown in Tables 3 and 4 respectively. The mean values in the cathode samples range from 197±364mg/kg in the Alkaline batteries to 842±72.1mg/kg in size C for lead; 3.1±1.3mg/kg in the Alkaline to 23.7±9.7mg/kg in Size AAA for cadmium; and from 40.2±15.mg/kg in Size C to 246±103mg/kg in the alkaline cells for copper. Similarly, the mean values for the anode samples range from 287±542mg/kg in the Alkaline cells to 4135±1712mg/kg in Size AAA for lead; 143±279mg/kg in Alkaline cells to 375±202mg/kg in Size C for cadmium; and from 88.6±83.4mg/kg in Size AAA to 173±75.6mg/kg in the Alkaline cells for copper.

Table 3: Levels of heavy metals in the dry cell battery cathodes

Battery size	N	Pb	Cd	Cu
Size D	(N = 10)	750±743* <4 – 2300**	18.0±8.7 1.03 – 32.9	58.4±30.8 <5 – 110
Size C	(N = 2)	842±72.1 791 – 893	17.6±7.4 12.4 – 22.8	40.2±15.1 29.5 – 50.8
Size AA	(N = 9)	421±386 46 – 1200	18.0±15.4 3.1 – 42.3	114±92.7 31.8 – 261.0
Size AAA	(N = 4)	392±287 149 – 797	23.7±9.7 15.5 – 37.5	197±134 10.5 – 328.0
Alkaline	(N = 4)	197±364 <4 – 743	3.1±1.3 1.3 – 4.1	246±103 92.5 – 306.0

*Mean±(Standard Deviation);**Range

Table 4: Levels of heavy metals in the dry cell battery anodes

Battery size		Pb	Cd	Cu
Size D	(N = 10)	2131±868* 1090 – 4040**	145±67.3 59.6 – 307	146±121 37.8 – 208.0
Size C	(N = 2)	3395±1096 2620 – 4170	375±202 232 – 518	127±114 46.3 - 208
Size AA	(N = 9)	3307±1631 1730 – 5600	182±120 5.03 – 276	148±93.8 13.3 - 217
Size AAA	(N = 4)	4135±1712 2700 – 6600	242±32.6 203.0 – 277.0	88.6±83.4 22.7 – 201
Alkaline	(N = 4)	287±542 4.83 – 1100	143±279 1.33 – 562	173±75.6 59.7 – 218

*Mean±(Standard Deviation);**Range

The data obtained was normalized by logarithmic transformation by calculating the geometric means of the values obtained. For the cathode samples, the geometric mean values range from 27.3mg/kg in alkaline cells to 840mg/kg in Size C for lead; 2.8mg/kg in the alkaline cells to 22.4mg/kg in Size AAA for cadmium; and 38.7mg/kg for Size C to 221mg/kg for the alkaline cells for copper. Similarly, in the anode samples, the geometric mean values range from 38.9mg/kg (Alkaline) to

3904mg/kg (Size AAA) for lead; 10.7mg/kg (Alkaline) to 346mg/kg (Size C) for cadmium; and from 60.1mg/kg (size AAA) to 153.4mg/kg (Alkaline) for copper (Figures 1-3).

Figure 1: Distribution of geometric mean copper values according to battery brand/type

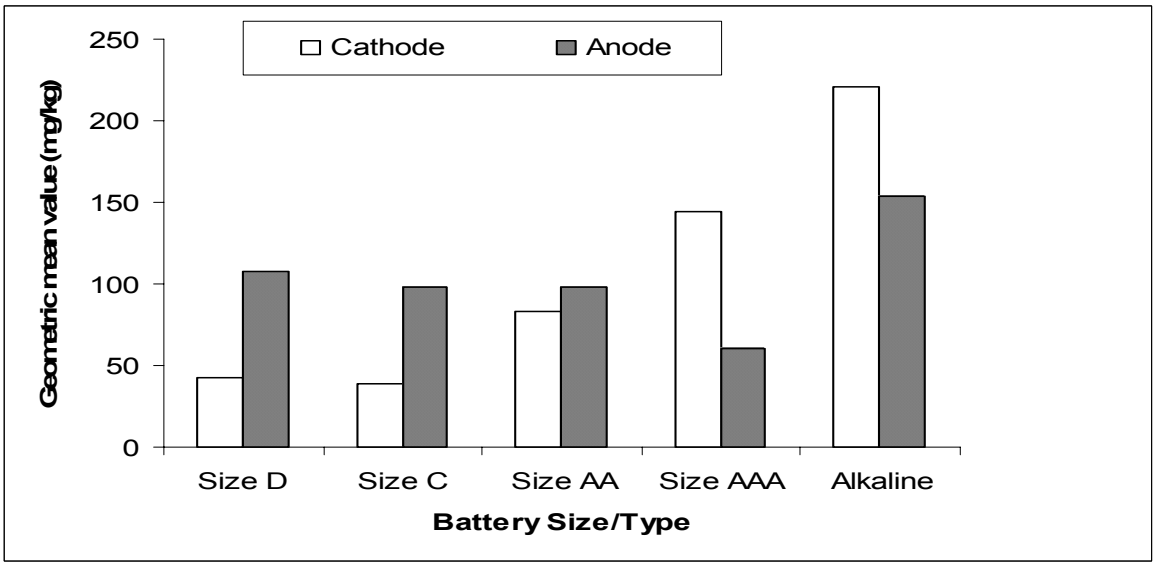


Figure 2: Distribution of geometric mean lead values according to battery brand/type

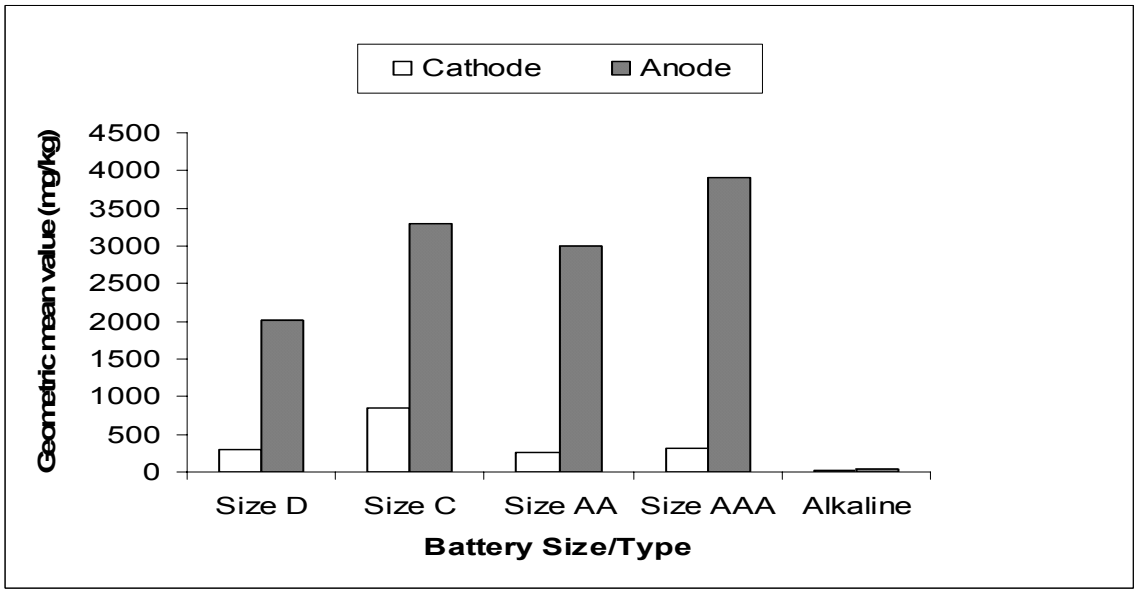
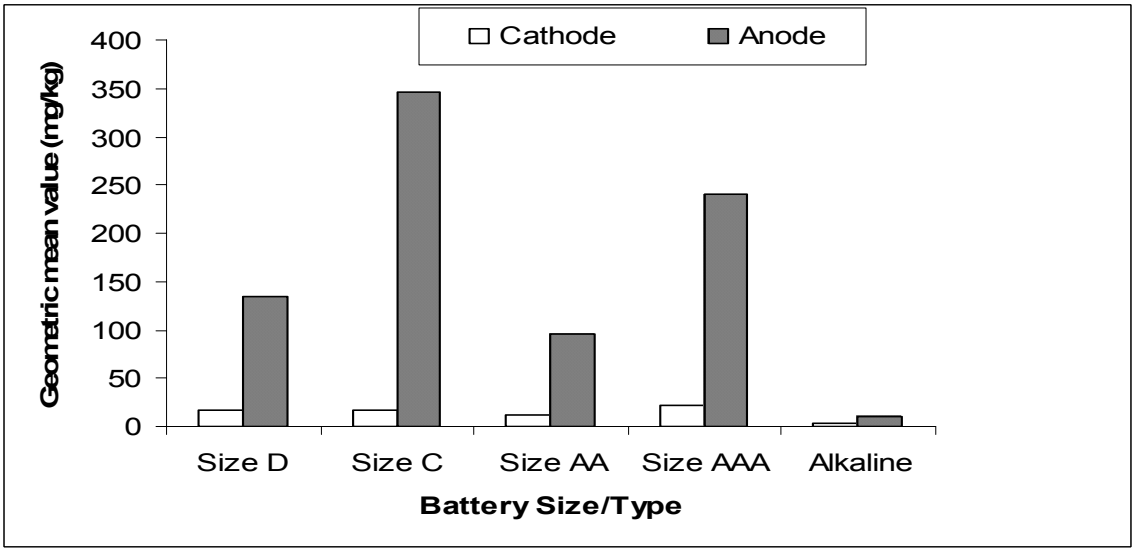


Figure 3: Distribution of geometric mean cadmium values according to battery brand/type



In the cathode samples, the mean Pb levels for the various sizes of the carbon-zinc batteries were approximately 2 to 4-folds the mean Pb values of the alkaline cells. Similarly their mean cadmium values were approximately 6-fold the alkaline mean value. In anode samples, the mean Pb levels for the carbon zinc batteries were approximately 7to 14-folds the mean value for alkaline cells. However, the mean Cu levels for the alkaline cells were generally higher in both the cathode and the anode of the zinc-carbon batteries of all sizes.

The summary of our result (Table 6) indicates that the mean values for Pb, Cd and Cu obtained for the anode; 2698.3mg/kg (Range, 4.83-6600mg/kg), 166.12 mg/kg (1.73-518.0 mg/kg) and 132.6 mg/kg (13.3-423 mg/kg) respectively were higher than the corresponding values for the cathode; 570.2mgPb/kg (range <4-2300 mg/kg), 16.96 mg/kg (1.03 – 42.3 mg/kg) and 121.1 mg/kg (<4-306 mg/kg) respectively. The alkaline batteries are less polluting as they contain less of the toxic metals Pb and Cd in both the anode and the cathode compared to the various sizes of the zinc-carbon dry cells studied.

Discussion

The very high level of Cd observed in the anodes indicates that Cd may still be utilized in large quantities in the manufacture of these batteries. Xara et al (1999) observed that the zinc anode of the Lechlanche cells often contain other elements particularly Hg and Cd which are added to avoid passivation during the electrochemical reaction.

The current European Union Directive (Council Directive 91/157/EEC) on batteries and accumulators specifies special disposal or recycling for batteries and accumulators containing more than 0.0025%Hg, more than 0.025% Cd, and more than 0.4% Pb (percent by weight). Our result indicates that 20% and 31% of the anodes of the dry cells studied contained $\geq$ 0.4% Pb and $\geq$ 0.025% Cd respectively. Our earlier study of the Pb and Cd contents of dry cells (anode + cathode) observed that about 5% of the dry cells contained $\geq$ 0.025% Cd whereas none of the samples was observed to contain lead levels $\geq$ 0.4% (Nnorom & Osibanjo, 2006b). Typical composition of zinc-carbon batteries indicates Cd levels of < 0.01% (Table 5). However, our results show that about 76% of the battery brands studied contained $\geq$ 0.01% Cd in their anode. The present study indicates that the anode is the main source of especially Pb and Cd in the dry cells.

Table 5: Typical composition of zinc batteries (%)

Dry cell type	Mn	Fe	Zn	C	Cu	Pb	Cd	Hg	H_2O	Other*
Zinc-carbon	18	21	35	9	-	0.1	-	<0.0005	11	5.8
Alkaline-Mn	23	25	16	4	0.5	0.5	0.01	<0.0005	7.0	24

*Oxygen in compounds, paper, plastics, electrolyte.

Table 6: Summary of levels of heavy metals in dry cell components

Component		Mean ± SD	GM	Range
Cathode	Pb	570±565	236	<10.0 - 2300
	Cd	17.0±11.2	11.9	<5.0– 42.3
	Cu	121±103	77.5	<10 - 306
Anode	Pb	2698±1611	1496	<10 - 6600
	Cd	166±122.1	84.3	<5.0 - 518
	Cu	133±83.1	101	13.3 - 423

GM: Geometric mean

Presently, the prevailing marketing strategy is to label dry cells as Hg-free and Cd-free. Our earlier study observed that the mean Pb and Cd content of dry cells labeled "Cd –free' (919.4 and 89.6mg/kg respectively) were lower than the corresponding values for the 'normal cells' – cell not labeled 'Cd-free' – (1157mg/kg and 118mg/kg respectively). This is however, not statistically significant (Nnorom and Osibanjo, 2006b).

Alkaline batteries dominate the consumer battery in most developed countries and make up more than 75% of the market (Reutlinger and De Grassi; Xara et al 1999) whereas in the developing countries, the zinc-carbon cells make up more than 90% of the dry cell battery market. Our results suggests that heavy metal pollution resulting from consumption emissions of dry cells would be more evasive in the developing countries, not only because of the larger quantities consumed or the higher levels of heavy metals in the types and brands prevalent in the developing countries, but also because of the low-end management practices for EoL (spent) batteries in these countries. Because the alkaline batteries dominate the market in developed countries and meets with national or regional regulations for heavy metal levels, these batteries are sometimes landfilled or incinerated. Also there are recycle facilities for the regular dry cells in Europe and the United States. Spent batteries not recycled are usually disposed via incineration or landfilling using state-of-the- art facilities/technology.

Management of spent dry cells is posing a lot of challenge to solid waste management experts. With any battery disposal method, the potential exists to release heavy metals into the environment through landfill leachate or incineration stack gases (DEHNR, 1996; Malloy, 1994).When released into the environment, by waste incineration or as landfill leachate, heavy metals can enter the food chain as they accumulate in soil, plants and animals. As such, these substances can harm human health and the environment. The management options available for spent batteries include: land filling, incineration or recycling. The comparison between land filling, incinerations and recycling in terms of environmental burdens could be made by analyzing a hypothetical case study comprising these options available for disposal of spent household batteries using the life cycle assessment (LCA) techniques (Xara et al, 1999).

The varied metal contents in consumer batteries and the available markets for each type of metal are the key factors in determining the scope of any battery recycling program (Reutlinger and De Grassi, 1991). Each type of battery presents unique collection, sorting, storage, transportation, recycling and disposal problems. Unfortunately, the public is generally unaware of the potential health and environmental risks of unrestricted disposal of dry cells (Shapek, 1996; Reutlinger & De Grassi, 1991). This situation is worse in developing countries where appropriate technology is rarely used for waste management, even for known hazardous wastes (Yanez et al, 2002). On a resource management level, batteries could be considered as an ore of secondary raw materials. Valuable metals such as zinc and manganese can be recovered. The use of recycled metals in battery production instead of virgin

metals has positive environmental impacts through reduced energy use and reduced pollution related to the mining of the virgin sources (Ferella et al, 2006).

Over 3 billion household batteries are sold and discarded in the United States each year, an amount that represents 12 batteries per person or more than 125,000 tons of waste per year (DEHNR, 1996). Household batteries consumption in the United State, Germany and France in 1994, were estimated at 83,000, 26,000 and 25,000 tons respectively (Gega & Walkowiak, 2001). In 2002, out of the 158,270 tons of portable batteries and accumulators sold in the EU (EU-15), 72,155 tons (representing 45.5% of sales) went to final disposal (landfill or incinerator) without any material recovery (Ferella et al, 2006). In 2004, the European Batteries Recycling Associations (EBRA) fifteen members recycled 23,900 tons of portable batteries and accumulators, of which 20,432 tons (~85%) were alkaline, zinc-carbon and zinc-air batteries (Ferella et al, 2006). Worldwide, more that 300,000 tons of zinc batteries or 7.5 billion cells are sold yearly. The production of this number of zinc batteries requires an average of 75000 tons of zinc, 60000 tons of manganese and 70000 tons of iron (Gega and Walkowiak, 2001). This tonnage corresponds with the amount of metals, which can be recovered from the spent batteries. The amount of recoverable materials or pollutants from spent batteries can be calculated from the average percentage of each component (e.g. Table 5) and the number of batteries discarded which can be assumed to be equal to the quantity sold in the same period of time. In Nigeria an estimated 11,000 tons of primary batteries and parts are imported yearly (Nnorom and Osibanjo, 2006a).

Technology exists and are evolving for the recycling of the rechargeable NiCd, NiMH and lithium ion cells (Tzanelakis and Scott, 2004a; Lupi and Pilone, 2002, Pietrelli et al, 2005). However, recycling technology has yet to catch up with dry cell batteries which are presumed to be less harmful (Malloy, 1994). Battery recycling facilities for the more common zinc-carbon and alkaline dry cells are few. A zinc/alkaline battery recycling plant in Switzerland recovers ferromanganese, zinc nuggets, zinc oxide and mercury from spent zinc-carbon and alkaline batteries (Envirogreen, 2005).

Environmental consideration has tended to push well-established battery technologies based on materials like Ag, Hg and Cd to the background (Lankey and McMicheal, 1999). The manufacturers of zinc-carbon and alkaline manganese batteries ceased the addition of Hg in the dry cells in 1992 (Malloy, 1994, EPA, 1992). And between 1988 and 1992, mercury consumption by battery manufacturers dropped 96 percent (DEHNR, 1996). The Pb and Cd levels of these battery systems have also been drastically reduced or substituted (Andrade-Tacca and Duarte, 2005).

Common solutions to dry cell battery management are incineration or stabilization of the batteries in concrete and dumping in controlled sites (Wiaux and Waelter, 1995). However, the recycling of spent batteries would be the most convenient solution from an environmental point of view, although there are practical and economical aspects that restrict this option. Although recycling of material may reduce the environmental impact, it is not necessarily harmless to the environment (Zickiene et al, 2005). Several processes for the recycling of batteries have been proposed based on pyrometallurgical and hydrometallurgical processes/treatments. The pyrometallurgical/thermal processes are the most used (Espinosa et al, 20004a, 2004b, Ammann, 1995, Kaneman and Matsnoka, 1995). Literature also abound on the hydrometallurgical and leaching processing of spent batteries for material recovery (Freitas and Petrie, 2004, Salgado et al, 2003, Veloso et al 2005; De Souza and Tenorio, 2004, Ferella et al, 2006 Andrade-Tacca and Duarte, 2005). The BATENUS process has been developed for the recycling of battery waste and has been reported to operate without any emissions and produces raw materials with remarkable high purity (Gega & Walkowiak, 2001, Lindermann et al, 1994). Other patent processes for manganese and zinc recovery from spent cells include the BATENUS; ZINCES & RECUPYL processes (Ferella et al 2006). Pyrometallurgical process generates less solid and liquid residues than hydrometallurgical ones. On the other hand they are energy intensive routes and generate gaseous toxic emission (Xara et al, 1999).

From an environmental point of view, one of the most efficient ways to reduce the environmental impact of a product is to reduce the flow of it. For household batteries, this would be to reduce the number of battery-powered products in use. This is however controversial in an economic

system predicted on consumption and growth. Provision of alternative environment friendlier or renewable energy source to power consumer goods that would otherwise be powered by household batteries, will help reduce the material flow of dry cells into Nigeria and other developing countries. Effective provision of grid electricity and solar energy in the form of solar home systems (SHSs) or solar battery charging systems (SBCS) is very essential. A study of the impact of grid electricity and SHSs in Namibia observed that the share of households consuming dry cell batteries is lowest among grid-electrified households (30%) compared to households with SHSs (67%) and un-electrified homes. Dry cell battery consumption in electrified and SHSs homes was attributed mainly to the incompatibilities of radio sets to grid electricity and the high voltage of the SHSs (12V) compared to most radio sets designed for 9V, thus a voltage converter is required (Wamukonye and Davis, 2001). This study observed that dry cell consumption is highest in households without any source of electricity supply. This is also the prevailing situation in Nigeria and most other developing countries. SHSs installed in individual household and SBCSs installed or located centrally in villages are alternatives to dry cell batteries use where there is no grid electricity (Greacen & Green, 2001; Wamukonye and Davis, 2001).

Conclusion

The results of our study showed high levels of heavy metals in the dry cell samples, and that the main source of the metals was the anodes. The results also indicate that zinc carbon dry cells are more polluting than the alkaline types of dry cell. However higher copper levels were obtained in the alkaline dry cells. The public is generally unaware of the potential health and environmental risks of inappropriate disposal of dry cells. There is an urgent need for the introduction of a framework for the separate collection, sorting, storage, transportation and management of spent dry cells using appropriate technology in order to mitigate the potential environmental pollution from such consumption emission.

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Homogeneity Influence on Active Power Losses

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Abstract

This Paper discuses, presents and analyses the homogeneity of electrical networks and investigates its relationship with the active power total losses, which are considered as criteria of optimality. Optimizing electrical network operation modes were introduced in loops by realization of optimum transformation ratios of transformers. A generalized index of electrical network homogeneity was cited, to evaluate quantitatively the value of electrical network homogeneity and An example was introduced. It was found that reducing the nonhomogeneity leads to reducing the active power losses as the reactance was reduced from 47 to 30 Ohm the e changed from 1.7 to 1.64 which reduce the active power losses from 2.44 MW to 2.07 MW (about 15.6 %)

Keywords: Homogeneity, active power losses, electrical networks, optimization.

1. Introduction

Optimization of electrical network (EN) heterogeneous modes can be achieved either by decreasing the homogeneity level or by forced change of the AC power flow in order to converge it to AC power flow in a homogeneous EN [1,2,3,4]. In the first case, the homogeneity itself is eliminated, but in the second case the consequence is eliminated.

In the first case the optimality of the mode is maintained irrespective of the load, in the second case- the control devices of mode parameters change the power flow in the electrical power system to appropriate operation.

With the development of automated systems of dispatch control (ASDC) of EN such as the systems of centralized control, and due to formalization of methods optimization, less attention has been given to the analysis of physical reasons which lead to additional power losses in EN. In other words, the efforts were directed to the reduction of consequences and not to elimination of causes.

As result of using computers in technological processes and wide application of microprocessor -both based systems the decentralization process control becomes more prevailing. Creation of a local automated control system of voltage and power flow on the basis of existing computing systems

necessitate the generalization of this phenomena in the form of control laws of dependence between EN optimum parameters and operating modes parameters. In this case, it is important to analyze the homogeneity of EN and investigate the relationship between homogeneity of EN and active power total losses, which are the criteria of optimality one of the main components of objective function while designing and reconstruction the EN.

2. Optimality conditions of power losses and EN homogeneity

Power losses in EN are determined as:

$$\Delta\dot{S} = \overset{*}{I}_t \, Z_B \dot{I} \tag{1}$$

where $Z_B = r_B + jx_B$ - is a diagonal matrix of branch impedances.

$\dot{I}$ - branch currents vector.

$\overset{*}{I}_t$ - conjugate of transposed branch currents vector.

The homogeneity of EN parameters is the reason for the unbalanced current flow in the loops, which leads to additional power losses. In order to establish the dependence of losses in EN on its homogeneity parameters, it is necessary to connect $\Delta\dot{S}$ with the circulating currents.

Currents in the branches are determined through circulating currents $\dot{I}_c$:

$$\dot{I} = N_t \dot{I}_c \tag{2}$$

where N- is a matrix of branches connections into loops. (second Incidence matrix).

According to references, $\dot{I}_c$ can be written as[2,4]:

$$I_c = C_\beta \dot{J} + Y_c \dot{E}_c \tag{3}$$

where $C_\beta = F + jH = - Y_c N_\alpha Z_{\beta\alpha} \; M_\alpha^{-1}$;

is the matrix of distribution which connects currents in nodes J with circulating currents for the system of basic loops (N_β =1); $Y_c = G_c + jB_c = (NZ_B N_t)^{-1}$ is the matrix of circulating admittance; $\dot{E}_c$ – vector of circulating e.m.f.

Taking into account eq. (2) and eq. (3) the eq. (1) will become:

$$\Delta\dot{S} = \overset{*}{J}_t Z_B \dot{J} - \overset{*}{J}_t C_\beta \dot{E}_c + \overset{*}{J}_t \overset{*}{C}_\beta \dot{E}_c + \overset{*}{E}_{ct} \overset{*}{Y}_c \dot{E}_c \tag{4}$$

active power losses in accordance with the last expression are determined from:

$$\Delta P = \overset{*}{J}_t r_B \dot{J} + 2\,\mathrm{Real}\left[\dot{J}_t \dot{J} H_t \dot{E}_c\right] + \overset{*}{E}_{ct} G_c \dot{E}_c \tag{5}$$

expressing J and $\dot{E}_c$ by means of their active and reactive components, eq. (5), can be rewritten in the following form:

$$\begin{aligned} \Delta P = {} & J_{at} r_B J_a + J_{rt} r_B J_r + 2(-J_{at} H_t E_{cr} + J_{rt} H_t E_{ca}) + \\ & + E_{cat} G_c E_{ca} + E_{crt} G_c E_{cr} \end{aligned} \tag{6}$$

ΔP losses consist of economic losses (in r-circuit of EN replacement [1,6]) and additional losses, determined by homogeneity. The additional losses are decreased by introduction of equalizing currents (Ie.q)- into the loops. In order to create $I_{e.q}$ (Regulation of active and reactive power in the loop), it is necessary to introduce in the loops additional e.m.f, their values are determined from the following conditions:

$$\left\{ \begin{array}{l} \dfrac{\partial \Delta p}{\partial E_{ca}} = J_{rt} H_t + E^0_{cat} G_c = 0 \; ; \\ \dfrac{\partial \Delta p}{\partial E_{cr}} = - J_{at} H_t + E^0_{crt} G_c = 0 \end{array} \right\} \tag{7}$$

where E^0_{ca} , E^0_{cr} - are of optimum loop e.m.f.

From the last system of equations we obtain:

$$\begin{cases} E_{ca}^{0} = -\,G_c^{-1} H J_r \\ E_{cr}^{0} = G_c H J_a \end{cases} \tag{8}$$

let's consider the physical sense of equalizing e.m.f E_{ca}^{0} and E_{cr}^{0}. For this purpose we represent in details $G_c^{-1}H$ from the definition Y_c we obtain that: $G_c^{-1} = N r_B N_t = r_c$.

From earlier equation $C_\beta = F + jH = -\,Y_c N_\alpha Z_{\beta\alpha} M_\alpha^{-1}$; for C_β after simple transformation we obtain that:

$$H = -G_c (N_\alpha X_{B\alpha} r_{B\alpha}^{-1} - X_c r_c^{-1} N_\alpha) r_{B\alpha} M_\alpha^{-1}$$

Then

$$G_c^{-1} H = -(N_\alpha X_{B\alpha} r_{B\alpha}^{-1} - X_c r_c^{-1} N_\alpha) r_{B\alpha} M_\alpha^{-1}. \tag{9}$$

In eq. (9) the value of the expression in brackets is defined by the ratio of resistance and reactance of EN, i.e, by the homogeneity of parameters. Proceeding from this fact, we will designate

$$\nu = N_\alpha X_{B\alpha} r_{B\alpha}^{-1} - X_c r_c^{-1} N_\alpha \tag{10}$$

where ν- the matrix of EN homogeneity parameters.

The size of ν is determined by the number of independent loops q and the number of branches m of EN. Taking into account equation (10) the expressions for equalizing e.m.f equation (8) will be rewritten in the following form:

$$\begin{aligned} E_{ca}^{0} &= \nu r_B M_\alpha^{-1} J_r; \\ E_{cr}^{0} &= -\nu r_B M_\alpha^{-1} J_a \end{aligned} \tag{11}$$

From equation (11) it is obvious that the values of e.m.fs to be introduced into the loops in order to minimize the additional losses of active power depend on the homogeneity of EN parameters and on the consumers load. That is the homogeneity of EN parameters is not the comprehensive characteristic of power losses increase. But that is an influence of homogeneity of EN on the equalizing e.m.fs of equation (11). This fact permits us to investigate the influence of homogeneity of EN on additional power losses.

It is obvious from equation (10), for the homogeneous EN, when for all the branches $x_i / r_i = \text{constant}$, $\nu = 0$. That is, irrespective of the load of EN.

Therefore $E_{ca}^{0} = 0$, $E_{cr}^{0} = 0$ and there are no additional losses in EN. In other cases, when x_i / r_i is not a constant value, $\nu \neq 0$ and accordingly $E_{ca}^{0} \neq 0$, $E_{cr}^{0} \neq 0$. In these cases, in order to compensate the additional losses in EN it is necessary to introduce equalizing e.m.f. in the loops[1,6].

The values of the equalizing e.m.f. are also can be expressed as:

$$E_{eq.a} = -\,E_{ca}^{0}, \qquad E_{eq.r} = -\,E_{cr}^{0}, \tag{12}$$

3. Similarity of Optimum Modes and the Law of optimum control

Considering some features common during the realization of equalizing e.m.f. in EN when the load flow is optimized. In equation (6) it is shown that the processes of current flow optimization in EN are similar. Using the technique given there and showing the similarity of the process of equalizing e.m.f introduction in the loops to optimize mode of operation of EN when load is changed (varied).

Writing down in accordance with equations (12) and (11) the active and reactive components of equalizing e.m.f. for two different modes of operation of j-th and $(j+1)^{th}$ order:

$$E_{eq.a}^{(j)} = -\nu r_B M_\alpha^{-1} J r^{(j)} \;;\; E_{eq.r}^{(j)} = \nu r_B M_\alpha^{-1} J_a^{(j)} \tag{13}$$

$$E_{eq.a}^{(j+1)} = -\nu r_B M_\alpha^{-1} J_r^{(j+1)} \;;\; E_{eq.r}^{(j+1)} = \nu r_B M_\alpha^{-1} J_a^{(j+1)} \tag{14}$$

Let's rewrite the equations (13) and (14) in criterial form, taking as a base the optimum mode with $E^{b}_{eq.a}$ and $E^{b}_{eq.r}$, J^{b}_{a}, J^{b}_{r}, Presented in the form of diagonal matrices:

$$E^{(j)}_{*eq.a} = -\left[E^{b}_{eq.a}\right]^{-1}_{d} w_B M^{-1}_{\alpha} \left[J^{b}_{r}\right]_{d} J^{(j)}_{*r} \quad ;$$

$$E^{(j)}_{*eq.r} = \left[E^{b}_{eq.r}\right]^{-1}_{d} w_B M^{-1}_{\alpha} \left[J^{b}_{a}\right]_{d} J^{(j)}_{*a} \quad ;$$

$$E^{(j+1)}_{*eq.a} = -\left[E^{b}_{eq.a}\right]^{-1}_{d} w_B M^{-1}_{\alpha} \left[J^{b}_{r}\right]_{d} J^{(j+1)}_{*r} \quad ;$$

$$E^{(j+1)}_{*eq.r} = \left[E^{b}_{eq.r}\right]^{-1}_{d} w_B M^{-1}_{\alpha} \left[J^{b}_{a}\right]_{d} J^{(j+1)}_{*a}$$

Where the vector elements:

$E^{(j+1)}_{*eq.a}$, $E^{(j)}_{*eq.r}$, $J^{(j)}_{*a}$, $J^{(j)}_{*r}$, $E^{(j+1)}_{*eq.a}$, $E^{(j+1)}_{*eq.r}$, $J^{(j+1)}_{*a}$, $J^{(j+1)}_{*r}$ are determined as a ratio of corresponding values of j^{th}, $(j+1)^{th}$ operation modes and base operation mode.

Let's introduce the following designations:

$$\pi^{E}_{a} = -\left[E^{b}_{eq.a}\right]^{-1}_{d} \nu r_B M^{-1}_{\alpha} \left[J^{b}_{r}\right]_{d} \quad ;$$

$$\pi^{E}_{r} = \left[E^{b}_{eq.r}\right]^{-1}_{d} \nu r_B M^{-1}_{\alpha} \left[J^{b}_{a}\right]_{d} \qquad (15)$$

Then

$$E^{(j)}_{*eq.a} = \pi^{E}_{a} J^{(j)}_{*r} \quad ; \quad E^{(j)}_{*eq.r} = \pi^{E}_{r} J^{(j)}_{*a} \quad ;$$

$$E^{(j+1)}_{*eq.a} = \pi^{E}_{a} J^{(j+1)}_{*r} \quad ; \quad E^{(j+1)}_{*eq.r} = \pi^{E}_{r} J^{(j+1)}_{*a}$$

As it is seen, for j^{th} and $(j+1)^{th}$ of modes π^{E}_{a} = constant; π^{E}_{r} = constant, and accordingly, we can state that the processes, described by equations (13)and (14), are similar [1,5,6]. In a given case it means, that processes of optimization of current flow in EN by introducing equalizing e.m.f in loops are similar, and Π^{E}_{a}, Π^{E}_{r} are the similarity criteria. That is for optimum operation modes of EN considering the process optimization in time.

$$E_{*eq.a}(t) = \pi^{E}_{a} J_{*r}(t), \; E_{*eq.r}(t) = \pi^{E}_{r} J_{*a}(t) \qquad (16)$$

Optimizing EN modes of operation are introduced in loops by means of transformers, autotransformers and special boost transformers. It is known, that the transformation ratio of these devices and loop e.m.fs are interrelated [1,8]:

$$E_{*eq.i} = 1 - \Pi_{j \in si} K_{ij}, \qquad i = \overline{1,q} \qquad (17)$$

where $E_{*eq.i}$ - is the e.m.f, to be introduced in the i^{-th} loop; Kij- is the transformation ratio of the j^{-th} transformer which enters the i^{-th} loop; Si- is the set of transformers of I^{-th} loop; q-is the set of independent loops of EN.

The system of equations (17) in general is non- linear and non definite. That is the optimum current flow corresponds to a number of transformation ratio combinations. For automatic realization of optimum transformation ratios, it is necessary to obtain the appropriate laws of controls, which, in this turn, require the establishment of unambguity conditions. This problem can be solved in the following way:

In order to control the power losses on the basis of Criterial Analysis from all the transformers of EN, q-transformers are chosen, which have the greatest adjusting effect [4, 6, 8]. So if the calculated model of EN is composed in such away that all these q transformers will be in co tree (chords), in this case in accordance with equation (17) we obtain:

$$\dot{K}_{ij} = 1 - \dot{E}_{*eq.i} \quad , \; i = \overline{1,q} \qquad (18)$$

Then taking into account equation (15) the vector of optimal transformation ratios will be presented in the following form:

$$\dot{K}=1-\Pi_a^E J_{*r} - j\Pi_r^E J_{*a} \quad ; \tag{19}$$

The last expression of transformation ratios of optimum control for the EN modes of operation, varying in time, and are presented as:

$$\begin{aligned} K'^{(t)} &= 1 - \Pi_a^E J_{*r}^{(t)} \\ K''^{(t)} &= - \Pi_r^E J_{*a}^{(t)} \end{aligned} \quad , \tag{20}$$

where K', K'' are the vectors of real and imaginary components of transformation ratios. these laws are quite indispensable for the functioning of automated control system [5]. As it seen from equation (15), they are defined by the homogeneity of EN. When they are realized, we can compensate the negative influence of homogeneity with the accuracy to the regulation step of transformation ratios, and direct the EN power losses to optimal.

4. Generalized Index of EN Homogeneity

When evaluating the efficiency of optimizing measures in EN and while solving the design problems it is necessary to analyze a great number of possible variants. The choice of the best variant must be unambiguous. The known critrea of optimality [3, 4] are multidimensional (in the form of vector of matrix) and that is why without the additional conditions do not give direct evaluation. The same drawback has been suggested in the given paper the index v of homogeneity. Let's introduce the generalized index of EN homogeneity, which must be dimensionless. In this case we obtain the possibility of achieving optimum decision.

Let's consider two composing matrices ν in equation (10) which are the component of functional metric set ν, for each pair of elements of this set corresponds to a non negative real number and which satisfy the axioms of matrix space [6]. The motorization of the set ν permits us to determine quantitatively the value of EN homogeneity through the distance between homogeneity of branches, carried a long the independent EN loops and homogeneity of loops, distributed along the branches of EN.

This distance can be determined by means of Euclid norm of system index homogeneity of the matrix [1, 4].

$$\begin{aligned} d\nu &= \int [N_\alpha . X_{B\alpha} . r_{B\alpha}^{-1} X_c r_c^{-1} . N_\alpha] \\ &= \| \nu \|_E = \left(\mathrm{tr}\,(\nu . \nu_t)\right)^{\frac{1}{2}} \end{aligned} \tag{21}$$

We shall designate $d\nu$ bas a generalized index of EN homogeneity and investigate what values it can accept.

The limits, in which the generalized index can be changed, are determined by an inequality [9]:

$$0 \le d\nu \le \sqrt{\sum_{i=1}^{q}\sum_{j=1}^{m}(N_{\alpha ij} . X_{Bjj} . r_{Bjj}^{-1})^2 + \sum_{i=1}^{q}\sum_{j=1}^{m}(X_{cii} r_{cii}^{-1} . N_{\alpha ij})^2} \tag{22}$$

The relative index of homogeneity

$$\delta\nu = d\nu \Big/ \sqrt{\sum_{i=1}^{q}\sum_{j=1}^{m}(N_{\alpha ij} . X_{Bjj} . r_{Bjj}^{-1})^2} \tag{23}$$

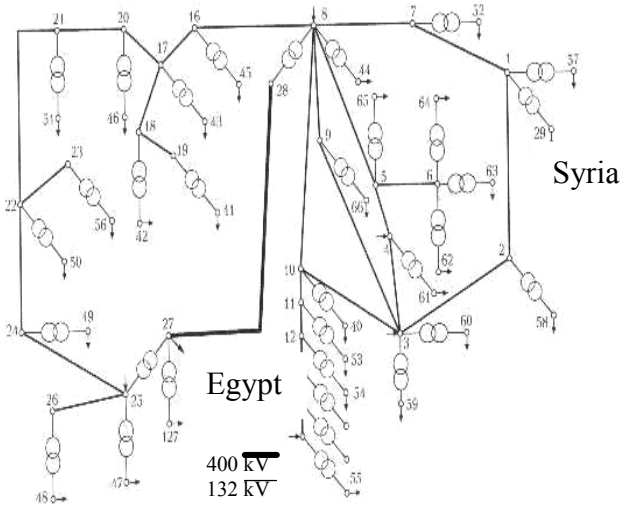
its values are within the borders:

$$0 \le \delta\nu \le \sqrt{1 + \frac{\sum_{i=1}^{q}\sum_{j=1}^{m}(X_{cii} . r_{cii}^{-1} . N_{\alpha ij})^2}{\sum_{i=1}^{q}\sum_{j=1}^{m}(N_{\alpha ij} . X_{Bjj} . r_{jj}^{-1})^2}} \tag{24}$$

by means of the generalized index of homogeneity δν it is possible to evaluate the influence of EN topology change, introduction of new transmission lines and transformers on the optimality of EN modes. They can be of great use while realizing the construction of EN in order to decrease

homogeneity, which is (i.e), to eliminate the reasons of non optimal operation modes and improve the economic indexes of EN.

Figure 1: A part of the Jordanian Electrical Network



To evaluate how for the EN is from homogeneity state, it is necessary to apply the relative index of homogeneity. The more close the value of relative index of homogeneity to its upper limit, determined by means of equation (22) the more heterogeneous is the EN.

To get the clear Idea of the previous presented work. For real electrical power systems (Jordanian notional electrical network) to give real calculated values of the generalized and the relative indexes of homogeneity. The results are shown in figure 2 and figure 3. The calculations were performed using the MATLAB software.

Figs 2 and 3 shows the dependency of changing the homogeneity on the active power losses for the nodes 1, 2, and 3 (*from figure 1*).

It is shown that the node 1 is more sensitive and affected easily by changing indexes of homogeneity than 2, 3 nodes, and any change in its impedances will cause a change in the active power. For example by reducing the it from 47 to 30 Ohm the will be changed from 1.7 to 1.64 which will reduce the active power losses from 2.44 MW to 2.07 MW (about 15.5%)

Figure 2: The Relative Indexes of Homogeneity

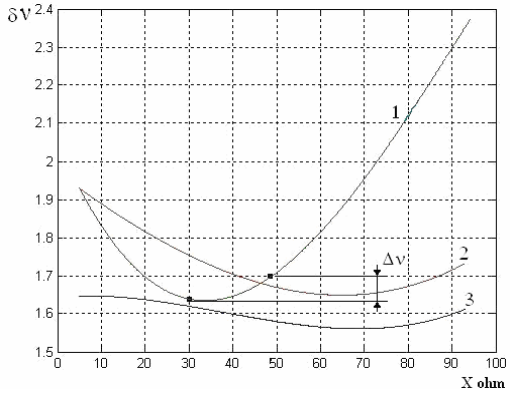
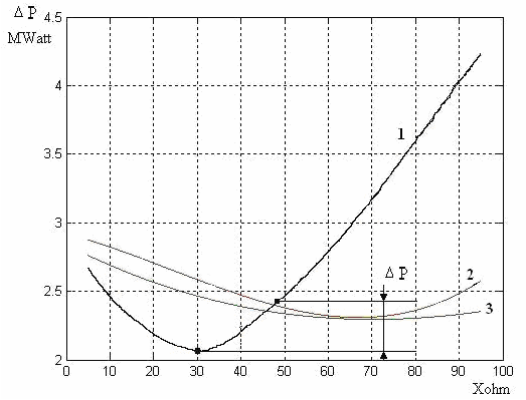


Figure 3: The Effect on the Active Power Losses



5. Conclusions

This presented overview analysis of the homogeneity and some indices for evaluating the homogeneity of electric power network. Provides and good solution of understanding the physical mechanism of power systems operation, and quantitative analysis for the homogeneity which is very important especially for electric power planning and operating process.

It shows that EN homogeneity defines the non-optimality and causes additional active power losses. By means of the generalized index of homogeneity δv it is possible to evaluate the influence of electrical network homogeneity. Realizing the optimum transformation ratios of control, the negative influence of homogeneity can be compensated with the accuracy to the regulation step of transformation ratios.

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Nomenclature Symbols

Δ	Power Losses.
^ *	conjugate.
t	transposed. Branch current.
Z_B	Branch Impedance matrix Z_B - Branch Impedance matrix.
İc	Circulating currents.
Y	Admittance matrix.
J	Nodal currents.
α,β	Indexes of the parameters, which corresponds respectively to tree and co-tree of the Graph.
C	Current distribution matrix.
G	Conductance matrix.
B	Susceptance matrix.
E	electromotive force
EN	Electrical network
ΔP	active power losses
r_B	real part of branch impedance matrix.
K	transformation Ratio
ν	Matrix of EN homogeneity parameters
π	Similarity criteria.
M	The 1-st incidence matrix.
N	The 2-d incidence matrix
$d\nu$	index of homogeneity.
$\delta\nu$	Relative index of homogeneity.
c	Circulating currents
α,β	Index of the parameters, which corresponds respectively to tree and co-tree of the graph.
t	transposed matrix.

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Investigation of Power Losses in Jordanian Electrical Power System

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Abstract

In this paper the influence of different methods to minimize active power losses in electrical power system practically has been studied. The study focuses on improving the performance of electrical power system operation by reducing the losses and improving the power quality. Controlling the transformation ratio of power transformers and the injected reactive power has been utilized to optimize system performance. Simulations have been implemented in MATLAB.

Determination optimal transformations ratios and injected reactive power are performed for different real operating modes (maximum, normal, and minimum loading) of Jordanian Electrical Power System. The power losses versus the controlling variables have been illustrated. Recommendations for the optimal controlling variables for main substations are obtained. Taking into consideration the regulation limits of the optimization process.

Keywords: Jordanian electrical system, transformations ratios, active power losses, injected reactive power.

1. Introduction

The problem of minimizing electric power losses in electrical networks is a major aspect of power systems research. There are many control methods used to improve the performance of the electrical system, in order to obtain the optimal mode of operation which satisfies the voltage quality and the reliability of the electrical system. The power losses are affected by means of the automatic voltage control for power transformers and control of the injected reactive power. On load tap changers and shunt capacitors where used to minimize the power losses and maintain voltage profile in the permissible values at the consumers' terminals.

As the loads of consumers of electrical power system are variable with time, obtaining the optimal operation mode could be realized by controlling the means of regulating devices.

Minimization the power losses is the main criteria of this study to determinate the economic operation of the power system.

Calculations for determining optimal transformations ratios and optimal injected reactive power are performed for different real operating modes [maximum, normal and minimum loading] of Jordanian electrical power system.

The operating modes loading values and parameters of the Jordanian electrical power system are entered to **Digsilent** program .The results of each case study are introduced in tables which include: active power losses, reactive power losses and terminal voltages.

Many mathematical models are studied to estimate the power losses using transformation ratio (and/or) injected reactive power using MATLAB. Equations reflect the relationships of power losses as function of transformation ratio (and/or) injected reactive power are obtained. Curves of the power losses versus the controlling variables have been illustrated. Optimal controlling variables for main sub stations are introduced. In this paper, new substations (Qatrana and Amman north) are studied, to measure the expected effect of adding these substations to Jordanian electrical power system.

According to the results obtained, recommendations for improving the performance of the power system are introduced. The regulation limits of the optimization process are taken into consideration and are not to be exceeded.

The power losses in electrical network as well as real and reactive power flows for all equipment connecting the buses can be computed by means of load flow simulation. The quantification and minimization of losses is important because it will determine the economic operation of the power system [5]. If we know how the overall losses occur, we can take steps to minimize them. Active power losses can be determined by various methods.

The power losses can be calculated by the equation [9]:

$$\Delta P = \sum_{i=1}^{n} R_i (I_{ia}^2 + I_{ir}^2)$$

With the following constraints:

$$MI_a = J_a$$

$$MI_r = J_r$$

$$(I_{ia}^2 + I_{ir}^2)^{1/2} \le I_{i.per}$$

$$J_{ia\min} \le J_{ia} \le J_{ia\max}$$

$$J_{ir\min} \le J_{ir} \le J_{ir\max}$$

where M: the first incidence matrix, R: branch resistances, I: branch currents, J: nodal currents. To obtain the relation ship between the losses and the transformation ratio $\Delta P_* = f(K_*)$ different numerical analysis methods are used to define the final formula:

$$\Delta P_* = aK_*^{\alpha} + bK_*^{\beta}$$

Where:

$$\Delta P_* = \frac{\Delta P}{\Delta P_0};\ K_* = \frac{K}{K_0}$$

The a, b, α, β - are constants that reflect the influences of the transformation ratio on the operating mode[10,11].

The power loss in a line can also be calculated by taking the algebraic sum of the total power flows in either direction and the total loss would be the sum of all the line losses [3]. Two methods in order to reduce the losses on the system network will be discussed in this paper. They include:

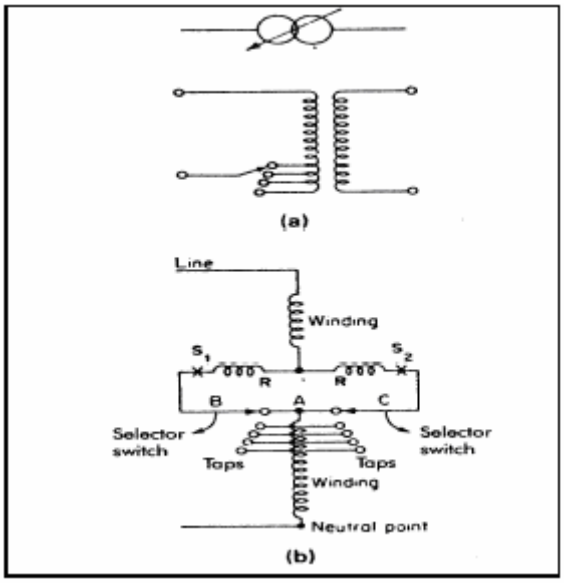
(1) the change of transformer tap settings

(2) addition of different values of capacitor banks to control reactive power distribution

2. Application of Tap Changers of Transformers

Tap changing can control the reactive power flow so optimum bus voltages can be determined and reduce the losses. A method of controlling the voltages in a network makes the use of transformers, the turns ratio of which may be changed. A schematic diagram of an off-load tap changer is shown in Figure 1 (a) which requires disconnection of the transformer when the tap setting is to be changed. Many transformers now have on-load tap changers as can be shown in Figure 1 (b).

Figure 1: (a) Off-load Tap changing transformer. (b) On-load tap-changing transformer with S1 and S2 transfer switches, T centre-tapped reactor [3]



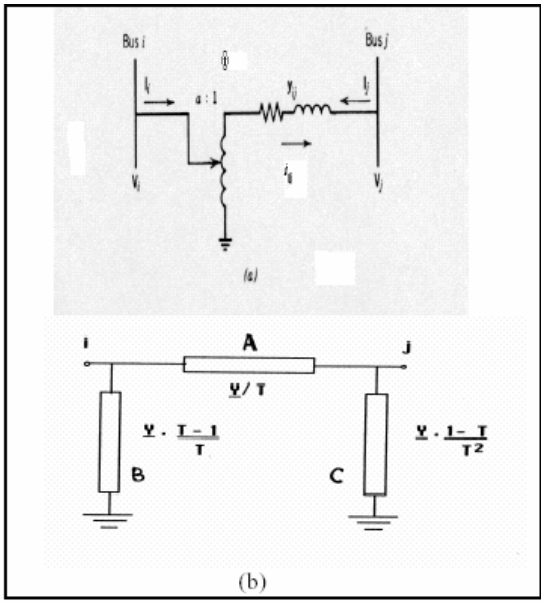
The presence of a tap changer allows manual or automatic change of the turn ratio, and hence of the output voltage. Because of the impedance of the lines, the voltage at the receiving end is slightly lower than the voltage at the sending end for most loads. In order to get a constant and rated voltage at the secondary of a 'normally' step-down transformer automatically, an on load tap changer with additional S1 and S2 transfer switches and R centre-tapped reactor is mounted at the primary side of it as shown in Figure 1 (b).

Assume that an automatic load tap changing transformer (OLTC) is connected to a particular bus to keep load voltage constant. It is possible to run the load flow program employing one tap setting and without mentioning the magnitude of load voltage. If the voltage magnitude determined by the load flow program run exceeds the given limits, a new tap setting is then selected for the next run. In general, when the automatic tap changing feature is employed to represent a manual tap-changing transformer, the output of the load flow program will specify the tap setting that gives the required bus voltage. The change of tap setting or turn ratio will change the system impedance matrix. Therefore, after each tap ratio adjustment, the Y bus admittance matrix has to be adjusted.

Another means of taking into account the OLTC transformer is to represent it by its impedance, or admittance, connected in series with an ideal autotransformer, as shown in Figure 2 (a). A model of a load tap changer needs to be developed. An equivalent circuit, as shown in Figure 2 (b) [13], can be developed in load flow studies. The

Presence of the tap changing transformer causes necessary modifications to the Newton-Raphson power flow technique. The elements of the equivalent □ circuit, can then be treated in the same manner as line elements.

Figure 2: O LTC transformer representations: (a) equivalent circuit; (b) equivalent ∏circuit .



The following parameters of the equivalent ∏circuit (Figure 2 (b)) in terms of admittances and off nominal turns ratio T can be derived:[5]

$$A = \frac{y_{ij}}{T} \;;\; B = \left(1 - \frac{1}{T}\right) y_{ij} \;;\; C = \frac{1}{T}\left(\frac{1}{T} - 1\right) y_{ij}$$

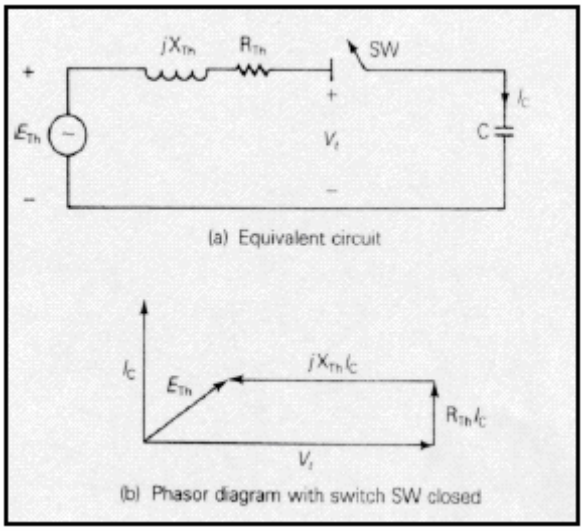
T - per unit turns ratio

The presence of a tap changing transformer changes the elements of both diagonal and off-diagonal of bus admittance matrix where the transformer is connected between two buses.

3. Application of Switched Capacitor Banks

Capacitors are used in the transmission/distribution line to increase line loadability (maximum power transfer) and to adjust the system voltage.[5] Shunt capacitors are used to deliver reactive power and increase the voltage magnitudes during heavy load conditions. Figure 3 shows the effect of adding a shunt capacitor bank to a power system bus. The system is represented by its Thevenin equivalent at the node, where the capacitor will be applied by closing the switch. With the switch open, the node voltage *Vt* is equal to the Thevenin voltage -*Eth*.

Figure 3: Effect of adding a shunt capacitor to a power system bus.



From the power flow standpoint, the addition of a shunt capacitor bank to a load bus corresponds to the addition of a negative reactive load. The power flow program computes the increase in bus voltage magnitude along with the small change in phase angle.

The additional capacitor is modeled with the susceptance B. Given a required reactive power injection of Q, the susceptance B can be calculated from Q = V2B. V is the initial voltage of the bus where the shunt capacitor needs to be installed.

The addition of capacitor bank changes the bus admittance matrix similar to the change of tap setting of transformer. However, it will only affect the element of the diagonal admittance matrix of the bus where the capacitor is added.

In this work, the Polynomial functions are implemented for there simplicity in: Definition, Roots and Graphs. The general form of this function:

$$f(x) = a_n X^n + a_{n-1} X^{n-1} + ... + a_1 X + a_0$$

The value of n must be a nonnegative integer. That is, it must be whole number; it is equal to zero or a positive integer. The coefficients, as they are called, are an, an-1, ..., a1, a0. These are real numbers. The degree of the polynomial function is the highest value for n where an is not equal to 0.

4. Case Studies

The substations Al Qatrana and Amman north are studied, to measure the expected effect of adding these substations to Jordanian electrical power system.

To explore the result in this paper we introduce only the data and the calculations for Amman South substation (maximum loading).

Power losses calculations for Jordanian Electrical Power System 400 – 132 – 33 KV.

Power losses reduction using voltage and reactive power control.

4.1. Power losses reduction using automatic tap changing (transformation ratio)

To obtain the relationship between the active power losses and automatic tap changing (transformation ratio), Δ P = f (KT), MATLAB curve fitting was used according to the real results.

The power losses can be determined by using

$$Y = a_1 X^3 + a_2 X^2 + a_3 X + a_4$$

Where:

Y: ΔP -indicates active power losses in (MW).

X: K_T -indicates transformation ratio.

a1: coefficient of X3.

a2: coefficient of X2.

a3: coefficient of X.

a4: absolute coefficient

The final formula of active power losses as a function of transformation ratio and injected reactive power are introduced for each substation.

4.1.1. Substation Amman South (400/132) Effect of Tap Changer on Active power losses

This study when the Jordanian System – no interconnection (maximum load)

Table 1: Substation Amman South (400/132

Tap Changer	Transfo-Rmation Ratio	High Voltage Termin-Al (KV)	Low Voltage Terminal (KV)	Active Power Losses (MW)	Reactive Power Losses (Mvar)
-9	0.280	439.10	122.33	31.66	-107.49
-8	0.286	426.64	123.92	30.65	-116.52
-7	0.291	434.07	125.44	29.77	-123.86
-6	0.297	431.40	126.19	29.01	-129.62
-5	0.302	428.64	128.29	28.36	-133.93
-4	0.308	425.81	129.63	27.81	-136.90
-3	0.313	422.91	130.91	27.35	-138.61
-2	0.319	419.95	132.13	26.98	-139.15
-1	0.324	416.95	133.30	26.69	-138.61
0	0.330	413.89	134.43	26.47	-137.06
1	0.336	410.81	135.50	26.32	-134.57
2	0.341	407.69	136.52	26.24	-131.19
3	0.347	404.55	137.49	26.22	-127.00
4	0.352	401.38	138.42	26.25	-122.03
5	0.358	398.20	139.31	26.33	-116.34
6	0.363	395.62	140.16	26.46	-109.99
7	0.369	391.82	140.96	26.64	-103.01
8	0.374	388.62	141.73	26.86	-95.44
9	0.379	385.42	142.46	27.11	-87.33

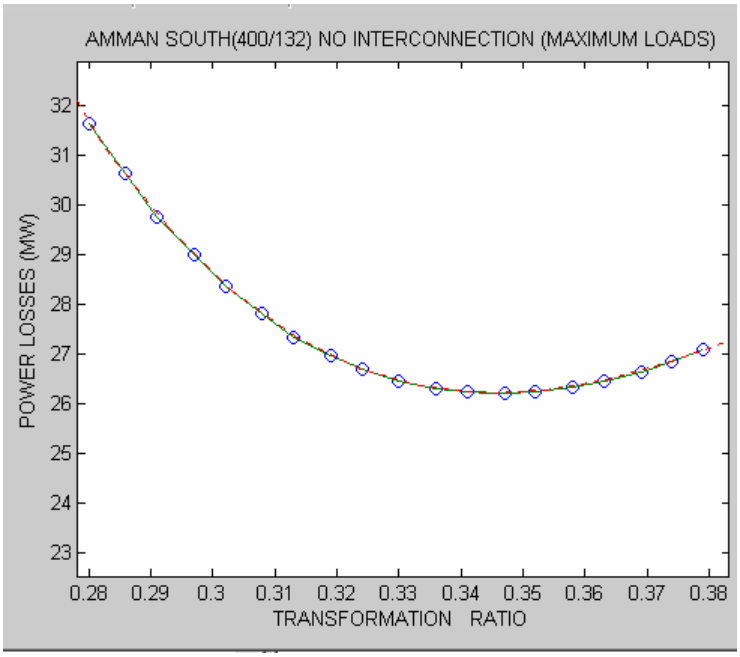
Power losses due to transformation ratio are given by the following expression:

P_{losses}=-5072.6*K_T^3+6198.5*K_T^2–2466.5*K_T+347.7.

$\Delta P = -5072.6K_T^3 + 6198.5K_T^2 - 2466.5K_T + 347.7$. The optimum transformation ratio for maximum load operation is: $K_T = 0.3470$.

The minimum power losses due to this transformation ratio are: ΔP = 26.22 (MW).

Figure 4: The Effect of the Tap changer a on the power losses



4.2. Power losses reduction by using shunt capacitors (reactive power control)

To obtain the relationship between the active power losses and the reactive power injected. $P = f(Q_{inj})$, MATLAB curve fitting was used according to the real results.

The power losses are determined by the following expression:

Y = A1 * X3 + A2 * X2 + A3 * X + A4

Where:

Y: indicates active power losses value in (MW).

X: indicates reactive power injected in (MVAR).

A1: coefficient of X3.

A2: coefficient of X2.

A3: coefficient of X.

A4: absolute coefficient

The final formula of active power losses as a function of transformation ratio and injected reactive power are introduced for each substation.

4.2.1. Substation Amman South (400/132) Effect of injected reactive power on Active power losses

This study when the Jordanian System – no interconnection (maximum load), table 2.

Table 2: The injected reactive power

REACTIVE POWER INJECTED (MVAR)	HIGH VOLTAGE TERMINAL (KV)	LOW VOLTAGE TERMINAL (KV)	ACTIVE POWER LOSSES (MW)	REACTIVE POWER LOSSES (MVAR)
5	407.33	127.06	34.37	- 62.14
10	408.97	127.62	34.06	- 69.22
15	410.61	128.19	33.77	- 76.13
20	412.27	128.78	33.48	- 82.88
25	413.93	129.33	33.21	- 89.45
35	417.29	130.49	32.71	- 102.06
40	418.99	131.07	32.47	- 108.09
45	420.69	131.66	32.26	- 113.95

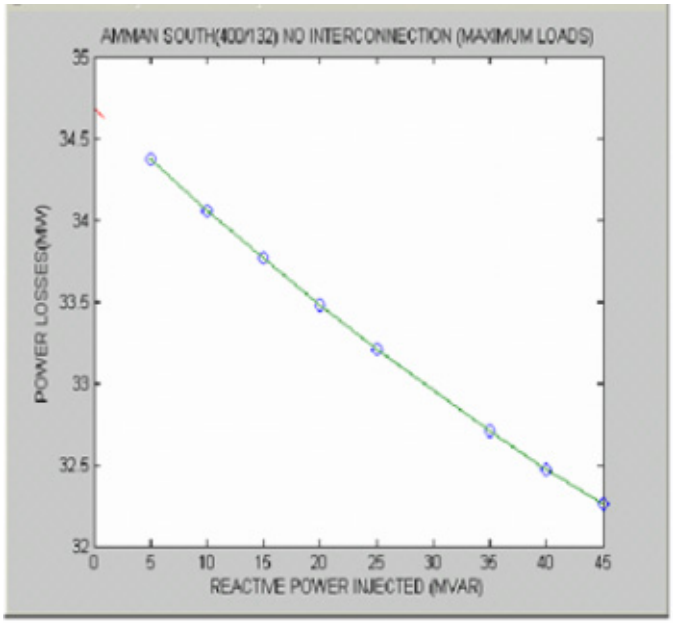
Power losses due to reactive power injected are given by the following expression:

$P_{losses} = 0.0002 * Q_{injected}^{2} - 0.0644 * Q_{injected} + 34.6865.$

The optimum injected reactive power for maximum load operation is:

$Q_{injected} = 45$ (Mvar). The minimum power losses due to optimum injected reactive power are: $P_{losses} = 32.26$ (MW).

Figure 5: The Effect of the injected reactive power on the power losses.



4.3. Power losses reduction using automatic tap changing transformer (transformation ratio) and shunt capacitors (reactive power control).

To obtain the relationship between the active power losses using automatic tap changing transformer (transformation ratio) and reactive power injected $P = f(KT, Q_{inj})$, MATLAB curve fitting was used according to the real results.

The power losses are determined by the following expression

$Z = A1 * X + A2 * Y + A3.$

Where:

Z: indicates active power losses value in (MW).
X: indicates reactive power injected in (MVAR).
Y: indicates transformation value.
A1: coefficient of X.
A2: coefficient of Y.
A3: absolute coefficient.

The final formula of active power losses as a function of transformation ratio and injected reactive power are introduced for each substation.

4.3.1. Substation: Amman South (400/132). Effect of the tap changer and injected reactive power losses.

This case study for the Jordanian system with interconnection (maximum loads)

Table 3: The transformation ratio and the injected reactive power

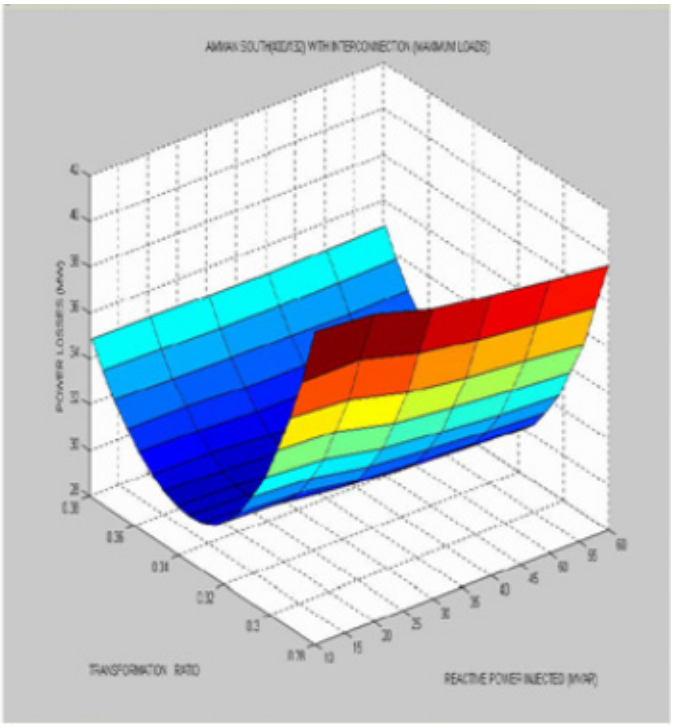
REACTIVE POWER INJECTED (MVAR) / TRANSFORMATION RATIO	Q = 10 MVAR	Q = 20 MVAR	Q = 30 MVAR	Q = 40 MVAR	Q = 50 MVAR	Q = 60 MVAR
0.280	41.61	41.38	40.62	40.23	39.88	39.57
0.286	39.20	38.98	38.28	37.93	37.61	37.33
0.291	37.11	36.90	36.26	35.94	35.66	35.41
0.297	35.31	35.13	34.54	34.26	34.00	33.78
0.302	33.81	33.64	33.11	32.85	32.62	32.44
0.308	32.57	32.42	31.94	31.71	31.51	31.35
0.313	31.60	31.45	31.02	30.82	30.65	30.51
0.319	30.86	30.75	30.34	30.17	30.02	29.91
0.324	30.35	30.24	29.89	29.74	29.62	29.53
0.330	30.06	29.90	29.65	29.52	29.42	29.35
0.336	29.97	29.87	29.61	29.49	29.41	29.37
0.341	30.06	29.98	29.75	29.65	29.59	29.56
0.347	30.33	30.25	30.06	29.98	29.94	29.93
0.352	30.76	30.69	30.52	30.47	30.44	30.44
0.358	31.34	31.28	31.14	31.10	31.08	31.10
0.363	32.06	32.01	31.89	31.86	31.86	31.89
0.369	32.90	32.86	32.77	32.75	32.70	32.81
0.374	33.87	33.83	33.76	33.76	33.78	33.83
0.379	34.94	34.91	34.86	34.87	34.90	34.96

Power losses due to transformation ratio and reactive power injected are given by the following expression:

$P_{losses} = - 0.0137 * Q_{inj} - 0.7759 * KT + 30.3657.$

The optimum transformation ratio and optimum injected reactive power for maximum load operation is: KT = 0.330. $Q_{injected}$ = 60 (Mvar). The minimum power losses due to optimum transformation ratio and optimum injected reactive power is: P_{losses} = 29.35 (MW).

Figure 6: The Effect of the Tap changer and the injected reactive power on the power losses



5. Recommendations

A) According to the results of calculations for power losses minimization in Jordanian Electrical Power System with Automatic Tap Changing Transformers (At Maximum Loading).

Table 4: recommendation data for the optimal transformation ratio (tap changer)

Transf-ormer (Sub-station)	Normal position		Optimal position		To optimize the performance of the electrical power system Change tap	
	Transformation ratio		Transformation ratio	Tap number	From	to
Amman South	0.330	0	0.341	2	0 to	2
Aqaba	0.324	-1	0.330	0	-1 to	0

B) According to the results of calculations for power losses minimization in Jordanian Electrical Power System with Reactive Power Injected.

1. (At Maximum Loading).

Table 5: recommendation data for the optimal injected reactive power.

Transformer Substation	Normal position	Optimal position	To optimize the performance of the electrical power system Change reactive power injected MVAR	
	Reactive power Injected (MVAR)	Reactive power Injected (MVAR)	From	To
Amman South	2*40	2*45	2*40	2*45

6. Conclusions

The main findings of the study can be summarized as follows:

- Optimizing operating modes of electrical power system can be made by controlling the transformation ratios and injected reactive power in main sub stations.

- Mathematical models are introduced to estimate the power losses using transformation ratios (and/or) injected reactive power using MATLAB program.
- Optimal controlling variables for main substations are obtained.
- Recommendations for improving the performance of the Jordanian electrical power system are introduced.

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Effect of Air Gap on Torque Density for Non-Slotted Axial Flux TORUS and AFIR PM Motors

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Abstract

There are two topologies for non-slotted double-sided axial flux PM (AFPM) motors. The stator of the non-slotted AFPM machine is realized by non-slotted tape wound core with AC polyphase air gap windings and the rotor structure is formed by axially magnetized fan-shaped surface mounted Neodymium Iron Boron (NdFeB) permanent magnets. Selecting an AFPM motors with high torque densities an important parameter in applications. So, comparison of torque density between different topologies of double-sided AFPM motors seems to be necessary.

In this paper, the sizing equations of axial flux non-slotted one-stator-two-rotor (TORUS) and two-stator-one-rotor (AFIR) type PM motors is presented and comparison of the TORUS and AFIR topologies in terms of torque density is illustrated. Finally a high torque non-slotted double-sided AFPM motor is introduced in the paper.

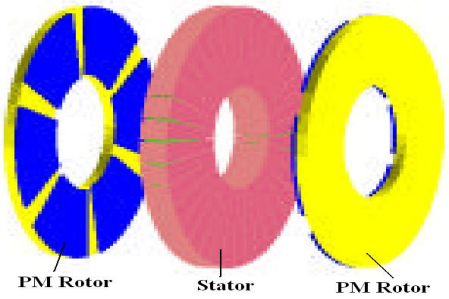
Keywords: Axial flux PM motors (AFPM), torque density.

I. Introduction

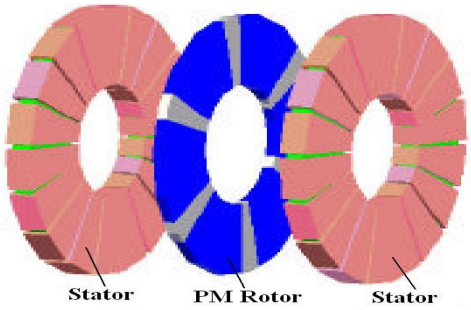
Double-sided axial flux PM motors (AFPM) are the most promising and widely used types. AFPMs (commonly called disc machines) are synchronous machines. In conventional machines, the air gap flux density has normally radial direction; in AFPMs, the air gap flux density presents mainly axial direction. In general, AFPMs exhibit an axial length much smaller than the length of a conventional motor of the same rating [1].

There are two topologies for non-slotted double-sided AFPM motors. These topologies are axial flux non-slotted one-stator-two-rotor (TORUS) and two-stator-one-rotor (AFIR) type PM motors. Two AFPM motors and their acronyms are selected TORUS-NS (Axial flux non-slotted external rotor internal stator PM stator) and AFIR-NS (Axial flux non-slotted internal rotor external stator PM motor) for detailed analysis. The stator of the non-slotted AFPM motors are realized by non-slotted tape wound core with AC polyphase air gap windings that are back-to-back wrapped around the stator core. The rotor structure is formed by axially magnetized surface mounted Neodymium Iron Boron (NdFeB) permanent magnets and shaft. Detailed views of the stator and rotor structures of the TORUS-NS and AFIR-NS motor are given in Fig.1. The portions between the windings are assumed to be filled with epoxy resin as in all non-slotted structures in order to increase the robustness of the structure and provide better conductor heat transfer. Moreover, the radial portions of the air gap windings are used for the torque production [3-4].

Figure 1: Axial flux non-slotted
(a) one-stator-two-rotor TORUS-NS type [4]
(b) two-stator-one-rotor AFIR-NS type [3]



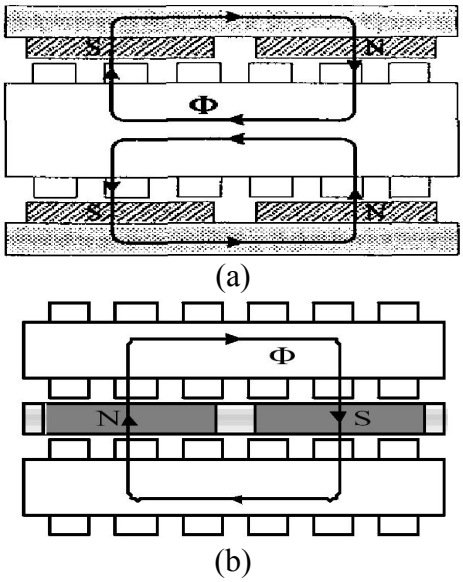
(a)



(b)

Flux directions of both AFIR and TORUS non-slotted topologies at the average diameter in 2D are also shown in Fig.2a and 2b.

Figure 2: One pole pair of the (a) TORUS-NS [4] (b) AFIR-NS [3]



Selecting a double-sided AFPM motors with high torque density is an important parameter, especially in electrical vehicle applications. So, comparison of torque density between different topologies of double-sided AFPM motors seems to be necessary.

Increasing the air gap length, maximum torque density will change in AFPM motors. These changes are not the same in different topologies. Maximum torque density of TORUS-NS is higher than AFIR-NS in large air gap length.

In Section II, the generalized sizing approach for TORUS-NS and AFIR-NS types PM motors is briefly discussed. Then, some results of comparisons of the TORUS-NS and AFIR-NS topologies in terms of torque density are illustrated in Section III. The conclusions are given in Section IV.

II. Sizing Equations of AFPM Motors

In general, if stator leakage inductance and resistance are neglected, the output power for any electrical machine can be expressed as

$$P_{out} = \eta \frac{m}{T} \int_0^T e(t).i(t)\, dt = mK_p \eta\, E_{pk} I_{pk} \tag{1}$$

where

$e(t)$ and E_{pk} are phase air gap EMF and its peak value, $i(t)$ and I_{pk} are phase current and the peak phase current, η is machine efficiency, m is number of phases of the machine and T is period of one cycle of the EMF[2-4].

The quantity K_p is termed the electrical power waveform factor and defined as

$$K_p = \frac{1}{T} \int_0^T \frac{e(t) \times i(t)}{E_{pk} \times I_{pk}} dt = \frac{1}{T} \int_0^T f_e(t) . f_i(t) dt \tag{2}$$

where

$f_e(t)=e(t)/E_{pk}$ and $f_i(t)=i(t)/I_{pk}$ are the expressions for the normalized EMF and current waveforms. In order to indicate the effect of the current waveform, a definition for current waveform factor, K_i, is also useful,

$$K_i = \frac{I_{pk}}{I_{rms}} = \left[\frac{1}{T} \int_0^T \left(\frac{i(t)}{I_{pk}} \right)^2 dt \right]^{-0.5} \tag{3}$$

where

I_{rms} is the rms value of the phase current. The peak value of the phase air gap EMF for AFPM in (1) is given by:

$$E_{pk} = K_e N_{ph} B_g . \frac{f}{p} .(1-\lambda^2) D_o^2 \tag{4}$$

where

K_e is the EMF factor which incorporates the winding distribution factor K_w and the per unit portion of the total air gap area spanned by the salient poles of the machine (if any), N_{ph} is the number of turn per phase, Bg is the flux density in the air gap, f is the converter frequency, p is the machine pole pairs, λ is the diameter ratio for AFPM defined as D_i/D_o, D_o is the diameter of the machine outer surface, D_i is the diameter of the machine inner surface. The peak phase current in (1) is given by:

$$I_{pk} = A \pi K_i \frac{1+\lambda}{2} . \frac{D_O}{2m_1 N_{ph}} \tag{5}$$

where

m_1 is number of phases of each stator and A is the electrical loading. Combining (1) through (5), the general purpose sizing equations take the following form for AFPM.

$$P_{out} = \frac{m}{m_1} \frac{\pi}{2} K_e K_p K_i A B_g \eta \frac{f}{p} (1-\lambda^2)(\frac{1+\lambda}{2}) D_o^3 \tag{6}$$

The machine torque density for the total volume can be defined as

$$T_{den} = \frac{P_{out}}{\omega_m \frac{\pi}{4} D_{tot}^2 L_{tot}} \tag{7}$$

where

ω_m *is* the rotor angular speed, D_{tot} is the total machine outer diameter including the stack outer diameter and the protrusion of the end winding from the iron stack in the radial direction, L_{tot} is the total length of the machine including the stack length and the protrusion of the end winding from the iron stack in the axial direction [2-4].

A. Sizing equations for the TORUS-NS

The generalized sizing equation approach can easily be applied to axial flux permanent magnet TORUS type motor [4].

The outer surface diameter can be written as

$$D_o = \left(P_{out} \Big/ \frac{\pi m}{2m_1} K_e K_p K_i A B_g \eta \frac{f}{p} (1-\lambda^2)(\frac{1+\lambda}{2}) \right)^{1/3} \tag{8}$$

The machine total outer diameter D_{tot} for the TORUS-S motor is given by

$$D_{tot} = D_o + 2W_{cu} \tag{9}$$

where

W_{cu} is the protrusion of the end winding from the iron stack in the radial direction. For the back-to-back wrapped winding, protrusions exist toward the axis of the machine as well as towards the outsides and can be calculated as

$$W_{cu} = \frac{D_i - \sqrt{D_i^2 - \left(2AD_g \Big/ K_{cu} J_s \right)}}{2} \tag{10}$$

where

D_g is the average diameter of the machine, J_s is the current density and K_{cu} is the copper fill factor.

The axial length of the machine L_e *is* given by

$$L_e = L_s + 2L_r + 2g \tag{11}$$

where

L_s is axial length of the stator, L_r is axial length of the rotor and g is the air gap length. The axial length of the stator L_s *is*

$$L_s = L_{cs} + 2W_{cu} \tag{12}$$

The axial length of the stator core L_{cs} can be written as

$$L_{cs} = \frac{B_g \ \pi\alpha_p \ D_o(1+\lambda)}{4p\, B_{cs}} \tag{13}$$

where

B_{cs} is the flux density in the stator core and α_p is the ratio of average air gap flux density to peak air gap flux density.

Since there is no rotor core in rotor PM topologies, the axial length of rotor L_r is

$$L_r = L_{PM} \tag{14}$$

Also, the axial length of the rotor core L_{cr} is

$$L_{cr} = \frac{B_u \ \pi D_o(1+\lambda)}{8p\, B_{cr}} \tag{15}$$

where

B_{cr} is the flux density in the rotor disc core, and B_u is the attainable flux density on the surface of the PM.

The PM length L_{PM} can be calculated as

$$L_{PM} = \frac{\mu_r \ B_g}{B_r - \left(\frac{K_f}{K_d} B_g\right)} (g + W_{cu}) \tag{16}$$

where

μ_r is the recoil relative permeability of the magnet, B_r is the residual flux density of the PM material, K_d is the leakage flux factor, K_c is the Carter factor, $K_f = B_{gpk}/B_g$ is the peak value corrected factor of air gap flux density in radial direction of the AFPM motor. These factors can be obtained using FEM analysis [4].

B. Sizing equations for the AFIR-NS

The concept of Double-sided Axial Flux two-stator-one-rotor (AFIR) type PM motors was presented in [2-3].

The outer surface diameter D_o is obtained from (6).

$$D_o = \left(2P_{out} \Big/ \frac{\pi m}{2m_1} K_e K_p K_i A B_g \eta \frac{f}{p} (1-\lambda^2)\left(\frac{1+\lambda}{2}\right) \right)^{1/3} \tag{17}$$

The machine total outer diameter D_{tot} for the AFIR type machines is given as

$$D_{tot} = D_o + 2W_{cu} \tag{18}$$

where

W_{cu} is the protrusion of the end winding from the iron stack in the radial direction and can be calculated as

$$W_{cu} = \frac{D_i - \sqrt{D_i^2 - \left(A D_g \Big/ K_{cu} J_s \right)}}{2} \tag{19}$$

The axial length of the machine L_e is

$$L_e = L_r + 2L_s + 2g \tag{20}$$

where

L_s is axial length of the stator, L_r is axial length of the rotor and g is the air gap length. The axial length of a stator L_s is

$$L_s = L_{cs} + 2W_{cu} \tag{21}$$

where

L_{cs} is the axial length of the stator core.

The axial length of the stator core L_{cs} *can* be written as

$$L_{cs} = \frac{B_g \, \pi \alpha_p \, D_o (1+\lambda)}{8 p \, B_{cr}} \tag{22}$$

Since there is no rotor core in rotor PM topologies, the axial length of rotor L_r is

$$L_r = L_{PM} \tag{23}$$

The PM length L_{PM} can be calculated as

$$L_{PM} = \frac{2\mu_r \, B_g}{B_r - \left(\frac{K_f}{K_d} B_g \right)} (g + W_{cu}) \tag{24}$$

III. Comparison of TORUS-NS and AFIR-NS

Comparison of two different Double-sided axial flux non-slotted PM motors in terms of torque density is accomplished for 10HP output power, 6 poles and 60Hz drive. In this comparison, other constant parameters of motors are tabulated in table1.

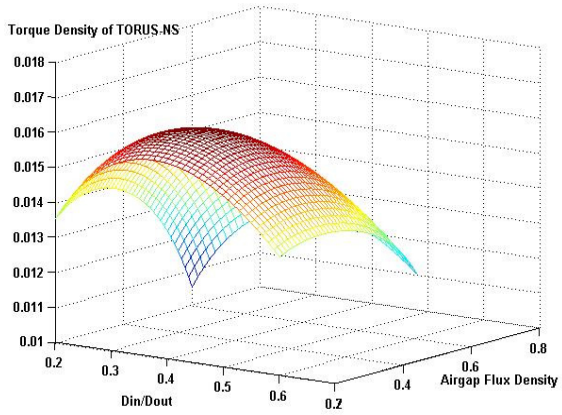
Table 1: Constant parameters of motors

Number of phases	3
Slot fill factor	0.8
Pole arc ratio	0.75
Slot per Pole per Phase	1
flux density in stator	1.5 T
flux density in rotor	1.5 T
Efficiency	90%
PM Residual flux density	1.1 T

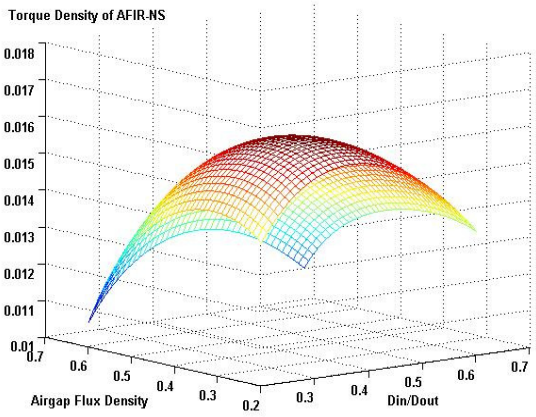
In AFPM motors, the air gap flux density, Bg and diameter ratio, λ and are the two important design parameters which have significant effect on the motor characteristics. Therefore, in order to optimize the motor performance, the diameter ratio and the air gap flux density must be chosen carefully.

Fig.3 shows the torque density variation as a function of air gap flux density and the diameter ratio for the AFIR-NS and TORUS-NS motors.

Figure 3: Torque density vs. air-gap flux density and diameter ratio for A=30000 (A/m), g=1 (mm), J_s=9000000 (A/m^2)
a) TORUS-NS b) AFIR-NS



(a)



(b)

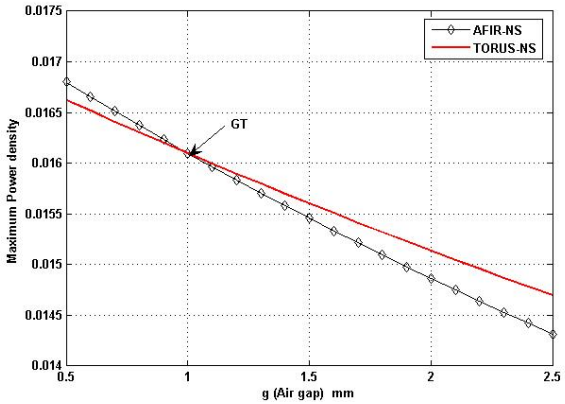
As can be seen from Fig3b, the maximum torque densityoccurs at Bg=0.312 T and $\lambda = 0.343$. Varying air gap length, maximum torque densityoccurs in different Bg and λ. Table2 shows maximum torque density with corresponding Bg and λ.

Table 2: Maximum torque density with corresponding Bg and

Type	g (mm)	Bg (T)	λ	Maximum torque density (N.m/cm^3)
TORUS-NS	1	0.32	0.36	0.0161
	1.5	0.32	0.365	0.0155
	2	0.32	0.37	0.0151
AFIR-NS	1	0.31	0.34	0.0161
	1.5	0.3	0.35	0.0152
	2	0.3	0.35	0.0149

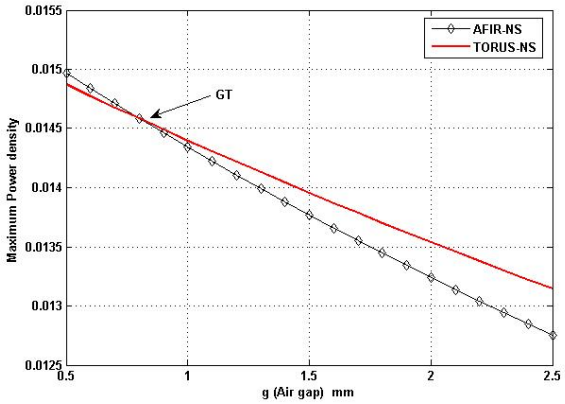
Fig.4 shows the maximum torque density variation as a function of air gap length for the AFIR-NS and TORUS-NS motors for A=30000 (A/m), Js=9000000 (A/m^2).

Figure 4: maximum torque density AFIR-S and TORUS-NS vs. air-gap length



In as special air gap length (this air gap length is called G_T) maximum torque density of AFIR-NS and TORUS-NS motors will be the same. Considering Fig.4, it can be concluded that in large air gap length, non-slotted TORUS motor has high torque density.

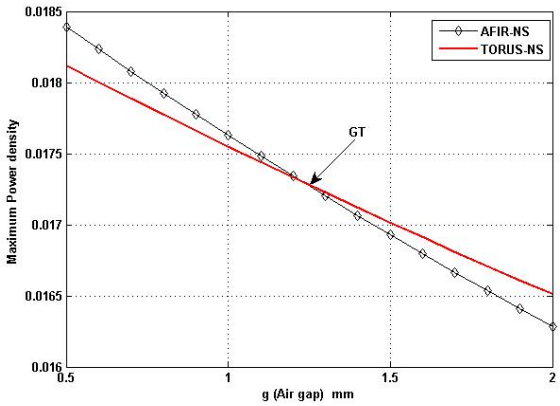
Figure 5: maximum torque density AFIR-NS and TORUS-NS vs. air-gap length



The considerable point is that the value of G_T will vary when the electrical loading 'A' and current density 'Js' changes. Fig.5 shows the maximum torque density variation as a function of air gap length in A=25000 (A/m) for the AFIR-NS and TORUS-NS motors.

Fig.6 shows the maximum torque density variation as a function of air gap length in A=35000 (A/m) for the AFIR-NS and TORUS-NS motors also.

Figure 6: maximum torque density AFIR-NS and TORUS-NS vs. air-gap length



According to Fig.5 it can be concluded that point G_T is shifted to larger air gaps and this means that in smaller air gaps AFIR-NS motor has higher maximum torque density. According to Fig.6 it can be concluded that point G_T is shifted to smaller air gaps and this means that in higher air gaps TORUS-NS motor has higher maximum torque density. Other value of G_T for various A is tabulated in table 3.

Table 3: Other value of GT for Various A

A	GT (mm)
15000	0.45
20000	0.62
25000	0.8
30000	1
35000	1.23
40000	1.47

IV. Conclusions

Selecting an AFPM motors with higher torque density is an important parameter in applications. The main goal of this paper has been introducing to double-Sided Axial Flux non-slotted PM Motors with maximum torque density. There are two topologies for non-slotted double-sided AFPM motors.

The maximum torque density is changed by different value of the air gap and electrical loading TORUS-NS topology has high torque density in low electrical loading. But, AFIR-NS topology has high torque density in high electrical loading.

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Power Law Fluid Modeling of Polymer Melts

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Abstract

Rheological characterization of materials has been a power full tool for the design of successful processing operations. For polymeric materials, Capillary Rheometry proved to be the mostly used tool to evaluate and model their rheological behavior. An experimental investigation has been made into the power law fluid behavior of different polymer melts by employing a simple rheometer as a device. The melts used were commercial grade Low Density Polyethylene (LDPE) and Polypropylene (PP), tested at different temperatures. Three different lengths to diameter (L/D) ratio extrusion capillary dies were used in this investigation. Wall shear stress (τ_w) and wall shear strain rates (ϕ_w) were evaluated and finally Power Law Fluid (PLF) model was tested by incorporating Rabinowitsch and Bagley corrections. It was observed that the melts obeyed the Power Law Model over a fair range of strain rates. The Power law index (n) increased with the temperature while the Consistency Coefficient (m) showed the reversed behavior. The pressure drop increased with the length to diameter (L/D) ratio and orifice pressure drop (ΔP_o) accounted for 42% for LDPE and 22% for PP.

Keywords: Capillary Rheometry, Bagley correction, Power law, Polymer melts, Rehology

Introduction

Capillary Rheometry is most widely used method for the determination of rheological properties of polymer melts like melt viscosity. Its gives the best simulation of fabrication process like extrusion, calendaring and molding (filling) by operating at high shear rates Goettfert and Axel (1986). Many groups have used this technique in order to study the effects of various parameters like molecular weight, chain branching in the case of homopolymers and composition and degree of mixing in the case of blends and filled systems. A detailed review on polyolefins' rheology is given by the Markus

Gahleitner (2001). Importance of rheology with respect to the properties is discussed especially in multiphase blends by Liang J.Z. and Ned J.N (1997). Shear viscosity and temperature effects (Arrhenius plots) were evaluated by capillary rheometer for Linear Low Density Polyethylene and Low Density Polyethylene (PE-LLDPE) blends. Interestingly, effect of the blend content on End pressure losses has been elaborated. Similarly polymer blends of five different common polymers were studied with capillary rheometer at 210ºC by Carley J.F. and Crossan S.C. (1981). Shear Stress at a range of corrected strain rates was evaluated and subsequently used in the calculation of shear viscosity (η). A model was proposed between η values and blend composition. High Impact Polystyrene (HIPS) was extensively studied under capillary flow conditions at a wide range of strain rates by Liang J.Z. and Ness J.N (1999). End pressure losses were evaluated and these values showed exponential dependence of the strain rates. Power law parameters were evaluated and the behavior showed high rate sensitivity at higher strain rates. Bgley correction or end pressure losses were studied by Mitsoulis.E. (1998); etc. al., and Mitsoulis.E (2003); etc. al., for Low Density Polyethylene and Polypropylene LDPE and PP using orifice die (L/D=0) and tapered capillary die. End losses proved to be the strong function of entrance angle. Three different grades of LDPE and High Density Polyethylene (HDPE) were rheologically characterized by capillary rheometer by evaluating the end losses and Extensional viscosity (η) by Padmanabhan.M (1997) etc. al.,~ Similarly, Steady state flow properties of melts, Bagley and Rabinowitsch corrections were made along with the extensional viscosity by Rosales C. (1999) etc. al., Instead of using moving piston rheometers, moving barrel rheometer was used in the study of rheological properties of melts by Sombatsompop N (2001) etc. al., and it was concluded that rheology did depend on the mode of operation and Capillary die size.

Capillary Rheometry has successfully been used in the characterization of raw rubber stocks. In a representative study Power law parameters were developed for rubber stock as the function of filler and loading temperature by Dick J.S. (2002) etc. al., Another example of new application the study of effects of rheological parameters on the Denier of the Polyethylene Terepthalate (PET) fiber was carried out by Kianc T.C. (1992) etc. al., Four samples of different Viscosity average Molecular Weight (M_v) were tested at the strain rate of 300-3000 (1/s) and were found pseudoplastic. Capillary Rheometry is not only restricted to the polymers but it has been already extended to the filled composites Schemenauer (2000) etc. al., and Liquid Crystal (LC) polymers White J.L, (2004) etc. al.,

In the present study, commercial grade commodity thermoplastics, Low Density Polyethylene (LDPE) and Polypropylene (PP) have been selected for their huge consumption and strong dependence of the properties on various grades. A simple capillary rheometry technique was employed with direct data access. Shear strain rates were kept in the range simulating extrusion processing.

Experimental Setup

Materials

All polymers, Low Density polyethylene (Lotrene CD 0230 by QAPCO) and Polypropylene (RELIANCE, India) purchased from market and all were of commercial grade.

Rheological Measurements

A moving piston melt flow tester (KARG Industrietechnik: 3100) with little in house modifications was used. The instrument was equipped with a two compartment polymer heating barrel with a precise temperature control within ± 0.2ºC. Three capillary dies were employed with different aspect ratios; each value is given in Table 1. The instrument was pressurized by using standard weights over the piston. Prior to each run, polymer conditioning time of $5 \leq t \leq 15$ minutes was given to ensure the full melting with in the barrel. LDPE was evaluated at 190 and 210ºC and PP was tested at single temperature of 190ºC.

Table 1: Dimensions of Capillary Dies

Sr.No	Length, mm	Diameter mm	Aspect Ratio (L/D)
1	8.009	2.095	3.82
2	9.91	2.095	4.73
3	29.91	2.095	14.3

Results and Discussion

Flow curves

The wall sear stress (τ_w) was calculated by measuring the pressure gradient (ΔP) along the die length (L). ΔP was calculated by using the standard weight on the piston.

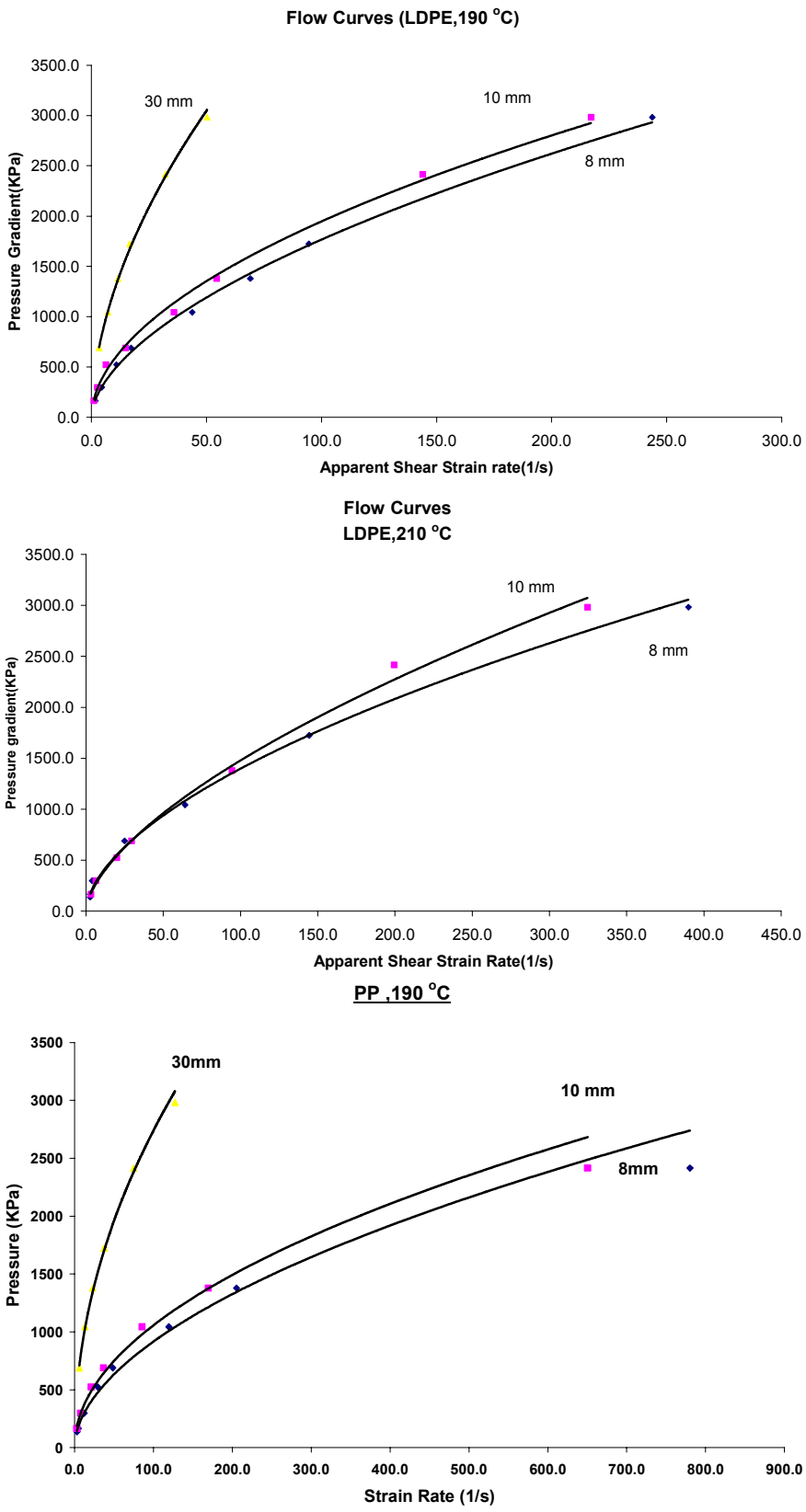
$$\tau_w = \frac{\Delta P R}{2L} \tag{1}$$

Only wall shear stress is possible to be calculated and it makes a representative stress value assuming fixed radial gradient in the capillary. Similarly, apparent shear strain rate ($\dot{\gamma}$) was evaluated once the extrudate volumetric flow rate (Q) has been calculated. The extrudate mass was measured and Q was calculated by using experimental melt density.

$$\phi = \frac{4Q}{\lambda R^3} \tag{2}$$

Flow curves, at each temperature and capillary dies, were evaluated and is shown in Figure 1. These are typical flow curves for a pseudoplastic liquid, exponentially rising and tend to flatten at high shear strain rates.

Figure 1: Flow Curves (a) LDPE (190ºC) (b) LDPE (210ºC) and (c) PP (190ºC)



Rabinowitsch and Bagley corrections

Wall shear stress (τ_w) values were plotted against the calculated apparent shear strain values (ϕ). The log-log plot would give the power law parameters but these couldn't be taken as the 'true' values since

many corrections were needed before any final plot was made. In capillary rheometry these correction include:

a) End Pressure losses
b) Viscous heating
c) Rabinowitsch
d) Reservoir correction and others.

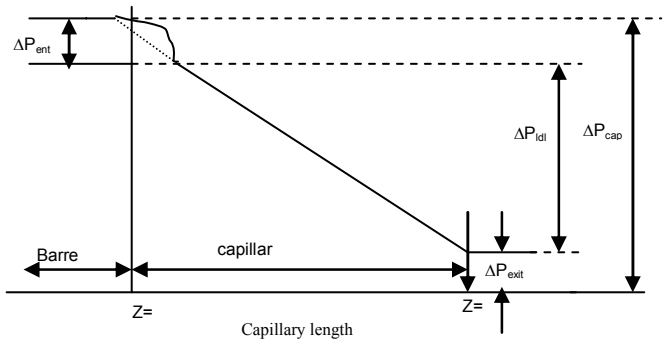
Among all these listed, Rabinowitsch and End Pressure losses are the most significant and usually the corrections are made for there two types of inaccuracies. Rabinowitsch accounts for the non-Newtonian behavior of the fluids and apparent shear rate (ϕ) is converted into the true shear strain rate ($\dot{\gamma}$) by the following formula:

$$\dot{\gamma} = [4n/(3n+1)]^n \phi \quad (3)$$

Where 'n' is the flow index achieved by plotting τ_w Vs shear strain rates. We performed the Rabinowitsch correction in another simpler way (sec 3.3 of this manuscript). Bagley or end correction is the most crucial of among all the corrections and end pressure loss accounts for a significant fraction of the total pressure drop across the capillary die. Actually it's the skin frictional pressure loss in Equation (1) which yields the wall shear stress under Poiseulli Flow, which is shown in Figure 2. The pressure loss at the entrance (ΔP_{ent} at z=0)) and at the exit (ΔP_{ex} at Z=L) is not only significant but also non-linear. So to get the pressure drop only at the capillary wall (ΔP_{ldl} at 0<Z<L), the pressure drop at the entrance (and at the exit) of an orifice die (P_o) is subtracted from the total pressure drop (P).

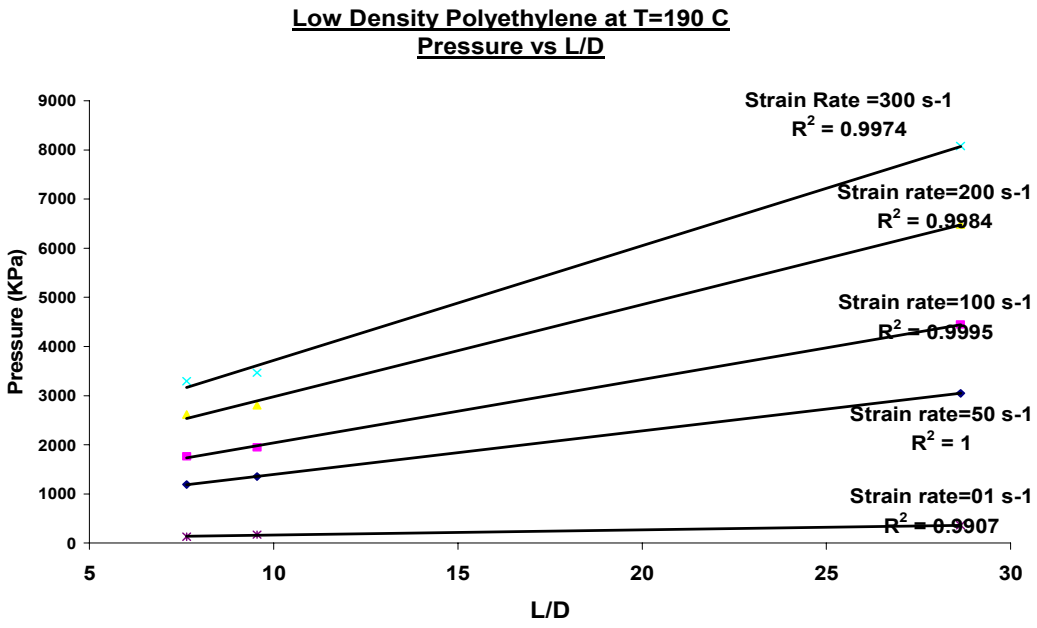
$$\tau_w = \frac{R(P - P_o)}{2L} \quad (4)$$

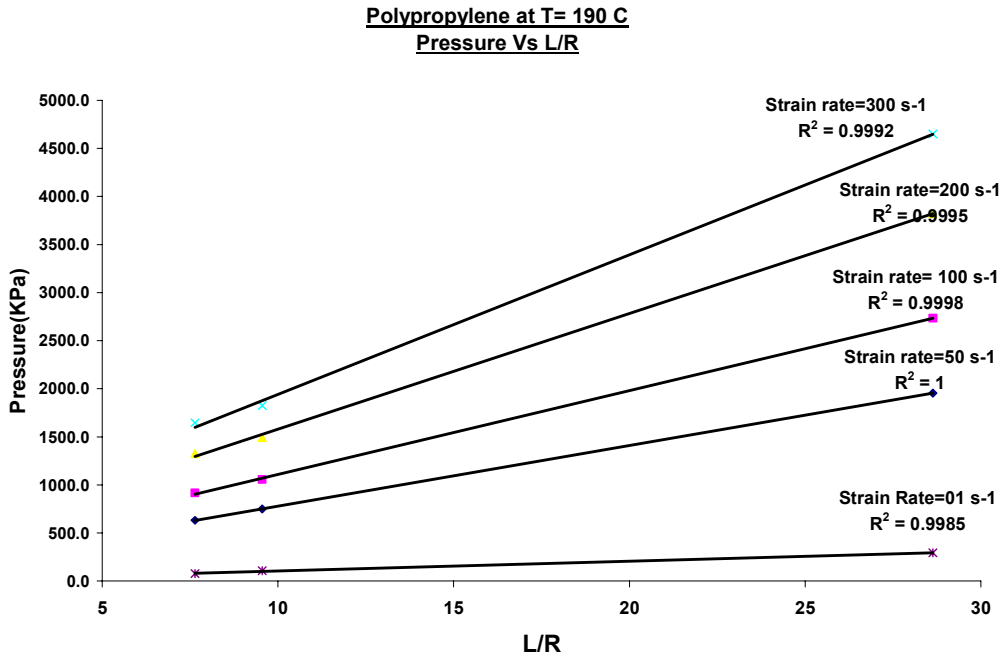
Figure 2: Schematics of the Pressure losses in a capillary die



Orifice pressure drop can be calculated by plotting pressure drops (P), at constant strain rate, versus L/D of the capillaries and then extrapolating to orifice (L/D=0) and is shown as Figure 3. These plots showed linearity so extrapolation is straight forward. The P_o values showed the strain rate dependence with higher values at higher rates.

Figure 3: Pressure drop versus capillary length (a) LDPE (b) PP





Power Law Fluid (PLF) model parameters

The PLF model is given by the relationship

$$\tau_w = m\ \dot{\gamma}^{n} \tag{5}$$

Replacing from equation (3)

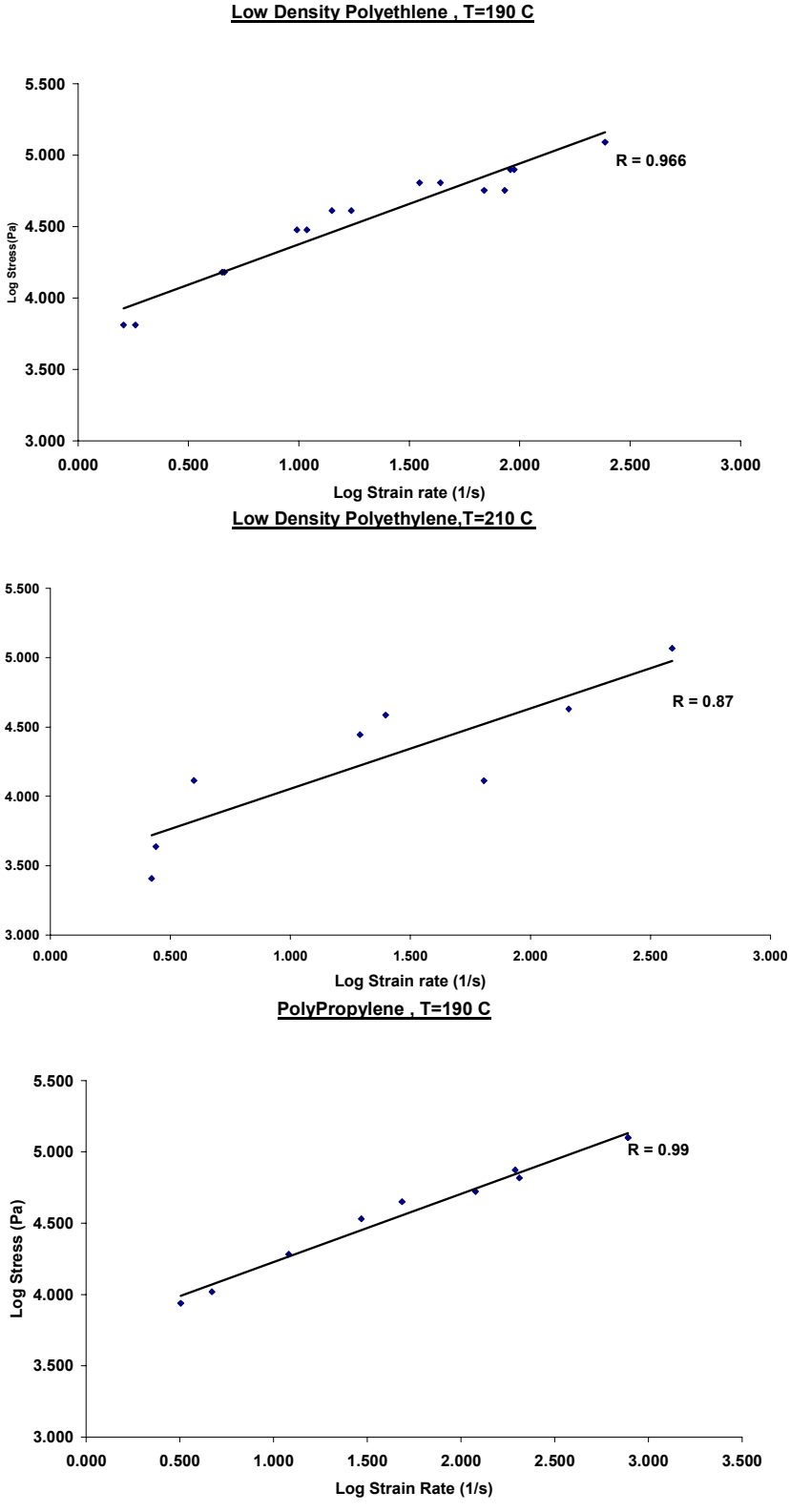
$$\tau_w = m\ [\frac{4n}{(3n+1)}]^n \phi \tag{6}$$

From equation (6), the y-intercept is $\log m\ [\frac{4n}{(3n+1)}]^n$

Where 'n' is the power law (pseudo plasticity) index and 'm' is called as the consistency coefficient. The corrected (by Bagley correction) wall shear stress values (τ_w) at each temperature were plotted against apparent shear strains (ϕ) on log-log scale and is shown in Figure 4.

$$\log \tau_w = \log \{m [4n/(3n+1)]^n\} + \log \phi \quad (7)$$

Figure 4: Shear Stress versus Shear Strain Rates (a) LDPE 190ºC, (b) LDPE 210ºC and (c) PP 190ºC



Instead of correcting strain rate (ϕ) to true strain rate ($\dot{\gamma}$), non ideality was incorporated into the consistency parameter (m) and m was calculated from the intercept value (m). The evaluated power law parameters are tabulated as Table 2.

Table 2: Evaluated Power Law parameters

Material	Temperature (°C)	Strain Rate range	Power Law Index (n)	Consistency Coefficient (m)
LDPE	190	1 to 250 (s^{-1})	0.5651	4621.3
LDPE	210	1 to 400 (s^{-1})	0.5802	2234.3
PP	190	1 to 1100 (s^{-1})	0.4773	3387.8

Conclusions

It has been shown that commercial grade thermoplastics can be characterized for their rheological behavior in a simple rheometer setup comprising various L/D capillary dies. Theses thermoplastics have shown to obey the power law (PLF) relationship provided once Bagley correction was incorporated. Bagley correction is mandatory as the used capillaries were of L/R <50 and orifice pressure loss, observed, around 40% of the maximum (at high shear rates). Rabinowitsch correction is also significant as the melts showed a reasonable degree of shear thinning behavior (n<1). From the observations, PP has been established more pseudoplastic as compared to the LDPE and temperature has not much effect on the pseudoplastic index values (n).

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Effects of Problem Context and Reasoning Complexity on Mathematics Problem-Solving Achievement and Transfer of Secondary School Students

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Abstract

This study investigated the effects of a problem context variant- personalisation and reasoning complexity on mathematics problem-solving achievement and transfer of 126 junior secondary school students. Students received personalised or non-personalised instruction involving either simple or complex reasoning. Two types of achievement questions were used, personalised contextual and non-personalised de-contextual involving either one-step or multi- computational steps to solve. Significant between-subjects main effects of problem context and reasoning complexity were found on students' problem-solving achievement and transfer. For problem context, students who studied personalised problems performed better on the problem-solving achievement test than those who studied non-personalised problems whereas for reasoning complexity, students who studied complex problems recorded better performance than those that studied simple problems. On transfer task, students who studied personalised context performed better than those that studied non-personalised context whereas students that received complex treatment outperformed their counterparts on simple treatment. Significant two-way interactions for problem context by reasoning complexity on students' problem-solving achievement and transfer and reasoning complexity by question complexity on students' problem-solving achievement were recorded. Students on the complex and simple treatments separately produced better performance when the context is personalised than when it is non-personalised while those on complex treatment performed better on multi-step problems than one-step problems. Students who studied simple, personalized context showed significant better performance on the transfer task than those that studied simple, non-personalised context

Keywords: Personalised and non-personalised instruction; problem context; reasoning complexity; problem solving

Introduction

The term context in learning is grounded in the contemporary frameworks of constructivism and situated cognition. These perspectives state that learning is energized when learners are cognitively pre-occupied with knowledge embedded in complex, realistic instructional contexts (Nesher, 2000; Bednar Cunningham, Duffy, & Perry, 1991; Choi & Hannafin, 1997). Constructivism is based on the premise that learners construct their own perspective of the world, through individual experiences and schema – an internal knowledge structure (Schuman, 1996; Brenda, 1998). Situated cognition emphasizes that knowledge is grounded in context, being specific to the real-life situation in which knowledge is applied (Nesher, 2000). The emphasis of these frameworks on learners' constructive processes indicates that cognition is embedded in, rather than isolated from, context.

Context appears to promote the use of knowledge and skills. In formal education setting, facts, and knowledge are often not embedded in the contexts that give them meaning (Choi & Hannafin, 1997) and this tends to hamper students' transfer of knowledge and skills to everyday life experience. Transfer may be enhanced when there is leverage between real-life and formal education settings. While contexts may suite this purpose, Choi & Hannafin (1997) suggest that students should be pre-occupied with real-life contexts that increase their motivation to learn and enhance transfer of knowledge and skills to situations. Real life contexts may bridge the gap between concepts and personal experience, thereby making transfer possible.

In mathematics learning, context is of great importance. It is an aspect of word problems that some researchers have found to impact student performance (Choi & Hannafin, 1997; Ross, Mccormick, & Krisak, 1986). Problem context or "story" in which the mathematics problem is set also refers to "non-mathematical meanings present in the problem statement" (Wiest, 2002). It is the verbal aspect of word problems.

Problem context gives meaning to the mathematical content in a problem (Wiest, 2002) and may also influence the problem solving stages of understanding a problem and devising a plan for its solution. Problem context is "foundational to mathematical activity" (Wiest, 2002) in that it is paramount to the construction of meaning the whole way through. Problem context is the backdrop against which the parts have to make sense (Bickmore-Brand, 1993). Problem context may also influence students' mental investment in a problem and perseverance in problem-solving performance. It may "influence problem-solving performance through the degree of interest and, hence, motivation it sparks" (Wiest, 2002).

Empirically, Hembree (1992) in a meta-analysis of 44 studies, in which problem context was varied while mathematical structure was held constant, identified six pairs of problem context manipulations as: abstract vs. concrete; factual vs. hypothetical; familiar vs. unfamiliar; imaginative vs. ordinary; personalized vs. impersonal; and preferred vs. non-preferred. His review indicated that familiar contexts strongly influenced better performance while concrete and imaginative context manipulations showed borderline significance in positively influencing problem-solving performance of students. However, no other links were recorded between other types of context manipulations and student problem-solving. Wiest (2002) has warned against this global analytic study, which smooths out the findings of individual studies, though personalised context study has been found effective on measures of problem-solving success and motivation (Ku & Sullivan, 2002; Hart, 1996; Lopez & Sullivan, 1992; Wiest, 2002) and also interest level of students appear to show favorable results when students solve personalized problems (Davis-Dorsey, Ross, and Morrison, 1991)

Personalized context involves manipulating the instructional content to contain learner's personal referents such as familiar names, persons, places or things. In many studies, personalised contexts either group based or individual based enhance word-problem solving by increasing the meaningfulness of contexts and stimulating student intrinsic interest to solve the problems (Cordova, 1993; Cordova & Lepper, 1996; Lopez & Sullivan 1992; Hart, 1996; Ku & Sullivan, 2002). Mathematics word problem has been targeted for this study. Aside the fact that mathematical word problem solving lends itself to personalisation study, its inclusion in this study is based on two reasons:

First, word problem solving is a vital skill used in everyday life (Choi & Hannafin, 1997) and secondly, word problem solving enhances student's application of mathematical knowledge to real-life situations (Bates & Wiest, 2004; Davis & Mckillip, 1980). Although word problems are difficult for students (Bates & Wiest ,2002; Akinsola & Tella, 2001; Onabanjo, 2004; Choi & Hannafin, 1997), their level of difficulty is engendered by cognitive demand. Choi and Hannafin (1997) identified two types of mathematics problem solving based on their reasoning requirements. They noted that multi-step word problems engender greater cognitive load than simple translation or one-step problems. However, one approach to reducing the cognitive demand of complex problems may be to provide increased contextualisation supplemented by familiar, relevant situations. Lopez and Sullivan (1992) for instance, found that personalisation was more effective for more demanding cognitive tasks (e.g., multi-step problems) than for less demanding tasks (e.g., one-step problems).

The present study, therefore, investigated the effects of variant of problem context-personalisation and reasoning complexity on mathematics problem-solving achievement and transfer. Group personalisation as against individual personalisation was used in this study because it is easy to implement in situations of inadequate computers in schools, as it is currently in Nigeria. Group personalisation involves incorporating whole-class common interests or preferences into the problem content rather than incorporating individual personal interests and preferences into it. It involves adapting the domain context of instruction to whole-class dominant interests or preferences to facilitate increased relevance and familiarity with new content.

In this study, students who were exposed to using personalised context problems supplemented with significant reasoning demands were predicted to perform best on complex problem-solving tasks, while students who were exposed to using non-personalised context problems supplemented with less significant reasoning demands were predicted to perform best on simple problem-solving tasks. Students in the personalised context with significant reasoning demands were also predicted to display excellent transfer of their knowledge and skills to everyday life mathematics problem solving.

Method

Subjects

The participants consisted of 126 junior secondary school students, from four classes taught by different teachers at a low-range socioeconomic public secondary school in Ibadan, Nigeria. All participants were present for the data-collection sessions.

Instruments

Four instruments were used in this study: Personal Interest Inventory, Instructional Programme on Mathematics Word Problem, Mathematics Word Problem Achievement Test, and Performance Transfer Assessment.

Personal Interest Inventory: This is a 20-item open-ended survey to determine the personal background and interests of the participants. Students wrote in their favourite places, foods, friends, sports and so on and their responses were analyzed using frequency count and percentage.

For instance, the highest frequency choice was recorded on their favourite fast food mall with 78% of the participant wrote in "Tantalizer". In all 20 items, more than 50% of the students indicated the most popular choice on 7 items, 40-50% on 9 items, 30-40% on 3 items and less than 30% on 1 item.

Instructional Programme on Mathematics Word Problem: Four different versions of an instructional programme on mathematics word problem involving the use of whole numbers and decimals were developed in print form in English. Each self-paced instructional programme consisted of four sections, namely, introduction, warm-up strategy for solving whole number and decimal problems and practice. In the introduction section, the goal and structure of the instructional programme were highlighted. The warm up section contained the procedural steps involved in basic mathematics

operations of addition, subtraction, multiplication and division of whole number and decimals. A Polya's four part strategy: understanding a problem, devising a plan, carrying out the plan, and looking back for solving the whole number and decimal problems together with application to appropriate examples were considered in section three. In the practice section, eight (8) word problems, each followed by correct answers to enable self-checking were provided. The four versions: simple/non personalized context, simple/personalised context, complex/non-personalised context, and complex/personalised context reflected a crossing of both reasoning and problem context-personalisation.

The simple versions contained the same computational skills and used identical numbers, and ditto for the complex versions but the problem context and reasoning requirement of all four versions differed.

The non-personalised context version contained word problems typical of junior secondary one mathematics textbook used by the subject. The information contained therein was somehow not related to students' personal experiences and its meaningfulness to everyday life experience was not totally feasible. The personalised context versions were written by incorporating the most dominant referents from the personal interest inventory. While the non-personalised context versions were written first and contained non-meaningful contextual information, the personalised context versions contained meaningfully related contextual information relevant to students' personal everyday life experience. Ten reasoning task, each for simple and complex problems were provided.

Four examples of word problems in their simple/non personalised context, simple/personalised context, complex/non-personalised context, and complex/personalised context forms follow:

Example 1

Simple/non personalised context: One barrel of crude oil sells for ₦70.50. What is the cost of 20 barrels of crude oil?

Example 2

Simple/personalised context: Tantalizer sells one piece of meat pie for ₦70.50. What is the cost of 20 pieces of meat pie?

Example 3

Complex/non-personalised context: A company sells one kilogramme of fertilizer for ₦80.50 and a barrel of crude oil for ₦70. How much do 5 kilogramme of fertilizer and 6 barrels of crude oil cost?

Example 4

Complex/personalised Context: Tantalizer sells one bottle of coca-cola drink for N80.50 and a piece of meat pie for ₦70.50. What is the cost of 5 bottles of coca-cola drink and 6 pieces of meat pie?

Mathematics Word Problem Achievement Test (MAWPAT)

The 28-item constructed-response posttest was used to measure each student's problem-solving achievement. The posttest contained 14 personalised contextual problems (7 simple translation problems and 7 multi-step word problems) and 14 non-personalized de-contextual problems (7 simple translation word problems and 7 multi-step word problems). The test consisted of word problems not included in the instruction. Each question was scored as correct or incorrect only based on the final answer. The KR-20 reliability coefficient was .86 for the posttest.

Performance Transfer Assessment

A performance assessment was carried out to measure transfer of knowledge and skills acquired in a formal educational setting to a real-world shopping activity in a simulated souvenir shop. The shop displayed several items together with their corresponding price tags. A sum of ₦3780 play money was shared equally among the participants and they were told to spend reasonably and guard against overspending the allotted money. Each student must buy at least three gifts for his/her immediate family with the money. Students listed their family members items bought for each and the price of each item on a worksheet. They also recorded the total cost of the items purchased.

Each student worksheet was rated on a 4-point rubric based on the following criteria:

1. Must buy at least 3 items from the shop.
2. Total cost must be kept within the allotted play money.
3. Each family member must be accounted for.

A rating of zero was assigned when the student provided no response; a rating of 1 was assigned if the student missed all requirements; a rating of 2 showed that one or two requirements were not met; a rating of 3 indicated that all requirements were satisfied. A rating of 4 was assigned if the student over-stretched their play money to include more purchases than minimally required.

Procedure

This study took place in four classrooms over a total of four days. Prior to the study, students were given instruction on the study's purpose, procedures, and instructional programme. Students received instruction on the computational aspect of whole numbers and decimals in the warm-up section in order to reduce the confounding effects of computational efficiency. The personal interest inventory was administered to students one week prior to the treatment. Subsequently, the most dominant choices from the survey were used to convert the non-personalized version of the instructional programme into the personalised version.

Students were randomly assigned to one of four treatment conditions: simple/non-personalised context, simple/personalised context, complex/non-personalized context, and complex/personalized context.

With the assistance of the class teacher, the researchers administered each of the four versions of the instructional programme in regularly scheduled mathematics classes of two 45-minute periods on consecutive days. On the third day, students completed the posttest while the performance transfer assessment was conducted on the fourth day. Minimum of 20 students were brought to the souvenir shop for 25 minutes during six intervals. After the shopping activity, students completed and submitted the worksheet together with play money to the cashier.

Data Analysis

Following Choi and Hannafin (1997) method of data analysis, the four posttest subscales were grouped into two within-subject factors: question context (contextual, de-contextual) and question complexity (one step, multi-step). This produced a 2×2×(2×2) random factors design of between-subjects factors of problem context (non-personalised, personalized) and reasoning complexity (simple, complex) and within-subjects factors of question version (personalised contextual, non-personalised de-contextual) and reasoning requirement (one-step, multi-step).

The performance assessment scores were analyzed by a 2×2 random factors analysis of variance (ANOVA), using context (non-personalised, personalised) and reasoning complexity (simple, complex) as the treatment factors. An alpha level of .05 was used for all statistical analyses.

Results

Table 1 reveals the means and standard deviations of posttest subscales. A 2 (problem context) ×2 (problem type) random factor analysis of variance produced between-subject main effects of problem context, F (1,122) = 86.51, p = .002 and reasoning complexity F (1,122) = 67.25, p = .004. For problem context, students who studied personalised problem (M = 19.3) performed better on the mathematics achievement test than did those who studied non-personalised problems (M=17.1). Also, for reasoning complexity, students who studied complex problems recorded better mathematics achievement (M = 19.5) than those who studied simple problems (M=17.2).

Table 1: Means, Standard Deviations and Totals for Posttest Subscales by Instruction Version

Question Version							
Instruction Version	**Personalized-Contextual**		**Non-personalized decontextual**		**Subtotals**		
Problem Context	**One-Step**	**Multi-Step**	**One-Step**	**Multi-Step**	**One-Step**	**Multi-Step**	**Totals**
Personalized Simple	5.9	4.8	4.8	2.7	10.7	7.5	
(n = 35)	(0.9)	(1.1)	(1.2)	(1.3)	(2.1)	(2.4)	18.2
Complex	5.4	6.2	4.5	4.5	9.9	10.7	
(n = 29)	(1.3)	(1.2)	(1.1)	(1.4)	(2.4)	(2.6)	20.6
Subtotal	5.6	5.5	4.6	3.6	10.2	9.1	
(n= 64)	(1.2)	(1.2)	(1.1)	(1.4)	(2.3)	(2.6)	19.3
Non-personalized Simple	4.2	3.8	4.8	3.5	9.0	7.3	
(n = 30)	(1.2)	(1.2)	(1.1)	(1.2)	(2.3)	(2.4)	16.3
Complex	5.4	3.9	4.6	4.6	10.0	8.5	
(n = 32)	(1.8)	(1.3)	(1.9)	(1.4)	(3.7)	(2.7)	18.5
Subtotal	4.8	3.6	4.7	4.0	9.5	7.6	
(n= 62)	(1.6)	(1.2)	(1.6)	(1.3)	(3.2)	(2.5)	17.1
Complexity Subtotals Simple	5.0	4.3	4.8	3.1	9.8	7.4	
(n = 65)	(1.3)	(1.1)	(1.1)	(1.2)	(2.0)	(2.0)	17.2
Complex	5.4	5.0	4.5	4.6	9.9	9.6	
(n = 61)	(1.2)	(1.4)	(1.3)	(1.4)	(2.5)	(2.8)	19.5
Totals	5.2	5.0	4.6	3.8	9.8	8.8	
(n = 126)	(1.3)	(1.2)	(1.2)	(1.4)	(2.3)	(2.4)	18.6

Note: Maximum score for the total test = 28 and for each post test subscale = 7
() = Standard Deviation

The 2×2 ANOVA also showed a significant two-way interaction for problem context by reasoning complexity F (1,122) = 25.73, p = .006. This interaction is shown in Figure 1 and reflects the fact that complex treatment and simple treatment separately produced better performance when the context is personalised than when it is non-personalised. A post hoc Tukey HSD contrasts (Min_{HSD} = 4.23) showed that complex treatments yielded significantly better performance when the context is personalised than when it is non-personalised (M =20.6 vs. 18.5), while the disparity between personalised and non-personalised simple treatments was not statistically significant (M=18.2 vs. 16.3).

Figure 2 also showed the interaction between reasoning complexity and question complexity. This interaction was significant, F (1,122) = 29.75, p = .005. A post hoc Tukey HSD analysis (Min_{HSD} = 3.18) showed that the slight difference in post test scores by question complexity (M = 19.8 for one-step, M =19.9 for multi-step) for students who studied simple reasoning problems during the lesson was not statistically significant, whereas the difference in scores favouring multi-step problems (M = 9.6) over one-step problems (M = 7.4) for students who studied complex reasoning problems was significant (p <. 05). This pattern did not support our claim in which students were predicted to perform best on the simple-translation problems.

Overall performance with regards to question version was better on personalised contextual questions (M = 10.2) than on non-personalised de-contextual questions (M = 8.4) and was significant F (1,122) = 58.78, p = .0001, while students recorded a unit difference in performance between one-step questions (M = 9.8 and multi-step questions (M = 8.8). This was, however, not significant.

Table 2: Means and Standard Deviations for Performance Transfer Assessment by Treatment

Problem Context	Reasoning Complexity		Total
	Simple	Complex	
Personalised			
M	2.9	3.8	3.3
SD	(1.1)	(1.3)	(1.2)
N	35	29	64
Non-personalised			
M	1.2	3.2	2.2
SD	(0.2)	(1.1)	(0.6)
N	30	32	62
Total			
M	2.0	3.5	2.7
SD	(1.0)	(1.2)	(0.9)
N	65	61	126

Note: Maximum score for the performance transfer assessment = 4

Table 2 shows the means and standard deviations for the performance transfer assessment. A 2×2 random factor analysis of variance (ANOVA) showed significant main effect of problem context F (1,122) = 8.63, p = .001 and reasoning complexity F (1,122) = 9.74, p = .012. Students who studied personalized context (M = 3.3) performed better on transfer task than those that studied non-personalised context (M =2.1). Also, students who received complex treatment (M = 3.4) outperformed their counterparts on simple treatment (M =2.0) on transfer tasks. A significant two-way interaction for problem context by reasoning complexity F (1, 122) =5.38, p=. 001 was also recorded.

Figure 3 showed the interaction. A post hoc Tukey HSD contrasts (Min_{HSD} = 3.17) showed that students who studied simple, personalised context (M = 2.9) scored significantly on the transfer task than students who studied simple, non-personalized context (M = 1.2), whereas the difference on the transfer task between complex personalised context (M = 3.8) and complex non-personalized context (M = 3.2) was not statistically significant.

Figure 1: Interaction between Problem Context and Reasoning Complexity

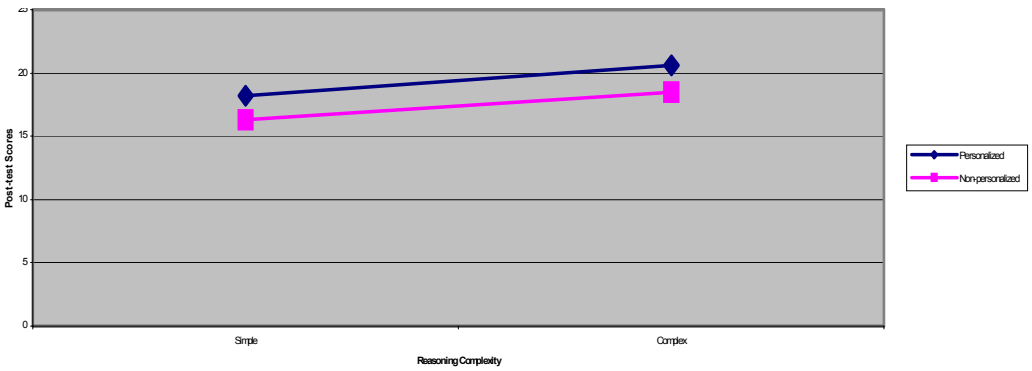


Figure 2: Interaction between Reasoning Complexity and Questi on Complexity

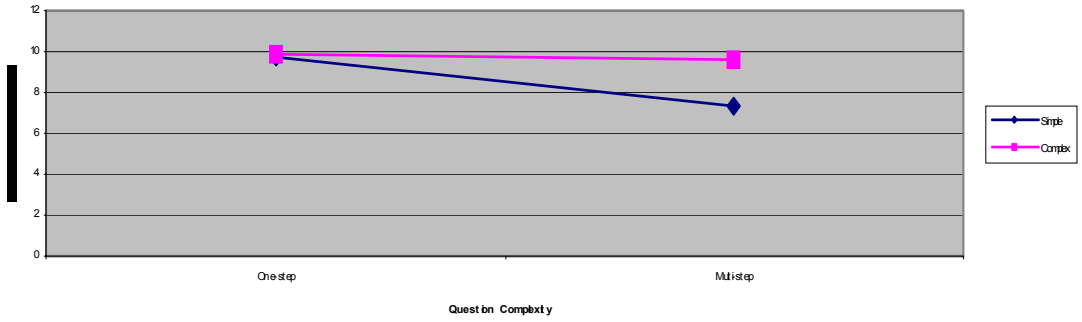
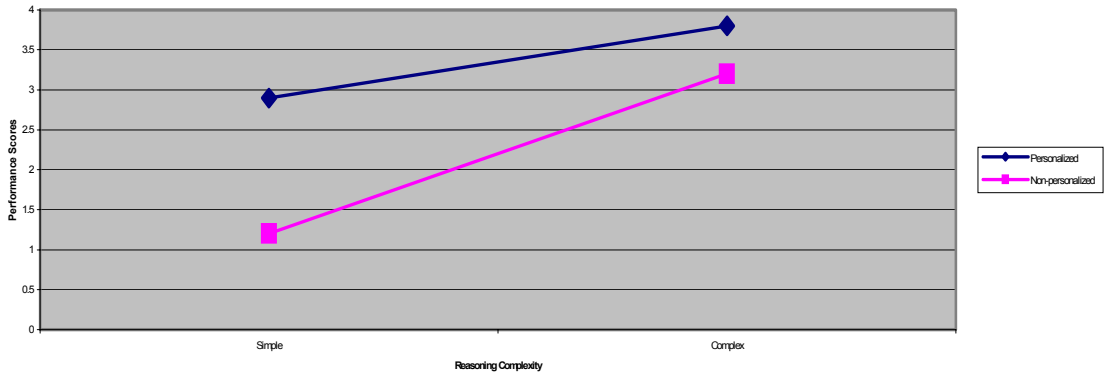


Figure 3: Interaction between Problem Context and Reasoning Complexity



Discussion

The purpose of this study was to investigate the effects of two levels of variant of problem context-personalisation (personalized and non-personalized contexts) and two levels of reasoning complexity (simple and complex) on mathematics problem-solving achievement and transfer of junior secondary one students in Nigeria. Significant main-effects were found in posttest problem-solving achievement and transfer by problem context and reasoning complexity treatments. Significant two-way interactions were recorded for problem context by reasoning complexity and for reasoning complexity by question complexity on the posttest. These two interactions revealed higher gains by those who received complex treatment than simple treatment. Significant two-way interaction for problem context by reasoning complexity on the transfer task showed high gains by those who received simple reasoning treatment. Subjects recorded better performance on personalised contextual questions than on non-personalised de-contextual questions. The significant main effect of problem context (personalisation) is consistent with several results on problem context studies (Anand & Ross, 1987; Murphy & Ross, 1990, Lopez & Sullivan, 1992). However, this effect is inconsistent with some results obtained as well (Choi & Hannafin, 1997; Ku & Sullivan, 2000; Bates & Wiest, 2004). The presence of a personalization effect on problem-solving achievement was probably caused by many factors. Generally, personalization stimulates intrinsic interest and enhances personal meaning of new content. This was achieved in this study by inserting dominant and interesting learner's personal referents into the problem content, thereby situating the complexity of the environment of the learner's everyday life in the context.

Practically, learners envisioned being in the problem context and this degree of association might have assisted them to accommodate new information with existing knowledge structures. In this

wise, students, may have attended to the personal meaning and relevance of the context to their everyday life experience.

Also, students who were exposed to familiar and relevant problem context seemed to have better understanding of the problem and were quick in devising a plan for its solution.

Another reason for the presence of significant personalisation effect on problem solving may be associated with the vicarious emotions and cognitive representations embedded in the learning tasks. By transforming textual information to contain familiar referents, learners can gain significant personal information about their capabilities with respect to the strategies enacted to engage the problem. In this study, students were able to picture personal referents in the problem and this experience may have motivated them to gain efficacy in the usage of the strategies for solving the problems.

The relatively old age of the students may have contributed to the results of this study. Studies have shown that older children in elementary school benefited greatly from personalised context of mathematics problem solving than younger children (Bates & Wiest, 2004; Davis-Dorsey, 1989). This is attributed to the fact that older children posses more developed schemata for processing information in a real-world context. The present study dealt with junior secondary one students and found significant effect of personalised context on their mathematics problem solving. Age may be a determining factor in the choice of technique(s) to stimulate student interest in mathematics problems solving. While higher grade levels are noted for increasingly difficult mathematics problems, the complexity of these problems may enhance personalised context to influence student problem solving achievement.

This study found significant effect of reasoning complexity on problem solving achievement. Rich complexity and context may increase the cognitive loads of the learning tasks, but they also appear to promote understanding of the utility of knowledge and skills (Choi & Hannafin, 1997). Students receiving instruction in the simple personalized context and those receiving instruction in the complex personalised context recorded the highest overall scores on simple, one-step problems and complex, multi-step problems respectively on the mathematics problem-solving task. It appears that the personalized context proved proportionately effective for both simple and complex learning tasks.

The present findings are partially consistent with those reported by Lopez and Sullivan (1992) which suggested that personally interesting and engaging problem contexts might be most important for difficult problems. Complex tasks may better address real-world problem solving and enhance transfer of knowledge and skills to everyday problems. Significant main effects of problem context and reasoning complexity on performance transfer suggest in part that students are better at transfer of gained knowledge and skills to everyday real problems when the context of instruction is personalised and show meaningfulness than when it is non-personalized and rarely relevant to their everyday life experience. The results also suggest that while simple problems may do little in cultivating transfer of knowledge and skills acquired in the formal classroom setting to real world problem situations, complex problems may create rich avenues for their deployment. However, the problem context by reasoning complexity interaction for performance transfer scores showed that students on the simple, personalised context version of the instructional programme displayed better performance than students engaged in simple, non-personalised context version.

The present study has implications for educational practice in Nigeria and elsewhere. The study reveals that personalization and reasoning complexity when adapted into classroom instruction can make learning more meaningful and its transfer to solving everyday real problem less difficult. Mathematics teachers should know the interests or preferences of their students and incorporate them into their mathematics problems and instruction. The content of new mathematics textbooks should be made more appealing to students by attending carefully to the context and reasoning complexity needed for addressing real-world problems.

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Modeling of Optimal Coagulant Dose Using Artificial Neural Network, Application to Water Treatment Plant of Boudouaou (Algeria)

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Abstract

The control of the feed-water quality has turned out to be a significant stake tackled by the plant managers of the drinking-water process and the research centres. Assiduous control is required for the processed water quality variation. This requirement has triggered off research operations targeting the development of models enabling an automatic control of the implemented methods.

From all the water treatment process chain, coagulation remains of a significant interest expressed out of the potable water process services. Here is below the step aiming at the elimination of colloidal and suspended matters. This process requires complex phenomena in the sense that its efficiency depends mostly on the treatable water quality and particularly on the coagulant dosage for injection. The last one complies with the production process plants and so based on either aluminium salts or iron. The monitoring of its use becomes an inescapable requirement. On one hand, the injection of an overdose entails onerous expenses; on the other hand, an underestimated dose reduces obviously the clarification return. Therefore, the optimisation of the particle aggregation and the operation cost mitigation are targeted during the coagulation phase.

Yet, there is no methodology enabling a precise determination of the coagulant dose for usage during the coagulation phase in the potable water process plants. It makes it compulsory to resort systematically to jar-tests, performed in laboratory, and requiring high costs and long time. This condition is inadequate if compared to the prompt intervention necessity in the event of a sudden change in the water quality incoming in the production plant. It is necessary therefore to proceed to the adjustment of the automation and monitoring systems by installing a model helping the decisiveness measures and facilitating efficiently the automation methods. This document attempts at a method of the coagulant dose determination in a potable water process plant (water treatment plant of Boudouaou) using artificial neural networks.

The water treatment plant is located at 7 km approximately from the dam of Keddara which supplies potable water to Algiers. This plant operates with a production capacity of 540.000 m^3/day. It provides feed-water to more than 4 millions inhabitants, using aluminium sulphate as a coagulant.

The data used for the determination of the neural model include six variables describing the raw water characteristics, i.e. temperature, pH, turbidity, conductivity, dissolved oxygen and the ultraviolet radiation. As the selection and the optimisation of the input number for a neural network requires specific analysis of the database used to design an adequate modelling of the process, a major component analysis has been conducted to reveal the contribution of each input-variable for understanding the phenomena subject to investigation, and even the determination of the coagulant dose for injection.

The neural model has been designed during the calibration period (learning). This enabled us to consider the seasonal variation of the raw water quality. The model has been tested later on during the validation period generality).

The model performances are evaluated based on the validation criteria. The coefficient of determination R^2 exceeds 0.8 in calibration phase and reaches 0.75 in validation period. The obtained results are significantly interesting. On one hand, the coagulant dose changes according to the six variables measuring the raw water characteristics as there is no other dominant variable, on the other hand, the neural networks capacity for modelling the complex and non linear methods

Keywords: Modelling, coagulant, artificial neural networks, principal component analysis.

1. Introduction

En Algérie l'approvisionnement en eau potable devient de plus en plus complexe. D'une part, les volumes mobilisés restent faibles par rapport à ceux disponibles, et d'autre part, la qualité de l'eau distribuée reste loin des normes de potabilité en raison de l'absence de techniques appropriées qui permettent un suivi régulier et ponctuel de la variation de la qualité de l'eau distribuée aux usagers.

Dans ce contexte difficile les gestionnaires d'usines de production d'eau potable font face à deux défis importants, d'une part, l'eau doit être produite en quantité suffisante et de façon continue, et d'autre part, elle doit répondre aux normes de potabilité en vigueur de plus en plus sévères.

Les usines de production se composent d'un certain nombre de procédés très complexes faisant appel à des procédures physico - chimiques et biologiques; le passage de l'eau dans un tel système provoque une modification notable de sa qualité, celle-ci varie d'une façon significative dans sa composition organique et physico-chimique. Les niveaux de variation se développent dans une large gamme de variables descripteurs, en particulier, la turbidité, la température, la conductivité, etc., et dépendent donc des caractéristiques de l'eau et en particulier du mode et du degré d'interaction avec les paramètres extérieurs caractérisant l'installation de production à savoir les réactions chimiques, Le grand nombre de variables, ainsi que leur nature dynamique complique grandement le suivi de l'évolution de la qualité de l'eau dans une usine de production.

La coagulation - floculation est l'étape la plus déterminante pour toute chaîne de traitement des eaux, pour déterminer la dose du coagulant à injecter, des essais dits de Jar-Test sont réalisés au laboratoire, et consistent à utiliser une série de béchers dans lesquelles on injecte différentes doses de coagulant, et sur lesquels on pratique une agitation avec un floculateur de laboratoire, à la fin de l'agitation on réalise sur l'eau décantée toutes les mesures; automatiquement la meilleure dose est celle donnant les meilleures performances de qualité parmi les six béchers **(BOMBAUGH *et al.*, 1967, BRODART *et al.*, 1989).**

Cette situation a motivé les chercheurs à développer de nouveaux modèles mathématiques afin de relier de façon correcte la dose du coagulant aux différentes variables descripteurs de l'eau brute.

Les coagulants principalement utilisés sont à base de sels d'aluminium ou de fer, on peut également dans certains cas utiliser des produits de synthèse, tels que les polyélectolytes **(DEGREMENT, 2005),** la réaction chimique lors de la coagulation pour le cas du sulfate d'aluminium s'écrit:

$$Al_2(SO_4)_3 + 6\,HCO_3^- \leftrightarrows 2\,Al(OH)_{3\downarrow} + 3\,SO_4^{-2} + 6\,CO_2 \quad (1)$$

Les techniques statistiques ont déjà fait l'objet de nombreuses applications dans ce domaine, **BRODART *et al.*, (1989), CRITCHLEY *et al.*, (1990)** ont développé un modèle linéaire qui utilise comme entrées la turbidité, la température de l'eau brute et le débit de la station de traitement comme variables explicatives, et la dose du coagulant comme variable à expliquer, les résultats obtenus sont d'une qualité médiocre, ce qui a conduit par la suite à l'abondant des méthodes linéaires dans ce domaine.

Avec le développement de l'outil informatique et des mathématiques, de nouvelles approches basées sur les réseaux de neurones artificiels ont été proposés, car ces derniers sont capables de trouver les rapports multi variés,et non linéaires entre les variables d'un processus donné.

2. Methodologie

Il a été démontré expérimentalement que la dose du coagulant à injecter lors de la phase coagulation - floculation, est très délicate à déterminer **(VALENTIN, 2000, HERNANDEZ, 2006),** cela peut s'expliquer par le fait que la relation entre la dose du coagulant et les variables descriptives de la qualité de l'eau brute est fortement non linéaire **(STANLEY et al., 2000),** ce qui rend la modélisation du problème en utilisant les approches linéaires complexe. De plus, en raison des restrictions dans les ressources disponibles pour la collecte des variables descriptives, de tels variables devraient être sélectionnés avec soin et leur nombre devrait être confiné au nombre minimum requis pour surveiller efficacement le procédé mis en jeu. De nombreux travaux de recherche ont été menés et se poursuivent pour développer des modèles basés sur la théorie des réseaux de neurones, citons en particulier, **(ADGAR et al., 1995,COX et al.,1996, GAGNON et al., 1997, MIRSEPASSI et al.,1995 ,MIRSEPASSI et al., 1997,NAHM et al.,1996, BAXTER et al., 2002, BAXTER et al., 2001a, BAXTER et al., 2001b),** ont montrés l'efficacité d'un modèle basé sur les réseaux de neurones artificiels pour la prédiction en ligne de la dose du coagulant.

L'objectif poursuivi est de déterminer les variables descriptives de l'eau qui influencent le plus sur le taux de sulfate d'aluminium utiliser (la dose du coagulant), ainsi que la prédiction de cette dose par le biais des réseaux de neurones.

L'analyse en composantes principales a été utilisée, pour aider à sélectionner les descripteurs les plus pertinents comme entrées du réseau de neurones, tout en cherchant à minimiser le nombre de variables à sélectionner.

Une fois les variables d'entrées du réseau de neurones fixées, on procède à la détermination des paramètres du modèle du réseau de neurones, qui ne sont autres que les poids des connexions entre les différents neurones, cette étape est la phase d'apprentissage qui sera suivie par une phase de validation, pour vérifier le bon choix de ces paramètres retenus sur des données non vu auparavant par le réseau de neurones pour évaluer les performances du modèle retenu.

3. Modélisation par les Réseaux de Neurones

3.1. Présentation des réseaux de neurones artificiels

L'utilisation des réseaux de neurones artificiels a connu un essor important, ils ont été utilisés pour résoudre une multitude de problèmes dans divers domaines, en particulier, dans les processus utilisant des bases de données complexes.

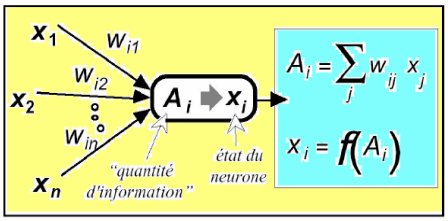
Les réseaux de neurones artificiels sont des modèles mathématiques inspirés de la structure du neurone biologique. C'est **Mc CULLOCH et PITTS, (1943)** qui ont donné naissance au concept de réseau de neurone formel.

3.2. Notion de neurone formel

Le neurone formel (figure 1) qui est la base des réseaux de neurones artificiels est inspiré du neurone biologique, il est décrit par:

- Son état (ou bien son activation).
- Ses entrées auxquelles sont associés les poids (les paramètres ajustables).
- Sa fonction qui est la somme de ces entrées pondérées par les poids.
- Sa fonction de transfert.

Figure 1: Structure générale du neurone formel. Architecture of neurone.



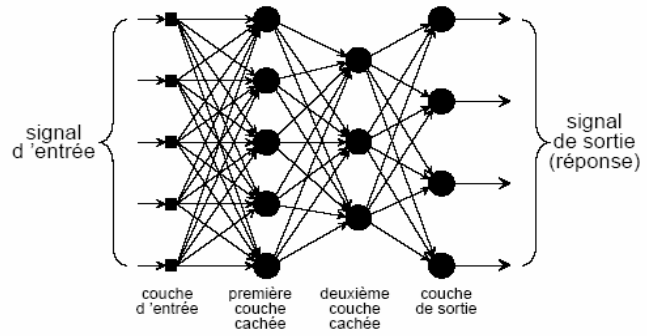
3.3. Architecture des réseaux de neurones

Suivant le nombre de couches, on distingue les réseaux monocouche et les réseaux multicouches. Dans le cadre de ce travail nous allons nous intéresser plus particulièrement à cette dernière catégorie d'architecture.

Un réseau de neurones multicouche est défini, d'une part, par le nombre de couches cachées, et d'autre part, par le nombre de neurones dans chacune de ses couches (figure 2).

Dans la plupart des réseaux de neurones, chaque neurone dans une couche cachée, reçoit les signaux de tous les neurones de la couche qui la précède, typiquement une couche d'entrée, et par l'intermédiaire d'une fonction de transfert il passe sa production à tous les neurones de la couche suivante.

Figure 2: Structure générale d'un réseau de neurones multicouches. Representation of a multi-layer artificial neural network



3.4. Processus d'apprentissage des réseaux de neurones

Un réseau de neurones est formé par une succession de couches interconnectées par ce que l'on appelle les poids ou les paramètres objet d'une procédure d'adaptation appelée apprentissage.

L'apprentissage est une étape importante pour la majorité des réseaux de neurones. C'est une procédure adaptative pour laquelle les connexions sont ajustées suite à un stimuli présenté à l'entrée du réseau, **(HEBB, 1949).**

L'objectif de l'apprentissage est de fournir au réseau une méthode lui permettant d'adapter ces paramètres **(HINTON, 1989)** lorsqu'on lui présente un certain nombre de données à traiter.

On distingue trois types d'apprentissage: supervisé, non supervisé et renforcé.

L'apprentissage supervisé exige la présence d'un ensemble de couples «entrée-sortie», chacun correspondant à un état du processus à étudier, la sortie calculée par le réseau est comparée à celle désirée, l'objectif de l'algorithme d'apprentissage est la minimisation de l'erreur, via une procédure itérative, l'algorithme le plus utilisé est la rétro propagation du gradient, qui est un algorithme, basé sur la règle du delta,en minimisant une fonction coût, généralement l'erreur quadratique moyenne. Les poids du réseau de neurones à ajuster seront initialisés par des faibles valeurs, généralement d'une façon aléatoire; le nombre de neurones formant la structure de la couche cachée sera choisie en fonction des performances obtenues, on procède généralement aux essais sur plusieurs modèles à plusieurs couches et neurones, et on retient celui qui donne les meilleures performances.

$$A_j = f\left[\sum_{i=1}^{n} w_{ji} x_i + w_{j0}\right] \tag{2}$$

$$Y_{(x)} = f\left[\sum_{i=1}^{n} w_j A_J + w_O\right] \tag{3}$$

Où:

W_{ji}: Poids entre les neurones de la couche cachée et la couche d'entrée;

X_i: Matrice des entrées;

W_{j0}: Entrée du biais pour le neurone j;

W_0: Entrée du biais pour le neurone de Sortie;

$Y_{(x)}$: Sortie activée de chaque neurone de la couche cachée;

L'algorithme de rétro propagation de l'erreur procède à l'adaptation des poids (neurone par neurone) en commençant par la couche de sortie. L'erreur observée $\mathbf{e_j}$ pour le neurone de sortie j est la différence entre la sortie désirée $\mathbf{d_j}$ et la sortie calculée $\mathbf{Y_{(j)}}$.

4. Résultats et Interpretations

4.1. Présentation de la station de traitement

Avant l'année 1987, l'alimentation en eau potable du Grand Alger était assurée par les champs de captage du Mazafran, de Baraki et du Hamiz (zones périphériques de la capitale).

La quantité des eaux souterraines n'arrivait plus à couvrir les besoins toujours grandissants des consommateurs, pour combler le déficit en eau potable de la région algéroise, un nouveau système d'approvisionnement a été mis en service à partir de 1987 et qui consistait en la mobilisation des eaux superficielles des oueds Isser, Boudouaou et Berraba.

L'usine de traitement se situe à environ 7 km du barrage Keddara, elle occupe une superficie de 17 hectares.

La station de traitement de Boudouaou fait partie du système de production Isser Keddara, appelé SPIK (figure 3). Elle traite les eaux des barrages Béni – Amrane, Keddara et Hamiz et alimente une population estimée à 4.000.000 d'habitants, avec une capacité de traitement de 540.000 m^3/j.

4.2. Description des variables utilisées

Les variables descriptives de la qualité de l'eau brute retenus, pour la modélisation de la dose du coagulant, sont:

1. La température;
2. Le PH;
3. La conductivité;
4. L'Ultraviolet;
5. L'oxygène dissous;
6. La turbidité.

Ces six variables sont mesurés deux fois par jour, parallèlement, la dose du coagulant est déterminée par les essais Jar-test effectués au laboratoire.

Nous avons exploité l'archive de la station qui nous a permis de constituer une base de données d'environs deux ans (726 enregistrements), qui sera par la suite utilisée comme base d'apprentissage et de validation du modèle, chaque enregistrement se compose des six variables descripteur, et la dose du coagulant à déterminer.

Les résultats de l'analyse statistique des variables retenus sont présentés dans le tableau 1 et l'évolution de ces derniers est présentée en figure 4.

Figure 3: Présentation de l'usine de production. Presentation of the production factory

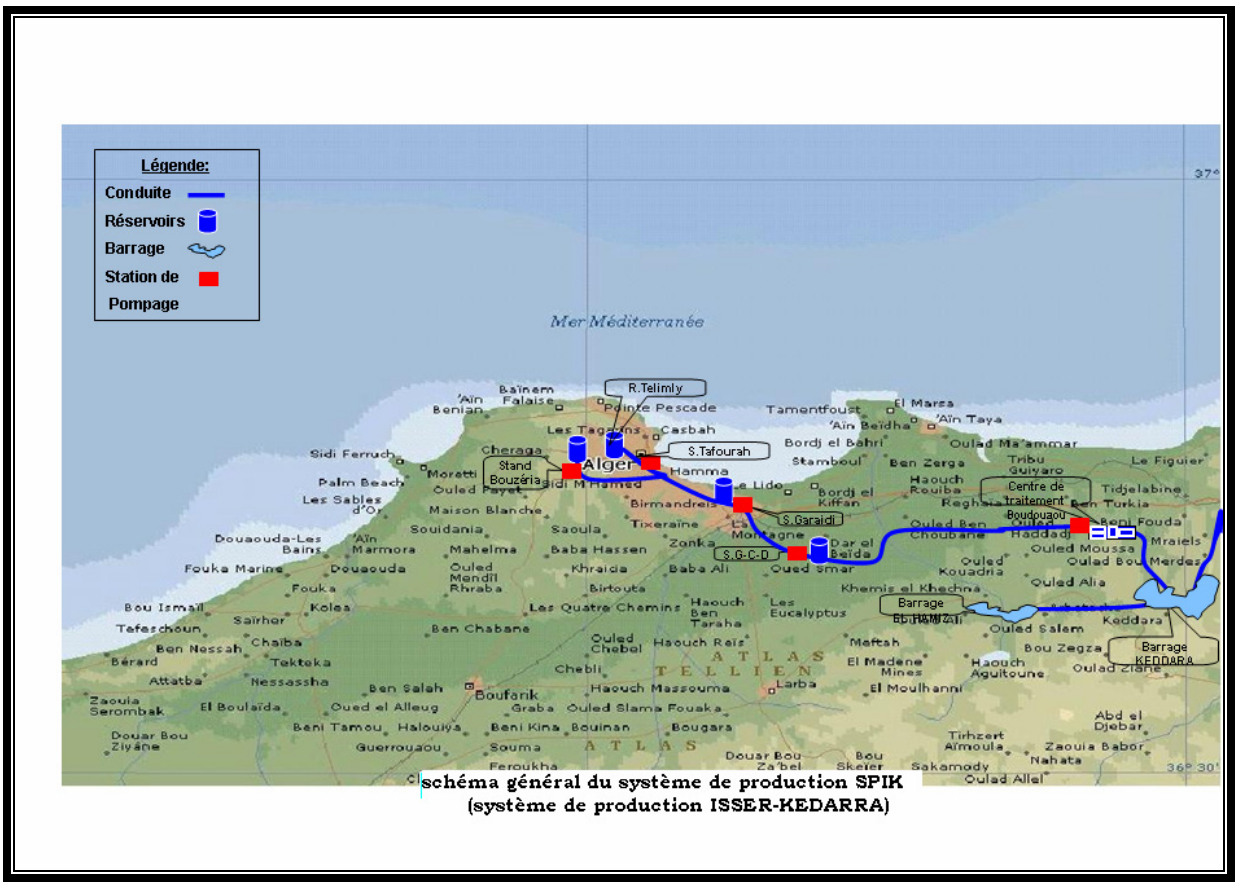
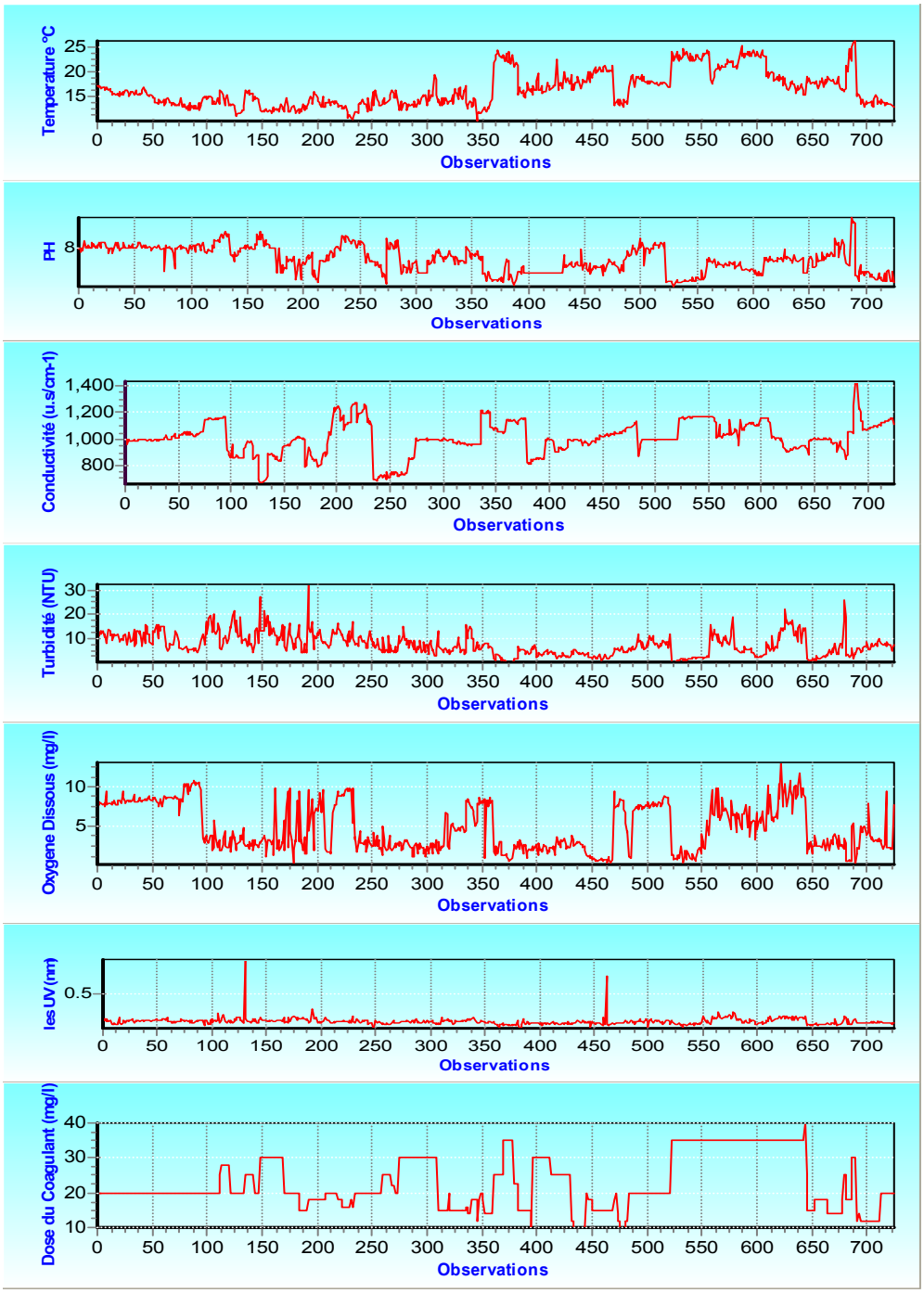


Table 1: Statistical of raw water data.

	Moyenne	Ecart type	Min	Max
Température (°C)	16.53	3.49	10.2	26.2
PH	7.76	0.25	7.23	8.6
Conductivité (µ.s/cm^{-1})	1009.48	122.27	668	1432
Turbidité (NTU)	7.58	4.54	0.44	32.4
Oxygène dissous (mg/l)	4.73	2.98	0.143	13.2
Ultraviolet (NM)	0.11	0.05	0.01	0.98
Coagulant (mg/l)	22.79	7.48	10	40

Figure 4: Caractéristiques des variables descriptives de l'eau brute. Characteristic of raw water data.



On constate des fluctuations notables pour les différentes variables analysées, cela est dû surtout à la succession des saisons, contrairement à l'ultraviolet où l'on constate pratiquement de faibles variations, sauf pour quelques valeurs exceptionnelles.

4.3. Critères de validation

La modélisation nécessite des critères de validation qui permettent de juger les performances du modèle élaboré.

4.3.1. Coefficient de détermination (R^2)

Il évalue le degré d'association entre deux variables, et juge la qualité de l'ajustement des valeurs observées et calculées:

$$R^2 = \left[\frac{\frac{1}{N}\sum_{i=1}^{N}\left(Y_{iobs} - \overline{Y}_{obs}\right)\left(Y_{ical} - \overline{Y}_{cal}\right)}{\sigma_{obs}.\sigma_{cal}} \right]^2 \quad (4)$$

Avec:

Y_{iobs}: Valeur observée;

Y_{ical}: Valeur calculée par le modèle;

$\overline{Y}_{obs}$: Moyenne de la variable observée.

4.3.2. Root Mean Square Error (RMSE)

$$RMSE = \sqrt{\frac{\sum_{i=}^{N}\left(Y_{obs} - Y_{cal}\right)^2}{N}} \quad (5)$$

Un RMSE proche de zéro signifie que le modèle est très bon.

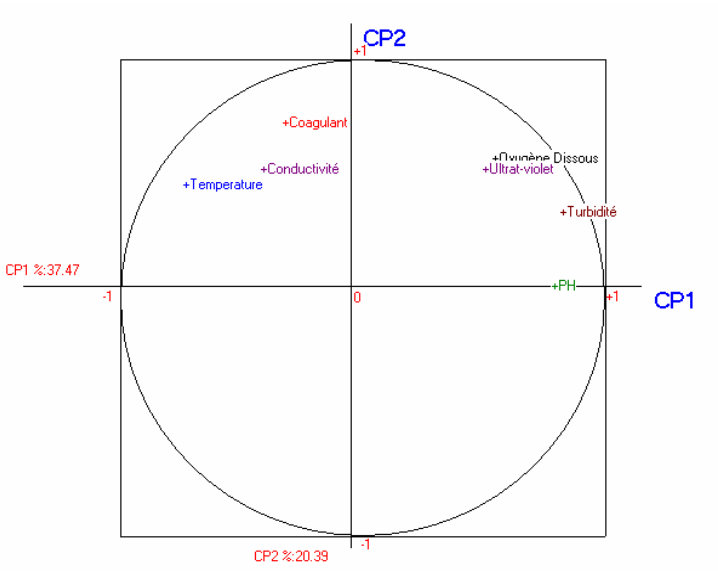
4.4. Approche par l'analyse en composantes principales

Le principe de l'analyse en composantes principales est de concentrer le maximum d'informations dans un nombre réduit de variables, le choix du nombre de composantes principales à prendre en considération dépend du pourcentage d'inertie expliquée

En général une analyse en composante principale fournie trois sources de renseignements, toutes nécessaires à l'interprétation:

- Un tableau de vecteurs et valeurs propres.
- Un tableau des corrélations des individus avec les axes factoriels.
- Un tableau des corrélations des variables aux axes principaux.

Figure 5: Résultats de l'application de l'analyse en composantes principales. Results whit application the principal component analysis.



La base de données retenues a été testée par l'analyse en composantes principales afin de déceler l'apport de chaque variable d'entrée dans l'explication du phénomène étudié, et cela pour optimiser le nombre total de variables à retenir pour l'application du modèle neuronal.

Nous avons remarqué qu'avec seulement deux composantes principales sur un total de sept, nous approchons les 57.9 % de la variance totale (figure 5).

4.5. Approche par les réseaux de neurones

L'élaboration d'un tel modèle passe à la fois par le choix des paramètres d'entrée, mais aussi par l'optimisation de l'architecture du réseau lui-même, ceci signifie qu'il faut trouver à la fois la meilleure répartition des données entre le set d'apprentissage, et celui de validation, et le nombre de neurones constituant la couche cachée.

L'optimisation du type de fonction non linéaire, et de la géométrie du réseau de neurones a été faite après de nombreux tests, en effet, le nombre de neurones dans l'unique couche cachée a été varié progressivement. Parmi les différentes configurations du réseau nous avons retenu celles qui donnent les meilleurs critères de validation.

La base de données est scindée en deux parties 2/3 pour l'apprentissage et 1/3 pour la validation.

Les résultats obtenus en se basant uniquement sur deux entrées (la température et la conductivité) pour le réseau de neurones étaient médiocres, en ce sens que la meilleure performance du modèle élaboré ne dépassaient pas 0.53 pour le coefficient de détermination (R^2) et un RMSE de 4.28, sur les données d'apprentissage, alors que pour la validation, ces performances ont encore régressé pour atteindre les valeurs de 0.15 pour le R^2, et 10.31 pour le RMSE.

En introduisant au réseau de neurones une nouvelle entrée, et en suivant l'évolution des performances du modèle, on a remarqué une nette amélioration des résultas obtenus à chaque ajout d'une nouvelle variable intervenant dans le phénomène étudié (tableau 2). Les meilleures performances sont obtenues en intégrant les six variables explicatives, ce qui confirme les résultats obtenus par l'analyse en composantes principales où nous avons constaté l'absence d'un descripteur prépondérant, finalement le modèle retenu est basé sur six variables descriptives comme entrée et treize neurones dans l'unique couche cachée (figure 6 et 7).

Figure 6: Prédiction de la dose du coagulant par le modèle retenu. Prediction of the coagulant dose by the retained model.

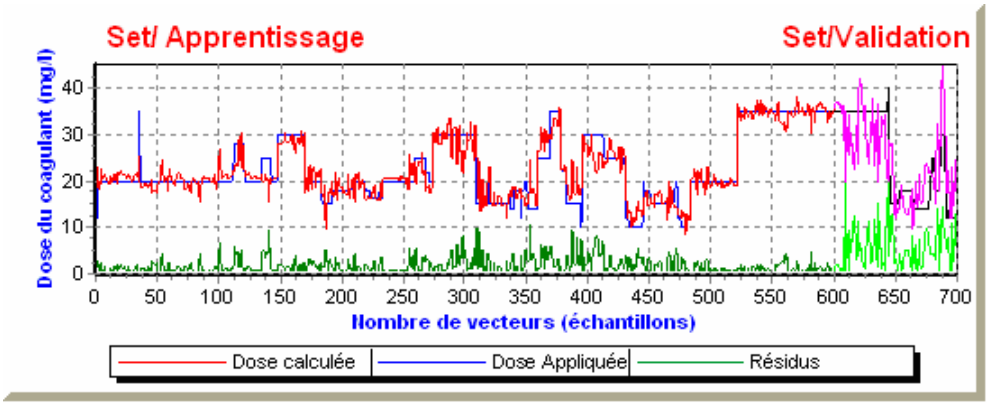


Figure 7: Dose appliquée et dose prédite. Estimated dose Vs observed dose.

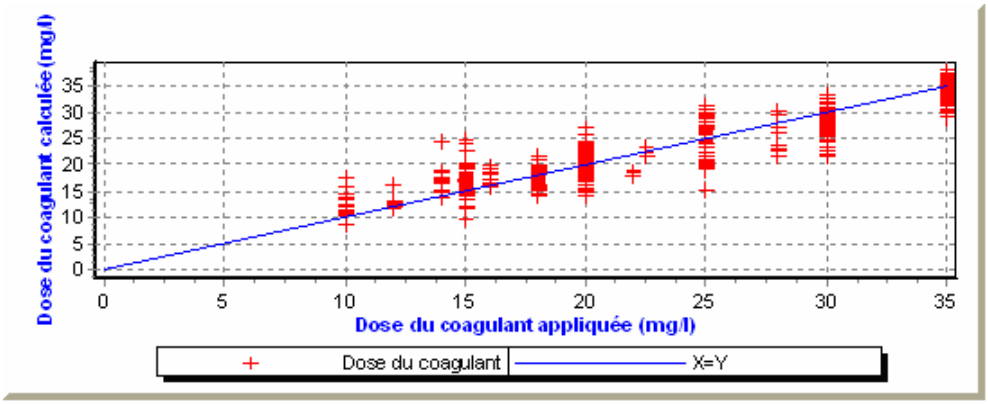


Table 2: Results of the model.

Variable d'entrée		R^2		RMSE	
		Apprentissage	**Validation**	**Apprentissage**	**Validation**
Deux entrées	Température Conductivité	**0.53**	**0.15**	**4.28**	**10.31**
Trois entrées	Température Conductivité PH	**0.58**	**0.17**	**4.24**	**9.76**
Quatre entrées	Température Conductivité PH Turbidité	**0.64**	**0.60**	**3.69**	**7.82**
Cinq entrées	Température Conductivité PH Turbidité Oxygène dissous	**0.72**	**0.62**	**2.65**	**7.65**
Six entrées	Température Conductivité PH Turbidité Oxygène dissous Les UV	**80**	**0.75**	**2.52**	**7.34**

5. Conclusion

A travers cet article, nous nous sommes attelés à rechercher une approche susceptible d'apporter une contribution aux problème du traitement des eaux en Algérie qui accuse un déficit relatif dans les apports en eau principalement dû aux fluctuations des conditions climatiques et à l'irrégularité de la répartition spatiale de cette ressource, et surtout dans le but d'apporter une contribution à l'amélioration de la qualité de l'eau potable distribuer aux usagers.

L'avantage de l'approche préconisée à travers le présent travail, c'est quelle a montré qu'en premier lieu les résultats de la modélisation sont tributaires de la qualité des données d'entrées, ce qui confirme la théorie de la modélisation.

Le choix des entrées pertinentes pour le réseau de neurones, constitue l'étape clé dans le développement du modèle de prédiction, partant de deux variables descriptives nous sommes arriver à l'utilisation de toutes les variables pour construire le modèle le plus représentatif,cela reflète la complexité du processus en question.

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Changes in Total and Reduced Sugars, Free Proline and Phenyl-Ammonia- Lyase Activity in Barley and Wheat Infested by Cecidomyie Insect

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Abstract

The objective of this study is to understand mechanisms of cereals responses to induced stress by cecidomyie. This study was carried in barley and wheat under infestation by *Mayetiola spp*. During the course of larvae penetrating the plant cell, besides of chemical secretion, the insect may cause mechanical signal by the physical pressure on the plant cell and involves some physiological and biochemical alterations. Biochemical indicators concerned by this research are total and reduced sugars, free proline and phenyl ammonia lyase activity. This study showed that the infestation of barley and wheat by *Mayetiola spp* induce. a significant change in the content of the all studied parameters. The amount of total soluble and reduced carbohydrates, total free proline and phenyl ammonia lyase activity increased in infested plants. The results suggest that the accumulation of those metabolites is a response to the stress induced by cecidomyie in barley and wheat

Keywords: Barley-wheat-cecidomyie-infestation-carbohydrates-proline-phenylammonialyase

Introduction

Wheat and barley are the most important cereals used extensively in all regions of Morocco for the preparation of bread and many bakery products. However, these two cereals are severely attacked by the *Mayetiola* (M) (Diptera, Cecidomyiidae) [1]. Two sympatric species of *Mayetiola* have been recognized as a serious damaging pest in semiarid Morocco. *Mayetiola destructors* (say) is found on both wheat and barley, but it is predominant on wheat where no gall is formed. *Mayetiola hordei* (Kieffer), the "barley stem gall midge" [2, 3] is found exclusively on barley and produces stem galls. *M. destructor* infested both bread (*Triticum aestivum* L.) as durum wheat (*triticum turgidum L.var.durum*). The damage caused by *M. destructor* can result in total loss of the wheat crop if high infestation occurs during the early stages of development (4). The damages caused by *M.hordei* in barley were not significantly different from those caused by *M.destructor* (1, 5).

There are many cellular mechanisms by which organism respond to the effects of environmental stresses; the accumulation of compatible osmolytes such as proline is one such phenomenon (6). In cereals, proline accumulation is one of the most frequently reported modifications induced by abiotic stress and biotic stress (7). It is often considered to be involved in stress resistance mechanism (8). Several functions are proposed for the accumulation of proline in tissues submitted to the stress such osmotic adjustment, carbon and nitrogen reserve for growth (9, 10), stabilization of proteins, membranes and subcellular structures (11) and protecting cellular function by scavenging reactive oxygen species (9, 12). In addition, proline biosynthesis may be associated with the regulation of cytosolic pH (13).

The carbohydrates are also known to change in plants responding to the biotic and abiotic stress (14). The carbohydrates are also considered to be the main organic solutes involved in osmotic adjustment (15, 16, 17). Carbohydrate changes are of particular importance because of their direct relationship with such physiological processes as photosynthesis, translocation, and respiration. Among the soluble carbohydrates, sucrose and fructans contribute to the adaptation to the stresses (18, 19, 20). Sucrose can act in water replacement to maintain membrane phospholipids and to prevent structural changes in soluble proteins. Glucose participates in cross linking with protein by a complex glycosylation reaction between amino and carbonyl groups known as the Maillard reaction (21). As respiratory substrates, monosaccharide promote respiration and mitochondrial electron transport which would seem to oppose the onset of quiescence and favour metabolism, energy production, and the formation of oxygen radicals (22).

Secondary metabolism is highly regulated in plants and the first step in phenolic metabolism catalysed by L-phenylalanine ammonia lyase (PAL) (EC 4.3.1.5), is subject to a number of control mechanisms (23). For example, PAL activity is induced by light, wounding, plant growth regulators, and biotic and abiotic elicitor molecules. PAL is a key enzyme of plant phenylpropanoid metabolism; it is involved in the biosynthesis of a wide variety of secondary metabolites, including acteoside, that are important for normal growth and for responses to abiotic and biotic stresses (24, 25). PAL catalyzes the deamination of L-Phenylalanine to yield trans-cinnamic acid, the common precursor for biosynthesis of phenolic derivatives like flavonoids, monolignols, and salicylates that are essential for adaptive, vascular, and reproductive plant development (23, 26, 27).

It's well known that the biotic stress in plant caused such by bacteria, virus, parasites, insect and others involves some physiological and biochemical alterations. The aim of this study was to understand the changes in selected metabolic and biochemical parameters in wheat and barely plants under infestation by cecidomyie. The objective of this study is to understand mechanisms of cereals responses to induced stress by cecidomyie. Biochemical indicators concerned by this research are total and reduced sugars, free proline and phenyl ammonia lyase activity.

Material and methods

1. Plant material and growth conditions

1.1. Insects

The insects used in this study were *Mayetiola destructor* and *Mayetiola hordei*. The insects were from colonies maintained at the Entomology Laboratory of Institut National de la Recherche Agronomique-Centre d'Aridoculture de Settat (INRA-Settat). These colonies originated from puparia collected from bread wheat and barely field in Sidi El Aidi Agricultural experiment station (INRA-Settat). The insects were maintained in the reproduction wooden boxes at 20+/- 3°C until adult emergency.

1.2. Plant material

Two susceptible cultivars were used in this experiment. The *Nesma* variety for the bread wheat (*Triticum aestivum* L) and *Kanby* for the barely (*Hordeum vulgar L*) were choosen. The seeds of the two cultivars germinated in separate standard wooden flats (54 x 28 x 8cm), containing soil and vermiculite. The flats were kept in greenhouse and the plant of two cultivars grew at a temperature of 20+/- 3°C. The flats were watered two to three times a week.

1.3. Infestation protocol

The infestation was occurred when the plants reached the second-leaf stage. Flat of wheat or barley was caged separately with a cheesecloth tent. Approximately, 50 newly mated females of *Mayetiola spp* were released under each tent. The infestations were made in the morning between eight and ten o'clock corresponding to the mating period of the insect and after three days, the cheesecloth tent was pulled. Three cases of infestation were realized. Ten flats cultivar of barely were infested by *Mayetiola hordei* and others ten by *Mayetiola destructor*. Ten flats of the bread wheat were infested by *Mayetiola destructor*. For each cultivar of barley and wheat, ten flats without infestation were used as a plants controls (uninfested) and were also grown in similar conditions.

1.4. Plant sampling

The different plant sampling for the laboratory analysis was carried at different old age of the cultivars, corresponding to the life cycle of larvae development. Three stages: 15^{th}, 25^{th} and 35^{th} day old age of plant were choosen corresponding to the first, second and third instar respectively of *Mayetiola ssp* life cycle larvae development (1, 5). The second (25^{th}) stage was also named the Feeding-Stage. Effectively, after the 15^{th} day, the larvae reached the base of the stem and they began to feed. The third stage (35^{th}) was named the Nonfeeding stage (1, 5).

Several plant samplings were withdrawered from the growth wooden boxes at the 15^{th}, 25^{th} and 35^{th} day of the cultivars growth in both infested and control plant. The fresh plant material was taken in ice and the laboratory analysis were carried immediately

2. Laboratory analysis

2.1. Carbohydrates

The extraction of the carbohydrates was done essentially as described earlier (28). Approximately 1g of the fresh plant material (leaves) from control (uninfested) and infested plant was homogenized and grounded in a 80 % ethyl alcohol at room temperature to extract free sugars. The homogenate was centrifuged at 5000g for 15mn at 4°C and the supernatant was used for the total and reduced sugar analysis. Estimation of total sugar was done by the anthrone-sulphuric acid reagent according to the Ashwell method (29). The amount of the reduced sugar was done by Samogyi modified method (30), using the cupro-alcaline and arsino-molybdate reagents. Known concentrations between 0 to 50 µg/ml of glucose were used to estimate the concentrations of total and reduced sugar in different plant samples.

2.2. Proline

The amount of proline was determined according to the modified method of Bates *et al.* (31). Approximately 0.3g of plant (leaves) from control and infested plants being cut in to small pieces and grounded in a cold mortar by the addition of 6ml of a mixture containing methanol, chloroform and water (12/5/1) (v/v/v). The homogenates were centrifuged at 5000g for 5mn at 4°C and the supernatant was used for the proline analysis. Each sample tube containing 1.9ml acid ninhydrin (ninhydrin in ethanol-acetic acid) was incubated at 60°C for 20mn. The aqueous isopropanol (1ml) was added at each tube and the absorbance was measured at 570 nm by a spectrophotometer. Known concentrations (0-2500 µg/ml) of proline were used to estimate the sample concentrations.

2.3. Phenylalanine ammonia lyase (PAL)

PAL was extracted and estimated according to Edward and Kessmann method (1992). The procedure for enzyme extraction and determination of enzyme activity was carried out at 0°C in an ice bath. Approximately 1g of the frozen plant was finely ground in a cold mortar by the addition of 5 ml of the Tris-Hcl (100 mm) buffer pH 8 containing $MgCl_2$ (10mM), DTT (2.5mM), FAD (10µM) and the EDTA (2mM). The homogenate was then centrifuged at 10000 g for 30 mn and the supernatant was used for the enzyme activity. Total PAL activity was determined spectrophotometrically by following the absorption of the reaction product, cinnamate using the phenylalanie as a substrate (32). The enzymatic mixture contains 1 ml of the enzymatic extract, 0.5 ml of the phenylalanine 0.005M and 1.5 ml of the Tris-Hcl (100mM) buffer pH 8. After incubation at 30 °C, the absorbance was read in two hours at 15min intervals at 290 nm using a spectrophotometer. The rate of appearance of trans cinammic acid was taken as a measure of enzyme activity using an increase of 0.01 A_{290} equal to 3.09 nmol of *trans*-cinammic acid formed. The enzymatic activity was estimated by the µM/min/g FP of the *trans*-cinammic acid formed by the enzymatic reaction.

2.4. Statistical analysis

The data were subject to an analysis of variance and significance of differences by an LSD test at the 5 or 1 % level.

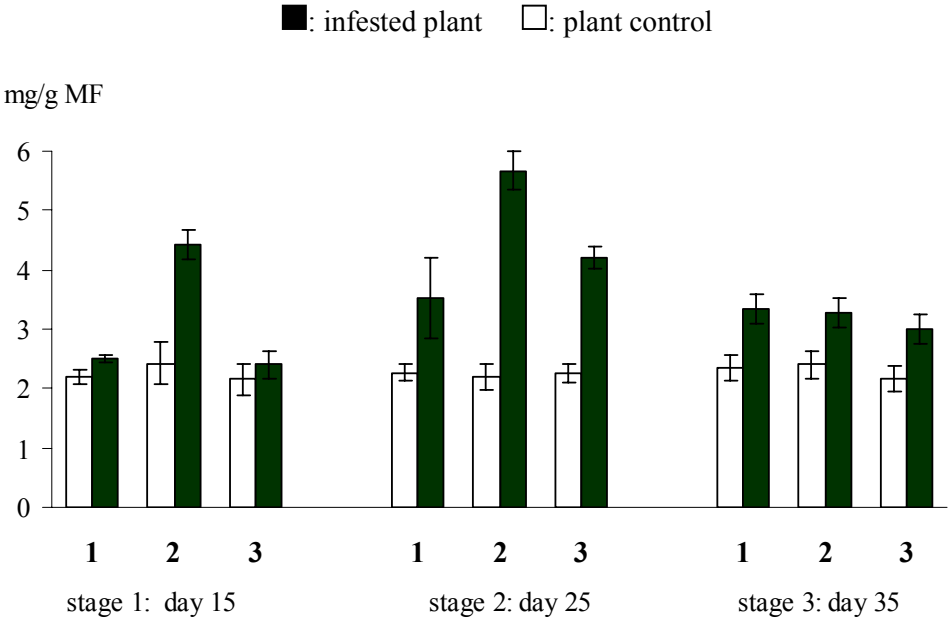
Results

1. Changes in carbohydrates content in barley and wheat

The mean change in free total carbohydrates in barley and wheat infested by *Mayetiola spp* are given in figure 1. The figure showed the comparison of the carbohydrates content in wheat infested by *M. destructor* and in barley infested both by *M. hordei* and *M. destructor*. During the three stages (15, 25 and 35th days) of this experiment, the mean total carbohydrates values in both barley and wheat plant control were similar, comparable and no significant difference was observed. However, after infestation, a significant difference between the control and infested plant in both wheat and barley was observed. The mean value for total carbohydrates concentration in both barley and wheat were significantly (p<0.05) high in the infested plant than in the plant control. In the case of barley, the infestation with *M.hordei* induced a significant increase in the total carbohydrates content from the first stage and reaches the maximum particularly during the second stage (3.53 mg/g F.M). During the last stage of experiment, the total carbohydrates content decrease but stained higher than the control (3.35 *vs* 2.34 mg/g F.M). In the second case, when the wheat was subject to the infestation, the free carbohydrate content increase also significantly from the first stage and the values were in maximum during the second stage of the experiment (5.67 mg/g M.F). At day 35 of the infestation, the carbohydrate content decreased but remained higher than in the plant control. In the third case, the

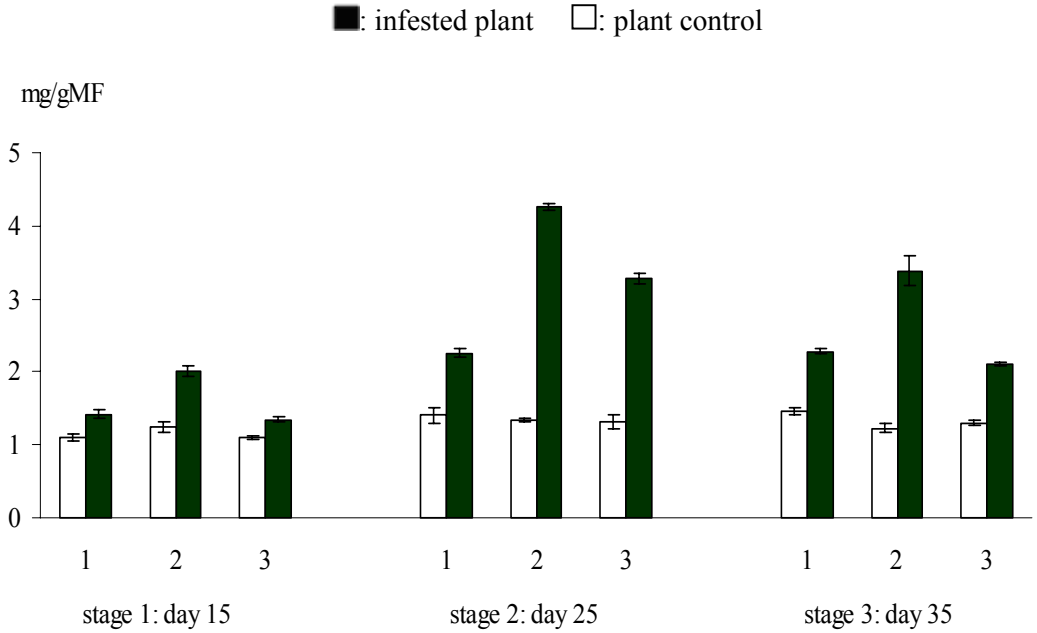
trend of total carbohydrate content in barley infested by *M. destructor* was similar to the precedent cases. The peak value was recorded at day 25 of the infestation (4.2 mg/g M.F). In general, the free total carbohydrates in both wheat and barley infested by *Mayetiola spp* presented similar evolution during all stages of the experiment. However, the free carbohydrate content was significantly higher in wheat than in barley ($p<0.05$).

Figure 1: Change in total carbohydrate in barley and wheat infested by *Mayetiola spp*.
1: barley with *mayetiola hordei*, **2**: wheat with *mayetiola destructor* **3**: barley with *mayetiola destructor*



The change in free reduced sugar is given in figure 2. The mean values of reduced sugar in wheat and barley plant control stained almost stable during the three stages of the experiment and no significant difference was observed. The infestation of barley and wheat by *Mayetiola ssp* produced an increase of the concentration of these metabolites. This increase begging at the first stage of the infestation and reach the maximum values during the second stage (4.25 and 3.65. mg/g MF for wheat and barley respectively). The reduced sugar decreased during the last stage of the experiment (35^{th} day) to a constant value. As observed in free total carbohydrate, the reduced sugar showed a significant difference ($p<0.05$) between barley and wheat during all stages. A significant difference was also observed in the reduced sugars content in barley infested by *M. destructor* and in barley infested by *M. hordei* during the second stage and the values registered were 3.28 and 2.26 mg/g MF respectively.

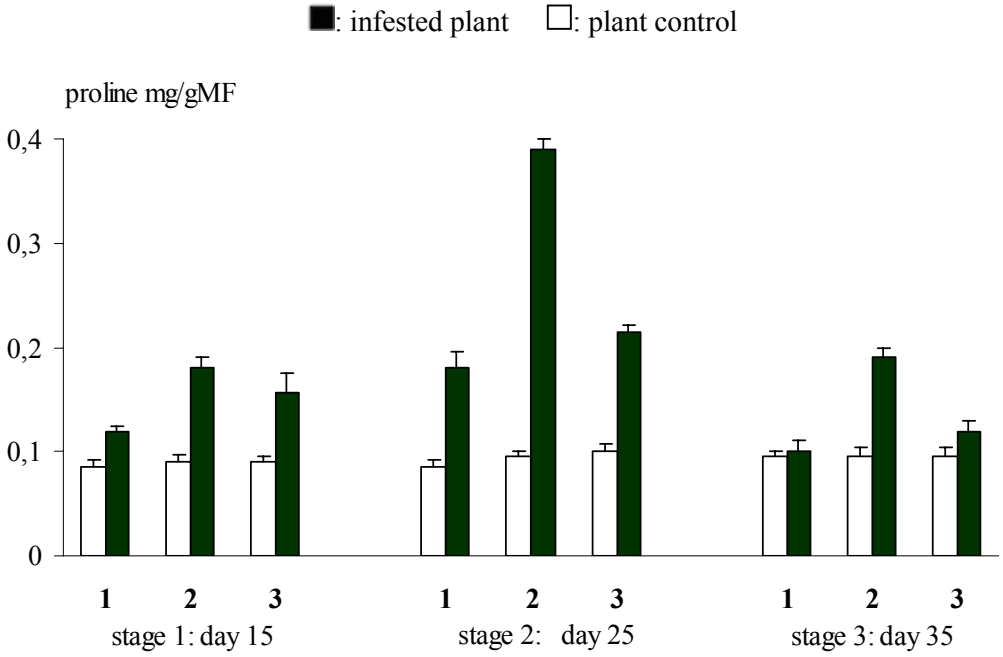
Figure 2: Change in reduced carbohydrate in barley and wheat infested by *Mayetiola spp*.
1: barley with *mayetiola hordei*, **2**: wheat with *mayetiola destructor*, **3**: barley with *mayetiola destructor*



2. Free proline

Free proline content in control and infested plants of barley and wheat were estimated on day 15, 25 and 35 of infestation, and the results are presented in figure 3. The mean values of proline content in plant control were between 0.085 and 0.1 mg/g M.F in both barley and wheat and no significant difference was observed during the three stage of experiment. When the infestation occurred, the free proline content undergone a change in barley and wheat at all infestation regimes during the three stage of infestation. The increase began from the first stage of experiment and remained higher on 25 day in both barley and wheat. Thus in this second stage, the increase in proline reach over 4 fold (0.39 mg/g MF) in wheat infested by *M. destructor* and 2 fold (0.215 mg/g MF) in both barley infested by *M. hordei* and by *M. destructor*. In the last stage of the experiment (day 35), the amount of proline decreased but stay higher than the control in both barley and wheat at the three infestations. In addition, a significant difference (p<0.05) in the free proline content was observed between barely and wheat during the three stages. The increase was more pronounced in wheat infested by *M. destructor* compared to barley infested both by *M. destructor* and *M. hordei*. The infestation of barley by *M. hordei* and *M. destructor* showed the same trend in proline content. During the three stages, the proline content was significantly higher in barley infested by *M. destructor* than in barley infested by *M. hordei*.

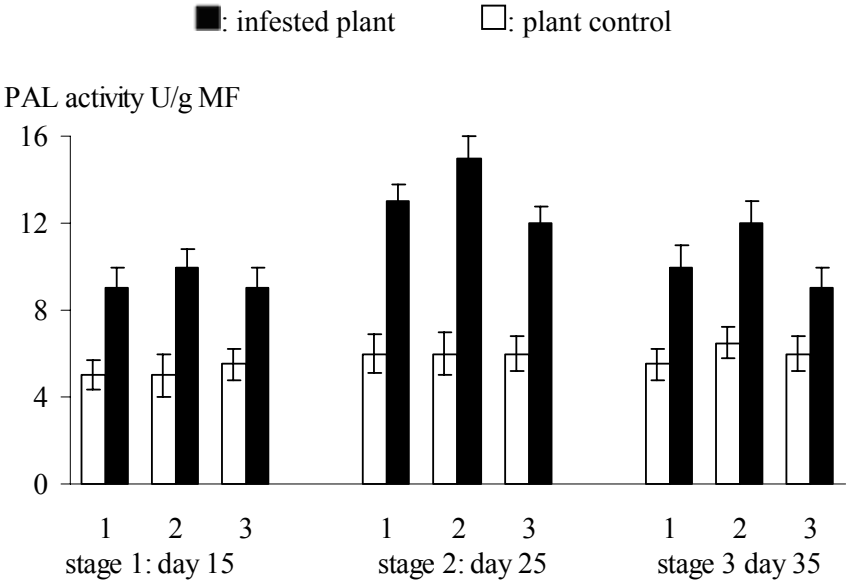
Figure 3: Change in proline in barley and wheat infested by *Mayetiola spp*
1: barley with *mayetiola hordei*, **2**: wheat with *mayetiola destructor* **3**: barley with *mayetiola destructor*



3. PAL activity

PAL activity in control and infested plant was estimated during the three periods and the results are presented in figure 4. The control plants showed a similar pattern of PAL catalytic activity in the different regims and during the three periods of the trial, as their activity were between 5.5 and 6.5 U/g. After infestation by *Maytiola ssp*, PAL catalytic activity in plant increased both in the infested plants of barley and wheat as compared to the control plants. This activity obviously increased after induction by insect stress and it reach the peak on the day 25 after infestation which is more elevated in wheat infested by *M. destructor* than in both barley infested by *M. hordei and M. destructor.* The values of PAL catalytic activity in this period of infested plants were 2.5 and 2 times greater than in the control respectively. At the end of study period, the activity of PAL appeared to return at lower values as registered in the first stage in the three infestations. It seems that there is no difference in PAL activity in barley infested by *M. destructor* and in barley infested by *M. hordei*.

Figure 4: Change in catalytic activivity of PAL in barley and wheat infested by *Mayetiola spp*.
1: barley with *mayetiola hordei*, **2**: wheat with *mayetiola destructor* **3**: barley with *mayetiola destructor*



General Discussion

In Morocco, *M.hordei* and *M.destructor* are responsible for the loss a third on the annual wheat and barley grain yields (1, 5). In our knowledge, this study is the first report on the change in some biochemical parameters in cereals infested by *Mayetiola spp*. The overall objective was to determine if the infestation of barley and wheat by *Mayetiola spp* caused modifications on carbohydrates level, proline content and PAL enzymatic activity. Morphologically, the infestation by *Mayetiola spp* stunted growth plant in both barely and in wheat.

Plants are continually exposed to a vast number of potential parasites and pathogens, as a result, they have evolved intricate defence mechanisms to recognize and protect themselves by setting up a series of defence responses to restrain the invading agents (36). When plants were impacted by with biotic, physical and chemical factors, the resistance of plants can be elicited efficiently (37, 38). The generation and accumulation of organic and inorganic solutes in plants were known as the major markers to the plants stress, the most conspicuous being carbohydrates and proline. The accumulation of compatible solutes may help to maintain the relatively high water content than otherwise necessary for plant growth and cellular function. Presently, it had been found on solanaceae, leguminosae and graminaea that the biotic and abiotic factors can induce the accumulation of carbohydrates and proline (39). The increase of the soluble carbohydrates in stressed plants was also previously described in other species such as *Vitis vinifera* (40, 41), *Lupinus albus*, *Eucalyptus globus* and *helianthus annus* (41). In our study a biotic stress was realized by the infestation of barley and wheat plant by *Mayetiola spp.* During the course of cecidomies larvae's penetrating in wheat and barley cell, besides of chemical secretion, the larvae's may causes mechanical signal by the physical pressure on the plant cell. The evolution of larvae development result on galls production on barley infested by *M. hordei*. This shows the firm attachment and the galling of leaf tissue around the flaxseed. In opposite, this formation wasn't observed if infestation was caused by *M. destructor*. Effectively, the infestation of wheat or barley by *M. destructor* shows the loose attachment and the lack of galling around the flaxseed. The gall formation was not apparent in wheat and in barley infested by *M. destructor*. The results demonstrate that the change in free carbohydrates in barley and wheat infested by *Mayetiola spp* showed a clear increase during times of infestation. The first carbohydrate accumulation occurred 15 days after infestation, reached maximum level at 25 day. This period corresponded to the first and the

second stage of the larvae development. These stages were recognised to the most hurtful in the development of the *Mayetiola spp* larvae, corresponding to the larvae feeding. At this stage, a depression, a discoloration of plant cells was observed at the feeding sites. The increase in free carbohydrates was also observed in wheat infested by *fusarium proliferatum* (42) and by *Agrobacterim* (35). The generation of the carbohydrates during the infestation of barley and wheat by *Mayetiola spp* could be in part resulting in the modification of the cell wall composition by the larvae enzymatic secretions. The accumulation of those organic solutes could be used for the cell osmotic adjustment during plant suffering and as a source feeding for the larvae development. High concentration of these solutes, by a feedback mechanism, may inhibit photosynthesis causing a reduction of plant growth (43). Effectively, the infestation by *Mayetiola spp* stunted growth plant in both wheat and barely as described by (1, 5). However, the accumulation of those carbohydrates was more elevated in wheat than in barley. This difference could be probably explained in part by the larvae cecidomie development. The number of larvae in barley was lower than in wheat. In wheat, the infestation by *M. destructor* induces an important larvae density and the higher accumulation of carbohydrate in this specie could be used probably as a source feeding for the larvae development.

In many plants under various forms of stress, the proline concentration increases up to 80 % of the amino acid pool (45) and several researches demonstrated the osmoprotective role of proline (6, 8, 46, 47). In our study, the proline concentration increased in barley and wheat under infestation by *Mayetiola spp*. and the highest levels were observed in the 25 day of the infestation corresponding to the feeding stage of larvae development. The proline accumulation was probably a result of tissue reaction to stress damage as reported by Hanson et al. (47, 48) and by Ferreira et al. (49). The biochemical mechanisms responsible for the proline accumulation in a specific plant tissue or organ are unclear (50). It is generally accepted that most of the proline accumulated during osmotic stress arises from its synthesis from glutamate (51, 52). However, the proline accumulation can be also associated with a decrease in its oxidation (50). In cereals and other plants, the accumulation of proline was observed essentially under salt stress studies (9, 10, 51, 52 53, 54). The infestation of barley and wheat by *mayetiola spp* caused a stress damage resulting probably in a change in the proline catabolic pathway and hence in the accumulation of the free proline. The proline accumulation was more important in wheat than in barley under infestation by Mayetiola spp. As in case of the carbohydrates, the higher proline content in wheat was in relation with larvae's development. The higher proline concentration could be due to tissue damage and cellulular osmotic adjustment. The proline biosynthesis affects carbon flux through oxidative pentose phospahate parhway (46). This in turn provides precursors to synthesize phenylpropanoids or secondary metabolites during stress condition. This consequently leads to change in the physical properties of cell wall and lignin accumulation (46). It was hypothesized that growth reduction may result from proline accumulation (55, 56). Further, it was proposed that proline might acts as an energy source during stress and therefore could be a key regulatory molecule capable of activating multiple responses that are part of the adaptation process (6).

Researches found that the stress stimulation increased the activities of some defense-related enzymes in plant. These enzymes act as the defensive chemical weapons against enemies and catalyze the formation of the physical defensive protection of the plant (57). The PAL is susceptible to the stress stimulation and plays an important role in the process of induced resistance by stress. The PAL activity increased significantly after stress induction. PAL is the key enzyme in the phenylalanine-like metabolic pathway; also it is the rate-limiting enzyme of lignin formation. Lignins thicken the plant cell wall, strengthening the physical fence against the penetrating pathogens (58, 59). In our experiments, we found that the stress caused in barley and wheat by *Mayetiola spp* increased the activities of PAL. The PAL activity increased significantly after biotic stress induction. The increase in PAL activity was also observed in cucumber under stress stimulus induced resistance to *cladosporium cucumerinum* (58, 59) and in maize under sunlight stress (60). The increase in PAL activity was more pronounced in wheat infested by *M. destructor* compared to barley infested by both *M. destructor* and *M. hordei*. This difference in PAL activity could be explained by the larvae population density. The other correlation between the aphid population density and increase in enzymes activity has been

reported in barley and wheat (61). The lower level of the PAL activity in barley compared to wheat is probably due to the galls formation in barley which reacts as a physical defence and the PAL activity could be used in the lignin synthesis for the galls formation.

During the third stage, the content of the carbohydrates, proline and PAL activity decrease in wheat and in barley. This could be explained by that during this period, corresponding to the third instar named the nonfeeding stage,. In barley, the infestation by *M. destructor* induce a higher increase in carbohydrates, in proline and in PAL activity than in the case of the infestation by *M. hordei*, a specific parasite. This difference could be explained in part by the fact that the biosynthesised carbohydrates and PAL activity were used in the lignin synthesis for the galls formation in barley infested by *M. hordei*.

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Influence of the Dynamic of *Albizia: Albizia Zygia* and *Albizia Adianthifolia* (Mimosaceae), on the Covering of *Chromolaena Odorata* (L.) R M. King & Rob. (Asteraceae) in the Post-Farming Vegetations of Oumé in Semi-Deciduous Forest Zone of Côte.D'ivoire

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Abstract

The present survey aims to establish the influence of *Albizia adiathifolia* and *Albizia zygia* (Mimosaceae) on the adventitious *Chromolaena odorata* (Asteraceae) covering during the reconstitution of post-farming flora. It was conducted at Oumé in the West Center of Côte d'Ivoire in semi-deciduous forest zone

The floristic statements and the measurements carried out in 54 gradual age parcels from 1 to more than 40 years showed that the recovery of *Chromolaena odorata* is influenced by the growthg of *Albizia adianthifolia* and *Albizia zygia* when height range from 15 to 20 m. The survey showed that *Albizia* stems density increase doesn't affect the recovery of *Chromolaena odorata*.

Keywords: *Albizia adianthifolia*, *Albizia zygia*, *Chromolaena odorata,* influence, dynamic, semi-deciduous forest zone, Côte d'Ivoire

1. Introduction

The reconstitution of the post-farming flora in tropical zone was abundantly observed and described by many authors (AUBREVILLE, 1947; ALEXANDRE *et al.*. 1978; ALEXANDRE, 1989, DEVINEAU, 1984 etc). However, the natural successions that they described are not always uniform in the same biotope.

In the chronology of descriptions, we note an evolution in the diversity and the richness of the flora, through these successions. In the descriptions of AUBREVILLE (1947) and SCHNELL (1976), they enumerated the main species of which the presence induced changes in the vegetable formation. Some of this species are: *Musanga cecropioïdes*, *Trema orientalis, Terminalia superba* etc.

The most recent authors (FLORET *et al.*, 1993, GNAHOUA, 1997, ANNE *et al.*, 2001), mention new species such as *Chromolaena odorata*, *Solanum verbascifolium*, *Albizia* spp etc. These

species are gradually replacing the quoted first. Also, in the recent models of reconstitution, the adventitious *Chromolaena odorata* is frequently described in the first stages of successions and plays a paramount role like it underlined by SLAATS *et al.* (1996). On the other hand, GNAHOUA (1997), DE FORESTA and SCHWARTZ. (1991) observed, that at the ultimate stage of development (maximum covering), this adventitious becomes a factor of inhibition of the post-farming reconstitution. We note, on the other hand in these parcel of land in reconstitution, the emergence of the woody leguminous plant stems; in particular that of the family of Mimosaceae (*Albizia* spp.).

However, the parts played by *Albizia adianthifolia, Albizia zygia* and the under ligneous pioneer *Chromolaena odorata* during the post-farming reconstitution are still variously interpreted and little known. However, DE FORESTA and SCWARTZ (1991) noted that, the bush with *Chromolaena odorata* delays the traditional form of known natural reconstitution in forest zone of Côte.d'Ivoire.

The present survey aims at highlighting, the influence of the dynamics of *Albizia* on the evolution of the covering of *Chromolaena odorata*. This with an aim of better including the news models of reconstitution and the adaptations of the flora in connection with the current climatic changes. This influence was evaluated on two levels:

- relation between the density of *Albizia* and the evolution of *Chromolaena odorata*; covering
- relation between dominant height of *Albizia* and evolution of *Chromolaena odorata*. covering

2. Materials and method

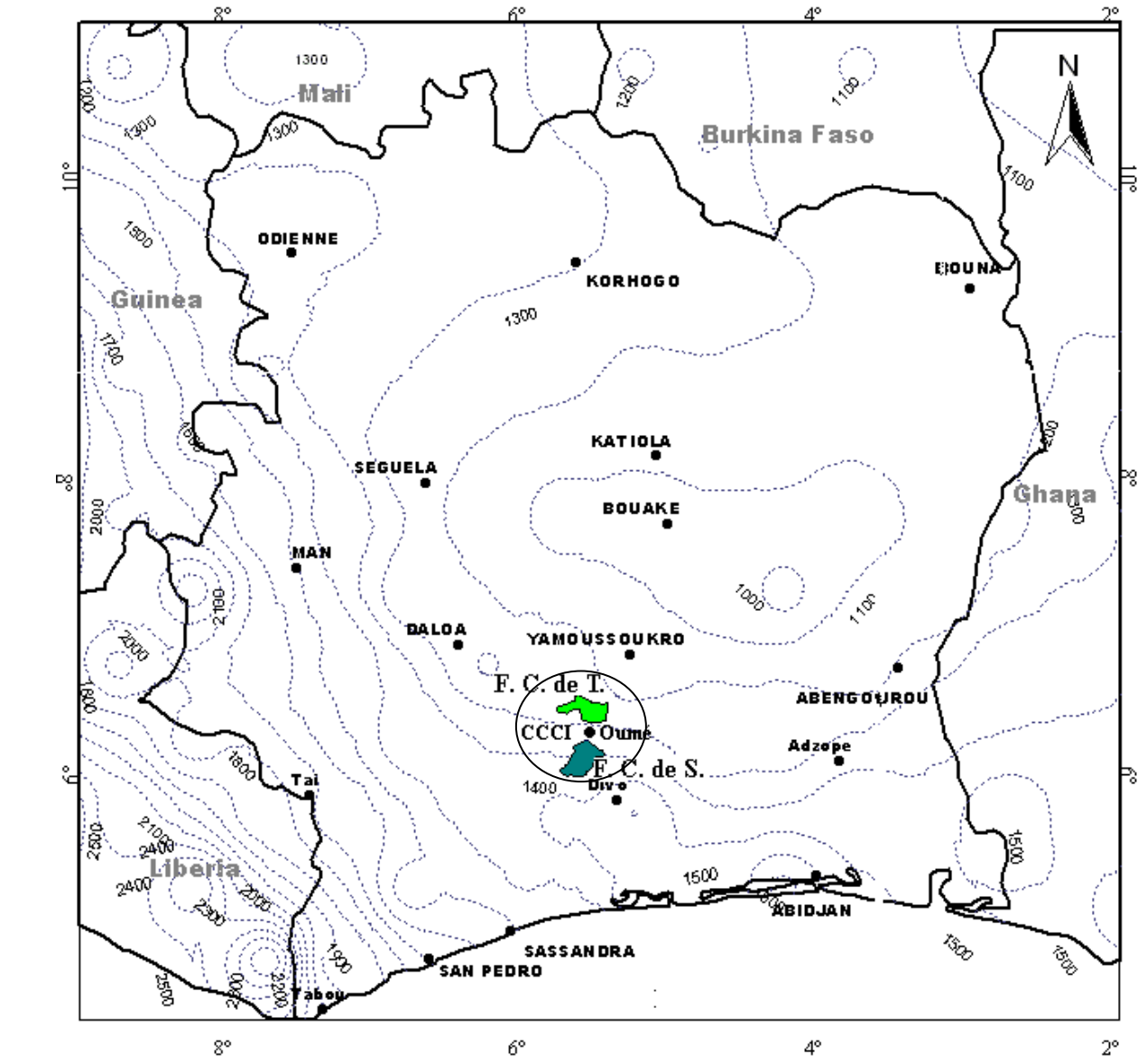
2.1. Site of the study

The survey took place in the Department of Oumé (Mid-West of Côte.d'Ivoire), in semi-deciduous forest zone, (Fig 1). This Department (2400 km²), is located at 260 km in the North-West of Abidjan, with for geographical co-ordinates: 6°et 7° N and 5°et 6° W.

The studied lands are located at the neighbourhoods and inside two classified forests (Téné and Sangoué) and on the site of the Company of the Cultures of Côte.d'Ivoire (CCCI), an agricultural development company. The classified forests of Téné and Sangoué respectively cover 29700 ha and 36200 ha (Anonymous, 2001). The farm of the CCCI extends out of approximately 2000 ha. The whole of the sites is under the influence of a bimodal subequatorial climate at 4 seasons: two rain seasons including one large from March to June, one small from September to October and two dry seasons including one large from November to February and one small from July to August (ANONYMOUS, 2001). The annual average temperatures vary from 24 to 25°C.

The annual average pluviometry of the area is about 1215 mm. The rain condition knows a very great variability. The grounds of the area are ferrallitic slightly outsatured (MONNIER, 1983).

Figure 1: Map of Côte.d'Ivoire and the localization of the study zone (Source: Monnier, 1983)
Scale: 1/400 000



Key

Survey zone

F. C. T. = classified forest of Téné
F. C. S.= classified forest of Sangoué

2.2. Materials

The survey related to 2 species of *the Albizia* genus (*Albizia adianthifolia* and *Albizia zygia*) and the adventitious *Chromolaena odorata*. *The Albizia* genus seems to be the vestiges of the semi-wet dense forests (SCHNELL, 1950). All the species belonging to this genus are deciduous.

Albizia adianthifolia (Schumach) W.F. Wigth is a species soudano-guinéenne which is present in the galleries forests and in their edges, as well as in the fallow developing on deep grounds (ARBONNIER, 2000). It is a tree with the sinuous trunk and the flattened summit. The bark brownish and is superficially cracked. The section is thin, yellowish and lets exude a gum. The leafs are alternate paripinnate composed. The petiole is pubescent. The flower carries a greenish chalice and a white corolla. The fruit is an oblong pod, punt more or less pubescent and membranous. It is brownish at maturity.

Albizia zygia (cd..) J.F. Macbr is also a species soudano-guinéenne. It shows similar ecological characteristics to *Albiazia adianthifolia*. It is a cylindrical barrel tree which can reach 1m diameter and which presents sometimes a light footing at the base. The summit of the tree is spread out. The bark smooth or craked brown gray color. The leafs are paripinnate composed. The leaflets increase gradually by size of the base towards the top of the limb. The inflorescence is made of flowers in spherical flowerheads, laid out in panicle at the end of the growths. The flowers have white petals and pink cheesecloths. The fruits are oblong pods, punts, glabrus, membranous, brown-dark at maturity.

Chromolaena odorata (L.) R. M. King & Rob. is a perennial shrub being able to reach 4 m height. Its leafs are opposite and reach sometimes 10 cm of length and 6 cm broad. They are green but are often tinted crimson. The petiole is approximately 1 to 2 cm length. The inflorescences are diffuse and final with white florets with blue pale. The young stems and the leaf give a very strong smell when they are ruffled.

Flowering proceeds from November at May (AKOBUNDU and AGYAKWA 1989). It is adventitious originating in the Central America (CRUTWELL-MCFADYEN, 1991; GAUTIER, 1993) who was propagated in Africa and Asia to the 20^{e} century. It is a colonizer of the open area (GAUTIER, 1992). It is dominant in the fields and the fallow of the forest zone and more and more in the savanna zone (AKOBUNDU and AGYAKWA 1989).

2.3. Method

The study related to 54 old parcel land from 1 to 50 years, located in rural environment and on the three sites presented above (CCCI, classified forests of Téné and Sangoué). On the whole, 18 parcels post-farming which were sampled on each site. The floristic statements, the inventory and the measurements carried out on *Albizia* were made in an unit parcel measuring each one 50 m. X 50 m. (Fig. 2).

The strength parameters (height, circumference) and the densities of settlements were measured on both *Albizia*.

In the heights measurement, only the individuals of more than 2 m were taken into account. As for the circumferences measurement, only the stems of more than 20 cm were retained. On the other hand, in the estimate of the density, all the stems of *Albizia*, since the young stage until to the raised stage were taken into account.

The age of each fallow was given with the records of the SODEFOR and the CCCI. On the other hand, in rural environment, this determination was based on surveys carried out near the farmers. Intact forest formations for more than 40 years, characterizing the ultimate stages of the reconstitution of the vegetation have been retained like pilot parcel land. The heights measurement was carried out using one dendrometer Blum-Leiss.

The measurement of the circumferences was made with a meter tape. For the estimate of the covering of *Chromolaena odorata,* unit surfaces of 2500 m² were divided into 5 under units of 500 m² and 25 m² (figure 3). The selected fallows were grouped inside 6 age groups (1 to 5 years; 6 to 10 years; 11 to 20 years; 21 to 30 years; 31 to 40 years; more than 40 years). These regroupings took account of the search for a balance between total numbers the groups' age.

The method of the linear statements, proposed by GAUTIER *et al.*. (1994) was associated that of the grixels (enumeration and classification of the species in parcel of 20 m with dimensions according to 4 cardinal points'). These grixels were subdivided each one in 4 squares of 10 m with dimensions. Each square of 100 m² of surface carries a code made up of the number of the parcel that of the grixel from which it results and of its sequence number (Fig. 3). Thus, the code of a square of 100 m² is never similar to that of another square.

Method of GAUTIER *et al.* (1994) combines the method of the transect and that of the point quadrat. This method used by KOUAME (1998) consists in reducing vertically a very fine needle (4 mms diameter) along a line materialized by a tape tended in vegetation.

Figure 2: Configuration of the great parcel for the inventory of *Albizia*

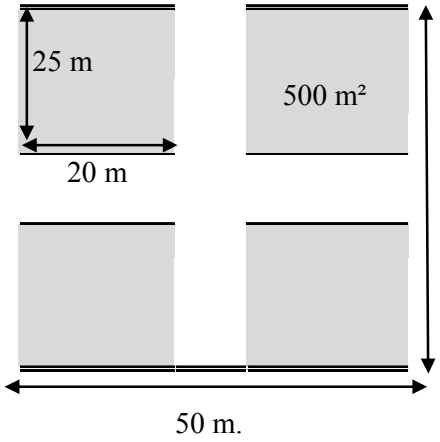
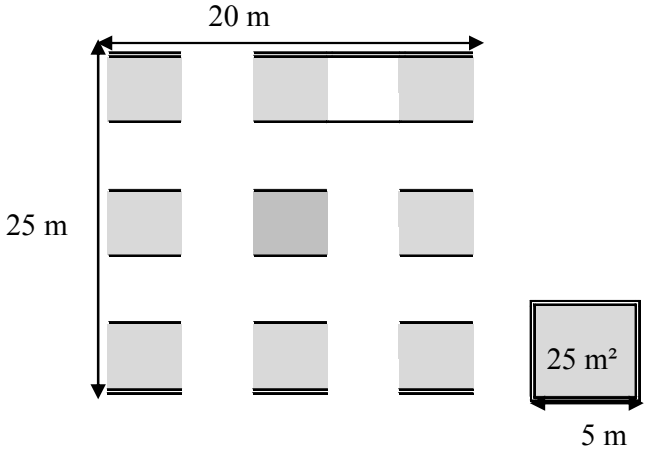


Figure 3: Configuration of the small parcel for the inventory of *Chromolaena odorata*



We note only the contacts of the needle and the species. The points of contact are located to each 10 cm; what gives a total of 100 points out of the 10 m. the number of points of contact of *Chromolaena odorata* is noted and expressed as a percentage starting from the formula (Ncc/Ntc X 100, with Ncc = a number of points of contact of *Chromolaena. odorata* and Ntc = a total number of points of contact along the 10 m). To eliminate skews related to the history from the parcel, we carried out the inventories in pieces which have the same farming precedent (the Coffee-tree). These fallow all were located on grounds of plates with sandy-clayey texture.

3. Data analyse

The data analyse related to the relations between the measured parameters of strength, the evolution of the floristic richness in the course of time and those of the parameters which chair the dynamics of these species. The software, SPSS version 11.1 was used for the statistical analyses.

4. Results

4.1. Age of the fallow, evolution of the density of *Albizia* and the covering of *Chromolaena odorata*

The bivariate correlation (table I) carried out with the density of *Albizia* and the covering of *Chromolaena odorata* in the course of time is nonsignificant. There is no correlation with the

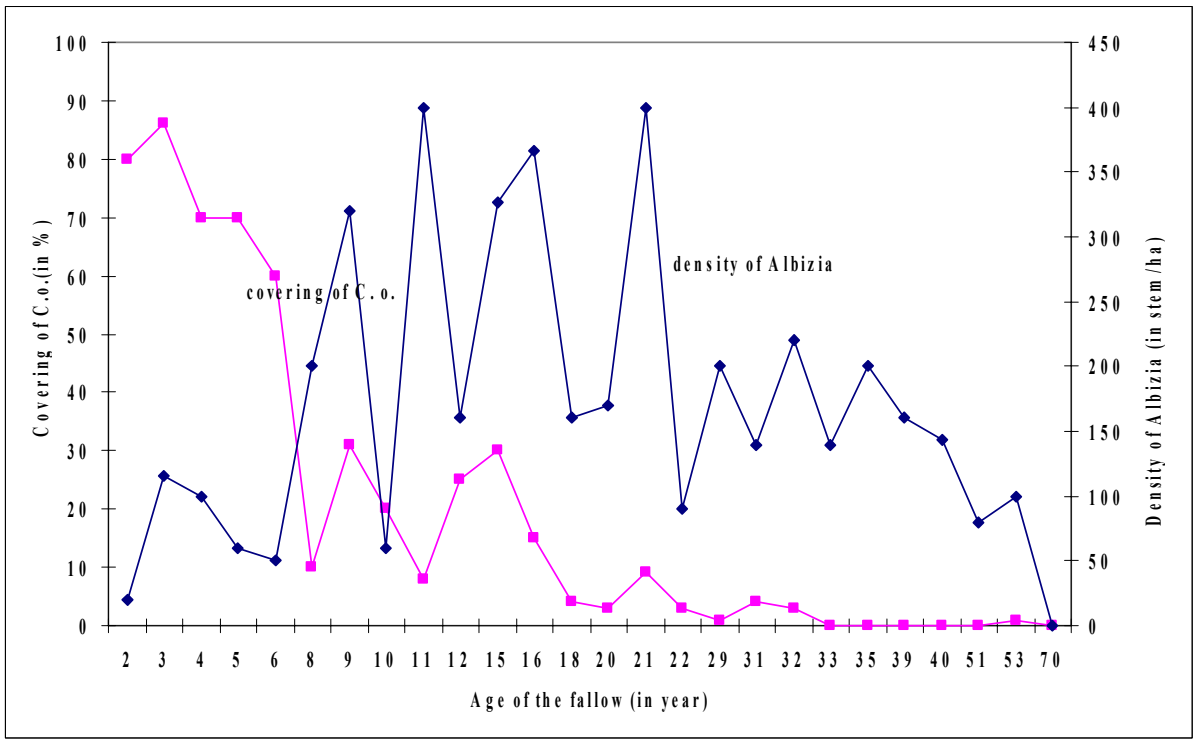
variations of the density of *Albizia* and the covering of *Chromolaena odorata*. On the other hand, these two parameters evolve in the same direction since the stages of young fallow, until more than 40 years (Fig 4). However, in the young fallow (1 to 5 years) we note an increase of the covering of *Chromolaena odorata*. (average covering estimated at 60 %). On the other hand the densities of *Albizia* are lower at this period and increase moderately.

The covering of *Chromolaena odorata* gradually decreases (40 to 30 % between 6 and 10 years; 30 to 10 % between 11 and 20 years) to reach an average value of less than 5 % in 30 years. The relatively low densities of *Albizia* (less than 100 stems/hectare) at the beginning (1 to 5 years) reach their maximum values (more than 200 stems/hectare) between 15 and 30 years. This period coincides with the disappearance of *Chromolaena odorata*.

Table 1: Bivariate correlation, density of *Albizia*, covering of *Chromolaena odorata* in the course of time

		Covering of *Chromolaena odorata*	**Density of *Albizia***
Covering of *Chromolaena odorata*	P Correlation	1,000	-0,135
	Sig. (2- level)	0,000	0,329
	N	54	54
Density of *Albizia*	Pearson Correlation	-0,135	1,000
	Sig. (2- level)	0,329	0,000
	N	54	54

Figure 4: Evolutions of the density of *Albizia* and the covering of *Chromolaena odorata* in the course of time



4.2. Age of the fallow, height average evolution of *Albizia* and the covering of *Chromolaena odorata*

The effect of the height average evolution of *Albizia* on the covering of *Chromolaena odorata* was estimated by a bilateral correlation (table II). This correlation is highly significant (with threshold 0.01) showing as well as the average height of *Albizia* and the covering of *Chromolaena odorata* were correlated.

The various average heights and coverings of *Chromolaena odorata* were projected on a graph (Fig 5). This projection shows height opposite average evolutions of *Albizia* and covering of *Chromolaena odorata*. Indeed, these curves of evolution show high values of the covering of *Chromolaena odorata* (50 to 80%) at the beginning of fallow (1 to 5 years) whereas the average heights of *Albizia* are very low (lower than 5 m.) at this stage. Beyond this period, the covering of *Chromolaena odorata* decreases gradually while passing from 70% to 15% to 15 years then with less than 5% after 30 years.

On the other hand, the heights average of *Albizia* move more quickly and pass from less than 5 m at the beginning of fallow to more than 15 m as from 30 years.

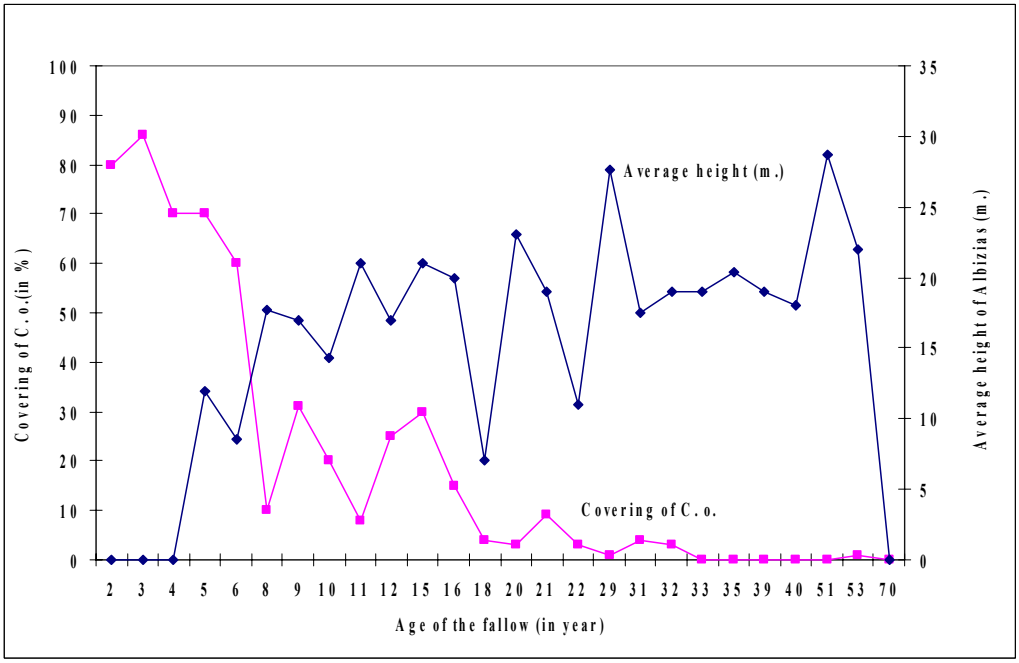
The maximum values average heights (more than 20 m) are reached between 20 and 30 years of fallow.

Table 2: Bivariate correlation, average height of *Albizia* covering of *Chromolaena odorata*

		Covering of *Chromolaena odorata*	**High or average of *Albizia* (in m.)**
Covering of *Chromolaena odorata. o*	Pearson Correlation Sig. (2-tailed) N	1,000 0,000 54	-0,555 0,000 54
Average High of *Albizia* (en m.)	Pearson Correlation Sig. (2 tailed) N	-0,555 0,000 54	1,000 0,000 54

** The correlation is significant with threshold 0.01 (bivariate).

Figure 5: Average height evolutions of *Albizia* and the covering of *Chromolaena odorata* in the course of time



6. Discussion

6.1. Duration of the fallow and evolution of the density of *Albizia* and the covering of *Chromolaena odorata*

The results of the analysis showed an absence of correlation between the evolutions of the densities of *Albizia* and the covering of *Chromolaena odorata*; what attests that the two parameters are not dependent. Thus, the covering of *Chromolaena odorata* evolves independently of the variation of the number of stems of *Albizia*.

On the other hand the shapes of the curves (fig. 4: densities of *Albizia* and covering of *Chromolaena odorata*) highlight a similarity between the evolutionary tendencies of the density of *Albizia* and the covering of *Chromolaena odorata* in the course of time. This similarity is on the one hand, related to the form of sampling and on the other hand to the competitions interspecific and intraspecific.

In fact, during the estimate of the densities of *Albizia*, all the phenologic stages were taken into account. Many young people seedlings of *Albizia* were sometimes counted under the bushes of *Chromolaena odorata*.

Les fortes densités d'*Albizia* en début de jachère (0 à 5 ans) en sont une illustration. Par ailleurs, *Chromolaena odorata* est plus recouvrante en début de jachère comme l'ont souligné SLAATS *et al.* (1996). Ces forts recouvrements et le nombre parfois élevé de jeunes plants de *Albizia* sous les buissons de *Chromolaena odorata* sont les raisons qui expliquent cette similitude d'évolution de la densité des *Albizia* et du recouvrement de *Chromolaena odorata* en début de jachère (0 à 5 ans).

The strong densities of *Albizia* at the beginning of fallow (0 to 5 years) are an illustration. In addition, *Chromolaena odorata* is more covering at the beginning of fallow like it underlined by SLAATS *et al.* (1996). These strong coverings and the sometimes high number of young seedlings of *Albizia* under the bushes of *Chromolaena odorata* are the reasons which explain this similarity of evolution of the density of *Albizia* and the covering of *Chromolaena odorata* at the beginning of fallow (0 to 5 years).

Beyond 5 years certain *Albizia* are eliminated during the intra competition and interspecific. In the same way some specimens of *Chromolaena odorata* are eliminated by the same process.

On the other hand, the ascent of the curve of *Albizia* on that of *Chromolaena odorata* beyond 15 years of fallow is related to the ecology of the studied species. Indeed, *Albizia* (woody species) are "longevives" and more competitive than *Chromolaena odorata* (herbaceous) which is species less "longevive".

6.2. Age of the fallow, height average evolution of *Albizia* and the covering of *Chromolaena odorata*

The effect the average height of *Albizia* on the decline of filled of *Chromolaena odorata* was highlighted by a bilateral correlation. This correlation is significant with a threshold of 0,01; what highlights, the existence of a dynamic interaction between these two parameters. This interaction is summarized with the influence average height of *Albizia* on the covering of *Chromolaena odorata*. However this influence becomes really perceptible as from 20 years.

The fall of the covering of *Cromolaena odorata* thus observed when the average height of *Albizia* reaches 18 m. shows that this level of the vertical layer of *Albizia* is inhibiting covering of *Chromolaena odorata*. However, it is junction of the summits of *Albizia* which the decline results from the bush of *Chromolaena odorata*, consecutively with the excessive shade of *Albizia* which affects the growth and the photosynthesis of this adventitious. On the other hand when *Albizia* miss in certain fallow, the reconstitution of the farming post- is often modified and blocked by the presence of *Chromolaena odorata* which becomes under these this conditions very invading. According to FORESTA (1995) and GNAHOUA (1997) *Chromolaena odorata* would slow down the emergence of the forest species thanks to its great capacity of regeneration. In the opposite direction, the fact that the evolution of *Albizia* is not blocked by the large tuft formed by the covering of this adventitious, is an advantage related to the particular characteristics of these leguminous plants to know, their fast growth and their capacity to be developed with very small quantities of light which enable them to cross the barrier drawn up by this adventitious. Moreover, ACHOUNDONG (1988) mentioned that at the beginning of reconstitution, *Albizia* with the flexible stems thread in the barrier formed by *Chromolaena odorata* by using the branches of this adventitious as tutors. This association is advantageous with the stems of *Albizia* which, thanks to their fast growth succeed in very quickly

supplanting the bush of *Chromolaena odorata*. In addition, the seeds of *Albizia* require minimal conditions for their germination (TAYLOR, 1962; 1989). However, the regression of the growing of *Chromolaena odorata* in the presence of *Albizia* judicious improving the food values of the ground by their fixing nitrogen (N) action confirms the assumption which stipulates that the deficit of light is that which inhibits the development of *Chromolaena odorata*. The decline phase of *Chromolaena odorata* corresponds to the period of timbering of the parcel as evoked by FLORET *et al.* (1993). This period which ranges between 15 and more than 20 years of fallow is relatively that to which one obtains the inhibiting average height of *Albizia* (18 m.). It east can be for this reason that GNAHOUA (1997) evoked an interrelationship between the dynamics of *Albizia* and the covering of *Chromolaena odorata*. NOBLE and SLATYER (1980) proposed a model of reconstitution of the vegetation based on the biological characteristics of the plants. According to these authors, the phenomena of succession and colonization could be considered like the consequences of differential aptitudes for the installation, the growth and the survival of species adapted to grow in various biotopes.

Two of the most significant attributes of the plants than they evoke, are the aptitude of a plant to be established to be maintained, become ripe after disturbance of the medium and time necessary to a species to reach the critical phases of its development. In this case, the disturbances due to the prolongation of the setting in culture of the pieces and which involve the proliferation of adventitious such as *Chromolaena odorata*, can be corrected by the development of *Albizia*.

Conclusion

The development of *Chromolaena odorata* is influenced by the dynamics of *Albizia*. This influence is the fact the average heights which is made conspicuous on the level of the air covering of the stems of *Albizia*. These average heights, when they reach 18 m are harmful with the development of *Chromolaena odorata*. On the other hand, the effect of the densities of the stems of *Albizia* has little or almost not influence on the evolution of the covering of *Chromolaena odorata*.

On the other hand, when, the strong densities of *Albizia* coincide with the inhibiting dominant heights, the cumulated effect of the density and the average heights is apparent on the covering of *Chromolaena odorata*.

Thus, the fast growth of *Albizia* and their aptitude to make regress *Chromolaena odorata* are properties which can be made profitable in the programmes of improvement of the fallow and reafforestation of the degraded sites.

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Renewable Energy Sources in the Greek Power Market: An Analysis of Policy and Regulations

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Abstract

The aim of this paper is to provide an analysis of policy and regulations for Renewable Energy Sources (RES) of the present situation in the Greek power market. The legal framework concerning RES in the European Union affecting Greece is described with the related directives. Also, the legal framework that regulated power market in Greece is presented with the new specific Greek laws and ministerial decision, while the main Greek institutions related to RES are reported. Finally, an outline of the current status of RES in Greece is presented.

Keywords: Renewable energy sources, electricity, legal framework, Greece
JEL Classification Codes: L52, Q20, O14

I. Introduction

The world economy depends in a great extend on energy availability and there is an impending need for sustainable development using Renewable Energy Sources (RES). RES are inevitably considered more and more by developed countries nowadays as a substitute to fossil fuels. It is well known that sun, wind, biomass, waves, rivers, tides and the heat from radioactive decay inside the earth are all abundant.

The obvious problem is the effective exploitation of the above natural activities in order to produce energy. Additionally, increasing the proportion of power derived from renewable energy sources is becoming an increasingly important part of many country's strategies to achieve reductions in greenhouse gas (GHG) emissions.

The structure of this paper is as follows: In Section II a brief literature on RES is presented for some countries worldwide, Greece and EU. Section III presents the current legal framework concerning RES in the European Union (EU) that influences Greece, and section IV refers to the present valid legal Greek RES framework. Section V depictures the role of the energy institutions related to RES in Greece. In Section VI an outline of the current status of RES in Greece is presented, and an estimation of the RES installed capacity requirements in order to meet the European Committee targets is made. Section VII concludes with a proposition for sustainable development with the application and use of RES in Greek power market.

II. Literature review

The literature on RES applications and research is vast in the international energy journals. Many researchers have investigated the renewable energy policies, the political organizations that shape these policies and the legal framework in general throughout the world. In most countries there is a strong willingness in theoretical basis to promote RES, but great barriers (political, administrative, legal, operational, economical and technical barriers) arise when theory is to be put into practice, especially in immature energy markets. In Africa, including as sample countries Egypt, South Africa, Nigeria and Mali, Bugaje (2006) proposed that, in order to harness the abundant renewable resources, skills and knowledge from each member state experience should be combined, leading to solutions in various key issues problems (development of appropriate infrastructural supports, etc.). In the GCC countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates) Doukas et al. (2006) observed that, despite the fact that there are large quantities of oil and natural gas, they are keenly interested in taking a more active part in the development of RES, especially in solar energy which has a significant potential in this area. However, a minor development of RES has been implemented during the last years. Katinas and Markevicius (2006) implied that in Lithuania, despite the government policy efforts to promote the exploitation of local and renewable energy sources (small-hydros, biomass, biogas, etc.), the total contribution of RES is minor (electricity production from RES was about 3.2% of the total consumption in 2004), and special subsidy policies are required by the government. Kaya, D. (2006) argued that in Turkey, although there are substantial reserves of renewable energy resources, the actual utilization of these resources is quite low, and governmental favourable policies are necessary for RES development. Also, Kinnunen (2006) noticed that, in Finland, the regulatory schemes were not too encouraging for new investments, and the uncertainty about the future developments has caused the investments to remain in low levels. Lee and Ahn (2006) for South Korea reported that the government suspended its electricity market reform (namely transmission open access and wholesale competition) till 2008, introducing retail competition thereafter. Finally, Wang (2006), in Sweden, while there is a common political decision to replace nuclear power with power from RES, implied that a lack of consensus about the pace of phasing out nuclear power is observed, due to negative impacts on competitiveness of the Swedish industry. Such a dilemma resulted in a lack of strong government commitment to the development of RES, and led to short-term programs with limited subsidies for RES investments.

Moreover, several Greek researchers have proposed applications of RES in the Greek power system. Kaldellis and Kavadias (2001) proposed a specific methodology of optimal wind-hydro solution estimation and then applied this to the Aegean islands, in order to define the most beneficial configuration of the proposed renewable station. Kaldellis et al. (2006) investigated the maximum wind energy penetration in a given autonomous electrical network. Their model estimates the maximum wind energy contribution, takes into consideration the operational characteristics of the local system, and predicts the minimum wind energy rejection. Mourelatos et al. (1998) formulate a general

methodological framework of an action plan for the large-scale integration of RES is presented. The realization of the plan concerns four steps: first, identification and ranking of RES, according to various criteria that must reflect the priorities of local community; second, formation of candidate sets of RES that satisfy the goal of minimum interventions to the energy system through selective location planning of RES projects; third, evaluation of the technical and the economical analysis; fourth, social acceptance of the proposed action plan, in order the social welfare of the local community to be increased. Finally, Tsioliaridou et al. (2006) introduced an energy planning methodology for more efficient promotion of RES technologies in the electricity sector. A comprehensive computer simulation tool is developed, which combines data and knowledge for different sources, such as wind, small hydro, photovoltaic, biomass and solar thermal plants, based on new or additional RES promotion schemes. The last three studies are applied to the autonomous system of the island of Crete.

Furthermore, several researchers [12] have investigated the implementation of the goal of the EU Directive 2001/77/EC, namely the share of RES to reach 12% of the gross domestic energy consumption of EU by 2010. Reiche and Bechberger (2004) investigated the value of different promotion strategies and deployed instruments, concluding in a number of success conditions for an increased use of RES, including long-term planning security for investors, technology-specific remuneration for green power, strong efforts in the field of power supply systems (grid extension, fair access to the grid, etc.) and measures to reduce local resistance against RES projects. Harmelink et al. (2006) evaluated several mid-term policies to support the development of RES, using a methodology to assess the effectiveness of policy instruments. This includes specification of relative check-lists for evaluating the effectiveness of several policy instruments, a description of success and risk factors, and a step-wise approach used to come from individual technology and instrument data to an overall assessment of the gap between policy targets and realization. The methodology quantifies the projected growth of individual RES at each EU country. The results indicate that the EU Directive target will not be met and that rapid additional policy implementation is needed.

Consequently, in the past literature several political, legal, economical, environmental and technical aspects that enhance or depress the potential for new RES investments are considered, and the respective conclusions are always interrelated to such factors.

III. Legal framework for RES in EU

The promotion of electricity produced from renewable energy sources is a crucial target of the European Commission's energy policy, as outlined in the White Paper on Renewable Energy Sources. RES have an important role to play in reducing net emissions of greenhouse gases (carbon dioxide, methane), which is a critical EU objective. Their share increase in the energy balance enhances sustainability and helps to improve the security of energy supply by reducing the EU's growing dependence on imported energy sources. The fact that increased market penetration of electricity produced from renewable energy sources will allow for economies of scale, thereby reducing costs at some RES in the medium to long term is also adopted and approved from the European Union.

Directive 96/92/EC

The basic directive that determines the operation of the electric energy market in the EU is Directive 96/92/EC, which is partially in force today. The EU Directive 96/92/EC defines common rules for the production, transmission, distribution and supply of electric energy in the EU, imposing minimal operational specifications for the internal electric energy market of the EU, with which all Member States should comply in national level. The directive imposes the establishment of an Independent System Operator (ISO) for the management of the high voltage transmission system, and it allows the access of third parties in the transmission system and in the distribution network on the basis of transparent and objective criteria, which are ensured by an independent authority for energy.

Directive 2001/77/EC

In order to ensure increased market penetration of electricity produced from RES, all Member States of the European Union should be required to set national indicative targets for the consumption of electricity produced from RES, as outlined in Article 2 of the Directive 2001/77/EC. The national indicative targets are consistent with the global indicative target of 12% of gross domestic energy consumption by 2010. Their detailed implementation should, however, be left to the Member States, thus allowing each Member State to choose the regime which corresponds best to its particular situation, in accordance with the principle of proportionality. Hence, this condition reveals, to some extent, each nation's level of efficiency on promoting RES.

Directive 2001/77/EC in its annex sets an indicative target for Greece of covering a part of its gross national electricity consumption by 2010 from renewable energy sources (RES) equal to 20.1%, the contribution of large-scale hydroelectric plants being included. This target is compatible with the international commitments of the country resulting from the Kyoto protocol signed in December 1997 within the context of the Rio UN framework agreement on climate change. The Kyoto protocol foresees for Greece a 25% increase of CO_2 and other gases that aggravate the greenhouse phenomenon by the period 2008-2012 with respect to the base year 1990.

IV. Legal framework for RES in Greece

In Greece renewable energy is produced by the exploitation of wind, solar, biomass, biogas, geothermal, sea and small hydro resources, or their combinations. This definition is used in the Greek legal framework (briefly stated below) and also in both the National Development Law (Law 2601/1998, "State support of private investments") and the Greek Operational Programme for Competitiveness (a programme within the third Community Support Framework for Greece, covering the time period from 2000 to 2006).

Law 1559/1985

The beginning of RES entry into Greece was Law 1559/1985, under which the Public Power Corporation (PPC), leading the way with RES, installed 24 MW whereas local government organizations confined themselves to a level of 3 MW and the private sector was left out of the scene entirely. In spite of the small outcome, the effort showed the weaknesses and strengths of the sector and especially the initial failures paved the way for more mature implementations.

Law 2244/1994

Law 2244/1994, modelled on the pattern of the German "Stromeinspeisungsgesetz", ushered in the RES era. The Law established fixed sale rates for renewable energy at a level in real terms equal to 90% of the medium-voltage, general use tariff and made it obligatory for the PPC to buy that energy. For the reimbursement of the capacity part, a scale pricing system was introduced according to the type of RES plant in terms of time availability. Roughly speaking, the capacity part merely augments the energy earnings by a small percentage in the range of 6.5% so that the final rate corresponds to 68.68 €/MWh. In the non-connected system the pricing is based on 90% of the low-voltage, household rate corresponding to 79.73 €/MWh and no capacity reimbursement is provided.

Law 2773/1999

The basic law governing RES electricity in Greece is Law 2773/1999, which specifies the establishment of the Hellenic Transmission System Operator S.A. (HTSO). The key provision of this Law for RES is that HTSO is obliged to give priority to RES plants (up to 50 MW, or in case of small hydro plants up to 10 MW). Also, HTSO is obliged to co-sign ten-year contracts with RES producers for the purchase of their electricity production. Additionally, Law 2773/1999 instituted the "production

license", which is the first license required to be acquired by an investor for a new power plant (conventional or RES), that includes among others land-use permission and approval of environmental terms and conditions.

Law 2941/2001

Law 2941/2001 filled some gaps in the current legislative framework, and also attempted to deal with the licensing process pathogenesis providing a clear definition of the conditions for permission to install RES power plants in forests and forestry lands. The basic points of Law 2941/2001 are:

a. The exemptions from the overall restrictions imposed by the forest laws applicable to the implementation of large-scale infrastructure works for public benefit in forests and scrublands, are extended to include RES.
b. With the exemption of civil works no building permit is required for the installation of solar systems and wind farms.
c. Connection lines of electricity producing facilities using RES with the interconnected system of the mainland and the grids of autonomous island areas may be constructed by any interested investor, according to specifications provided by HTSO.
d. The renewable electricity projects including the connecting lines, substations and infrastructure works in general are deemed as public utility works irrespective of the entity implementing them and therefore the expropriation of landed property or the mandatory acquiring of rights in them is possible.
e. The issuing of a joint ministerial decision is provided, by means of which more relaxed zoning and subdivision controls, in comparison with the generally applicable town-planning regime, will be enacted in areas beyond the limits of existing city plans to facilitate RES development.
f. The Planning and Development Directorates of the relevant Regions having jurisdiction over the issue of installation and operating permits, act in some ways according to the one-stop shop principle, by coordinating the issues of environmental licenses that include many public services and other bodies.

Law 3010/2002

Law 3010/2002 enforced the harmonization of national legislation for the protection of the environment with the EU Directives. Specifically, it specified the general terms and procedures for obtaining the necessary environmental licenses for any given investment project (including RES projects).

Law 3017/2002

By virtue of Law 3017/2002, the Greek Parliament put on an official footing the country's commitment to actions to counter the growth of the greenhouse phenomenon.

Ministerial Decision 1726/2003

On the regulatory level, the joint ministerial decision 1726/2003, in the formulation of which numerous Ministries were involved, was issued in order to adjust the overall licensing procedure of RES projects to the environmental consent process. Among the regulations to be introduced into the joint ministerial decision, it is worth mentioning the fixing of reduced time limits. Should no action be taken within these limits, the authority managing the licensing procedure is entitled to consider as positive the interim approvals or opinions lacking from other Services and bodies and thus to press the licensing process forward to completion. This expedient fully reflects the requirements of article 6 of Directive 2001/77/EC.

Law 3175/2003

Law 3175/2003 established for the first time a comprehensive set of rules for the rational use of geothermal energy. The new framework is compatible with Community's view on geothermal energy as a renewable energy source contributing to sustainable development. Thus, Law 3175/2003 moves along a path at variance with the long entrenched view of geothermal energy as a mineral obeying the rather stiff rules of Legislative Decree 210/1973 "Mining Code" (Government Gazette A 277). In short, any geothermal field is addressed as a unique deposit-source by avoiding any breakdown according to individual concession procedures. A concrete bidding procedure is set up for the whole range of products, by-products and process residues. The recoverable potential of the two fully explored high-enthalpy fields for power generation purposes amounts to 170 MWe whereas the probable potential of the whole country exceeds 500 MWe.

However, the main scope of the new law was to revise Law 2773/1999 in order to make up for the slowness of the liberalization process of the electricity market mostly attributed to the dominant position held by PPC. This revision was also necessary in order to reflect the modifications portended in Directive 2003/54/EC concerning common rules for the internal market in electricity and repealing of Directive 96/92/EC.

In the realm of RES, Law 3175/2003 reiterates the definition of Directive 2001/77/EC article 2 regarding hybrid plants in order to remove the existing ambiguity with respect to the actual classification of the energy produced from these systems. Thus, they enjoy the same favourable pricing regime as other forms of RES although especially in the non-connected system they are not exempted from a tendering procedure being a precondition for being granted production authorizations.

In the pattern of breakthrough law-making initiatives taken to speed up the implementation progress of works pertinent to the 2004 Olympics (that took place in Athens), Law 3175/2003 provides further actions including the introduction of shortened and simplified procedures regarding expropriations necessary for the reinforcement and extension of power transmission lines which will also serve RES deployment.

Law 3468/2006

Law 3468/2006 is considered as a breakthrough in the legal framework in Greece, regarding the support for the installation of RES power plants. The basic points of Law 3468/2006 are summarized in the following:

a. The exceptions from acquiring a production license are changed. The installed capacity of RES power plants that are exempted from acquiring a production license are increased, in order to facilitate the simplest possible procedures for potential investors.
b. The conditions for the issuance of the installation and operation licenses is defined and simplified (as compared to the past years).
c. The RES producer co-signs a contract with HTSO (or the system operator of the non-connected islands of Greece in case the investment is located in such islands), stating that for 10 years the electricity produced by the RES power plant is going to be absorbed by the transmission network. The expiry date of this contract can be extended for another 10 years unilaterally by the RES producer (in case of such intension).
d. For the first time in Greece, Law 3468/2006 applies special feed-in tariffs for power production by RES, giving special attention to power production by PVs. In the interconnected power system electricity by PVs will be sold at 450 €/MWh, while in the non-connected system of the Greek islands the electricity by PVs will be sold at 500 €/MWh. This constitutes a breakthrough for solar energy in Greece, since the value of solar energy before this Law was equal to about 68 €/MWh in the interconnected system and about 80 €/MWh in the autonomous islands.
e. A new program for the utilization of the solar energy is established by the Ministry of Development, which states that until 2020 500MW of PV power plants shall be connected to the Greek interconnected power system and another 200 MW of PV power plants shall be

connected to the power systems of the non-connected Greek islands. This program constitutes a great perspective for the utilization of solar energy in Greece.

V. The identity and the role of the energy institutions in Greece

The Centre for Renewable Energy Sources (CRES) is a critical institution for the promotion of RES in Greece. Also, in order to comply with Directive 96/92/EC, the Regulatory Authority for Energy (RAE) and the Hellenic Transmission System Operator (HTSO S.A.) have been founded and operate in Greece.

Centre for Renewable Energy Sources (CRES)

The establishment of CRES was provided in article 25 of Law 1514/1985 and was implemented by virtue of Presidential Decree 375/1987. The scope of CRES is the promotion of RES, energy saving and the rational use of energy, as well as any kind of support for activities in those fields. Further, by virtue of article 11 of Law 2702/1999, CRES operates as the national coordinating centre of all those activities. CRES has laboratories for certification of RES technologies, carries out studies for the determination of the physical as well as technical and economical potential of RES and participates effectively in the evaluation and monitoring of the investments implemented in the sector, including the energy savings field.

Regulatory Authority for Energy (RAE)

RAE was established by virtue of article 4 of Law 2773/1999, and is founded as an independent authority with main obligations the control and the supervision of the liberalized energy market. Furthermore, the Minister of Development and the RAE should take actions in order to protect the environment, to meet the demand in electric energy, to check whether the holders of generation and supply licenses are capable of financing their activities or not, to promote competition in the sectors of electric energy generation and supply, to protect the interests of consumers, to promote efficiency, to take into consideration the expenses for Research and Development (R&D), and, finally, to protect the public health and safety. RAE formulates proposals to the Minister of Development with regard to the issue of power generation authorizations and thereafter monitors the implementation progress of the RES projects through quarterly reports. The evaluation of all applications is performed by RAE assisted in the technical part by the Centre for Renewable Energy Sources, which is mentioned below.

Hellenic Transmission System Operator S.A. (HTSO)

HTSO (in accordance with article 14 of Law 2773/1999) was established by virtue of Presidential Decree 328/2000. HTSO is entrusted with the enforcement of the law's provisions, which aim at the development of genuine competition on the basis of a more liberal and flexible daily market. HTSO should cover power demand, based on the economic offers (bids) that are submitted in the day-ahead market by all technically available production units. HTSO should also take into consideration the technical restrictions of the transmission network, and its obligation to give priority to plants that use Renewable Energy Sources (RES) and co-generation plants.

VI. Outline of RES in Greece

The types of RES that are currently developed in Greece are small hydroelectric, biomass, PVs and wind plants.

The values of installed capacity of RES (not including large-scale hydros) in the Greek power market from 1983 to 2005 **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε**.are illustrated in Figure 1.

Figure 1: Historical records of installed capacity of RES in Greece

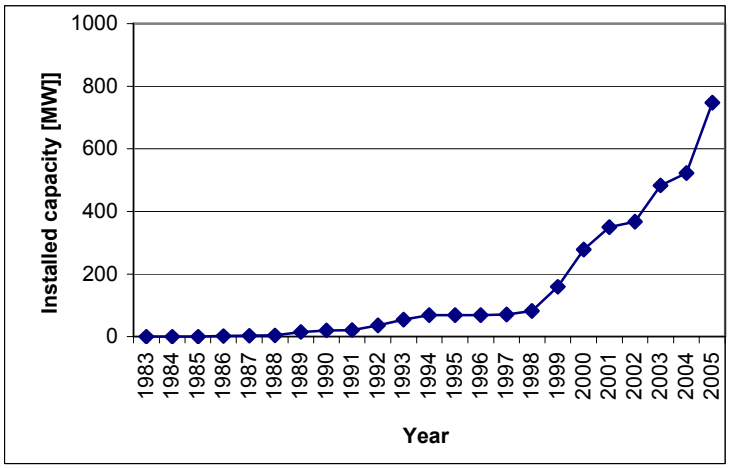

Table 1 presents the installed power of RES in Greece in January 2006, including also the large-scale hydros, which are usually not considered as RES, but rather as peak-load conventional power plants.

Table 1: Installed power of RES in Greece, in MW (January 2006)

	Installed power [MW]					
Region	**Large-scale hydros**	**Wind parks**	**Small hydros**	**PVs**	**Biomass**	**Total**
Eastern Macedonia and Thrace	500.0	162.2	1.00			**663.20**
Attica		2.6		0.2	20.70	**23.30**
Northern Aegean		28.7				**28.70**
Western Greece	1,282.2	36.1	17.62			**1,335.92**
Central Macedonia	492.0	17.0	23.90	0.15	2.50	**535.55**
Epirus	543.6		28.70			**571.40**
Ionian islands		10.2				**10.20**
Thessaly	130.0		4.94		0.35	**135.29**
Crete		104.5	0.60	0.80	0.17	**106.27**
South Aegean		20.1				**20.10**
Peloponnese	70.0	36.0	2.00			**108.00**
Central Greece (Sterea)		204.3	22.00			**226.30**
Total	**3,017.8**	**621.7**	**99.86**	**1.15***	**23.72**	**3,764.23**

* not included are several PV plants that are not connected to the distribution network (about 4 MW)

Except from the figures presented on Table 1, RES projects with installed power of about 590 MW (505 MW of wind parks, 62 MW of small hydros and 22 MW of biomass power plants) have already acquired production licenses by RAE and installation licenses by the prefectures of Greece, and are considered as "mature" investments, ready to be realized and connected to the grid.

A reliable preview of the investment interest for RES in Greece is given in Table 2, in which the installed power of the projects having acquired production license but not installation license is presented. Those projects are considered as "immature", and they need to take many steps in order to be realized.

Table 2: RES projects that have acquired production licenses, but have not acquired installation licenses by the prefectures of Greece

Technology	Installed power [MW]
Wind parks	2,190.0
Small hydros	290.0
Biomass	7.0
Geothermal units	8.0
PVs	1.3
Total	**2,496.3**

In order to meet the target of Directive 2001/77/EC (to cover 20.1% of Greek gross national electricity consumption by 2010 from RES, including the contribution of large-scale hydroelectric plants), and given that in 2010 the gross power consumption in Greece is expected to reach 68 TWh, there is a need for penetration of renewable energy sources at a level of 13.7 TWh.

In order to estimate a realistic scenario for new installations of RES to meet the target of Directive 2001/77/EC, the following assumption is made: The allocation of the part of each type of RES in the total installed capacity will not change within the next five years. In this case, the required installed capacity in order to meet the target of the Directive 2001/77/EC is presented on Table 3. According to the figures of Table 3, the total installed capacity of RES in 2010 (excluding large-scale hydros) should be 3,869 MW.

Table 3: Installed power requirements for each type of RES in 2010, in order to meet the target of Directive 2001/77/EC

	Installed power requirements in 2010 [MW]	Energy production in 2010 [TWh]	Percentage of each type of RES in 2010 [%]
Wind parks	3,372	7.09	10.42
Small hydros	364	1.09	1.60
Large-scale hydros	3,325	4.58	6.74
Biomass	103	0.81	1.19
Geothermal units	12	0.09	0.13
PVs	18	0.02	0.03
Total	**7,193**	**13.67**	**20.10**

VII. Conclusions

The legal framework concerning RES and the identity and the role of the energy institutions in Greece have been briefly described in this paper. An outline of the current status of RES in Greece has been presented, and an estimation of the RES installed capacity requirements in order to meet the European Committee targets has been made.

The situation of Greek power market demonstrates a great increase in the installed capacity, which can be attributed to the new legislation in the RES sector in Greece, giving institutional and economical incentives for investments on RES in the upcoming years. Greece has taken great steps to promote the installation of power plants using RES. Financial incentives have been provided to potential investors, whereas bureaucratic barriers and procedures have been removed. Although current market trends are encouraging, they may be proven not sufficient for the ambitious target of Directive 2001/77/EC, for a 20.1% RES electricity production (including the large hydro plants) to the total electrical production by 2010. Consequently, further political and economical measures should be taken in order to achieve this goal.

Endnotes

The views expressed are those of the authors and do not necessarily represent the policies of the institutions with which they are affiliated.

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Rural - Urban Migration: A Composite Vehicles Phenomenon (A Case Study of Lahore District)

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Abstract

The total population of the Lahore district was 6.32 million, while the migrants among them were 1.03 million which constitute about 16.4 percent of the total population. A relatively higher proportion (70.3 percent) of migrants was literate, while 62 percent of them were matriculate or higher qualified. Self employed and those engaged in private jobs were 67.1 percent of the migrants. About 75.3 percent of the migrant-households' earned income was in the range of Rs. >15000 to 50000, which reflected their low consumption level. Better job opportunities and employment opportunities emerged as the main pull factors of rural to urban migration among others. Average family size and non-accessible basic necessities were the principal push factors for such migration. Income from non-farm sources and family size contributed significantly in migration process of rural to urban localities, since handy cash income earned due to more economic opportunities and diversity of occupations in urban localities result in better prospects of prosperity than the schedule bound farm income. However, farm income contributed positively as well as negatively but insignificant in both the cases which could be attributable to status quo of farm families. Transport facility contributed negatively, since it becomes a source of commuting for the workers performing jobs in nearby villages or even remote urban localities. Provision of health and education institutions proved check on rural- urban migration. Reduction in family size, involvement of rural population in non-farm activities to reduce pressure on farm land by provision of opportunities of income generating activities out of farm enterprises could be the policy implications in this context.

1. Introduction

In the course of economic development structural changes take place. Generally, the design and pace of structural changes depend on policies of the country. With the development of industry urban areas also grow and hence pressure of population in urban areas increases. This unprecedented increase in population and its growth rate are attributed to rural-urban migration and rate of natural increase. Migration to urban centre has been viewed as a vehicle of change for those who move and as a factor in the redistribution of population from rural to urban areas. There is a wide range of evidence that economic factors are dominant in migration, though social and political factors are important as well, and at times are the major causes of migration (Mazur, 1984).

Urbanization is a world wide phenomenon with different rates and patterns in different countries, because of the varying definitions of the process of urbanization. A wide range of changes have taken place to the world settlement–cities, smaller urban centers and villages. The average population of world's 100 largest cities was over 5.0 million in 1990 compared to 2.1 million in 1950

and less than 0.2 million in 1800. The world is more urbanized with unprecedented proportion living in large cities over the past few decades.

Lewis (1977) places a high financial burden on urban governments – a financial problem made especially acute in the third world due to imperfect capital markets there. High capital requirements of city building, the cost associated with congestion and pollution become challenging issues in the contact of rural urban migration.

In brief, with rapid population growth in general, rapid urban growth increases the difficulties of providing a population with the necessary sustenance, employment, services and infrastructure. Income per capita growth adds to these demands and complicates urban problems. Growth in urban population and incomes strains health and educational budgets, complicates the reduction of unemployment levels, and exacerbates problems connected with provision of adequate housing, food, energy supplies, transport, water, and sanitary facilities. The "demographic investment" needed just to maintain present standards in many rapidly urbanizing areas means a doubling or tripling of institutional plan. This becomes overwhelming challenge to urban planners to provide environment pacing with the additional needs of migrated population in an effective and equitable manner. Such situation demands check on rural-urban migration. This results in more disparities in rural areas and contributes in pushing the labour force to travel to urban developed localities.

Pakistan with a population of around 156.77million in 2006-07 (Economic Survey), is one of the most populous countries in the world. The historical trend indicates a continuously increasing growth in the population. It also has witnessed accelerated process of urbanization.

An increase in the urban population took place due to natural causes as well as rural-urban migration. The natural increase accounted for 70 percent of urban growth while rural-urban migration for 22 percent, place transformation or amalgamation of areas for the remaining 8 percent. The high rate of natural growth in the urban areas was also the consequence of declining mortality and near constant fertility. The magnitude of recent increase is even more alarming when measured in absolute numbers, 32.8 million persons have been added to the urban population during the last 37 years (1961-98), compared to 3.6 million urban population added during the first decade (1951-61). Overall population at the national level has increased from 28.3 percent on 1981 to 32.5 percent in 1998. This reveals that at present every third Pakistani is living in the urban area i.e. the cities and towns of the country.

The city of Lahore, according to a Hindu legend was founded by Lauh; the son of Raja Ram of Ramayan. The present Lahore district consists of Lahore Tehsil only. There has been a steady expansion of industrial sector in Lahore after Karachi in Pakistan. The total population of the district was 6.32 million, while the migrants among them were 1.03 million, which constitutes about 16.4 percent of the total population. (District Census Report of Lahore (1998)).

Thus the area is faced with the growing educational, health, housing, water, sanitation and other social problems because of squatter settlements, rapidly emerging demand to houses these migrants. Consequently, urban social sector is being over-taxed.

The percentage of urban population may well be over 50 percent in the slums of LDCs. Meier (1984). Thus, rural-urban migration is fueling the problems like pollution, congestion and crime. Consequently, on the one hand this phenomenon has increased the social cost and on the other, it yielded no economic benefits. This study was thus conducted to observe the status of migrants, analyze factors resulting in rural-urban migration in Lahore district and suggest certain policy options to reduce the impact of this issue on economic and social situation of the area:

2. Objectives of the Study

The principal objectives of the study are as under:

- To study the profile of the rural households of migrants.
- To determine distance range of migrants to Lahore city.

- To identify the factors resulting in rural-urban migration and assess their contribution in migration phenomenon.
- To examine the employment pattern of rural migrants.
- To suggest certain policy implication regarding to the migration phenomenon

In section-III sampling procedure and methods of analysis of collected data have been discussed. Section-IV is concerned with migration status, rural migrants' household profiles and causes of migration. Determinants and Diagnostic analysis of rural urban migration has been discussed in Section-V. Finally conclusions and recommendations are given in Section-VII.

3. Sampling Procedure and Methodology

Considering the scope and objective of the study, Primary data and Secondary data were collected and analyzed to derive the objective's concerned conclusions. Secondary data were collected from the published sources, concerned departments and other relevant agencies that possessed statistical information. Primary data were collected from the sample size selected from the universe of the study.

3.1. Sampling Procedure

Sampling procedure comprises the process to be followed to ensure representation of the universe concerned areas and determination of the sample size, though a case study need not be a representative sample. However an effort was made to make the data representative at least to the universe. The following sampling techniques were adopted for this:

- Simple Random Sampling
- Stratified Random Sampling
- Systematic Sampling with random start

3.2. Universe and its Stratification

The study was confined to Lahore city; therefore all the rural localities of Lahore district were the universe of the study. To minimize the sampling error; further stratification of the universe was done on the basis of distance from Lahore city and other surrounding big cities. This stratification was made as under:

Stratum I: Area nearby Lahore city.

Stratum II: Area middle of the district boundary and jurisdiction of municipal corporation Lahore.

Stratum III: Area near the boundary line of the district of Lahore.

Thus, three villages were selected on each direction of Lahore district considering the above given stratification. With the consequent 12 villages were included in the sample for study purpose. The next big city was given consideration in selection of sample village and the distance coverage criterion was viewed in this regard.

3.3. Determination of the Sample Size

The sample size was determined by using well known statistical formula suitable in the absence of population considering the guessed variability i.e. 50 percent. (Kasely and Kumar 1989). The formula was as under:

$$n = z^2 v^2/d^2$$

where

n = Sample Size

Z = Normal Variate or confidence level about the limit of the error (95%)

V = Assumed Variability with respect to income of rural households i.e. (50%)

d = Acceptable error margin in the estimates (6%)

$$n = \frac{(1.96)^2 \times (50)^2}{(6)^2} = 267 \text{ say } 270$$

All these 270 respondents were selected from the 12 villages (3 villages from each direction). Since the sample size was equally distributed among the sampling villages, the needed data was collected from 276 sample households i.e. 23 respondents from each of the sample villages. However, the sample size was proportionately distributed between, farm and non-farm households on the basis of population proportion of concerned category of respondents within the village. The details regarding the distribution of sample size are given in Table-1.

Table 1: (No. of Respondents)

Categories	Nearby	Middle	End village
Non Farm Households	32	32	32
Farm Households*	60	60	60
Small A	34.8	34.8	34.8
Small B	19.2	19.2	19.2
Medium	4.2	4.2	4.2
Large	1.8	1.8	1.8
Overall	92	92	92

* Small A = < 6.25 acres, Small B = 6.25 to <12.25 acres, Medium = 12.25 to <25.0 acres, Large = 25 acres and above.

4. Methodology

Methodology of the study comprises two sections. In the first section, the various hypotheses were tested under cross tabulation techniques while Z-tests and chi-square test (x^2), wherever was suitable, applied to determine significance level of the concerned variables. In the second section econometric model was applied as diagnostic analysis.

4.1. Econometric Model

Several versions of the empirical migration function based on econometric theory are available in literature. However the use of some specific depends upon the objectives of the study as well as the data available on parameters of basic concerns. Broadly two methodological approaches have been adopted to isolate contribution of various factors in migration from rural areas to urban end. These are as follows:

- Linear Regression Approach – is used to isolate contribution of various factors resulting shift of rural labour force to urban localities.
- Cobb Douglas Approach – is adopted to determine migration elasticity of labour force on the basis of various quantified socio-economic characteristics of the rural-households.

  The functional form, thus, adopted for linear regression was:

  $$Y = a_0 + \sum_{i=1}^{n} b_i x_i + e$$

  The Cobb Douglas functional form was

  $$\ln Y = \ln b_0 + \sum_{i=1}^{n} b_i \ln x_i + \ln e$$

  On the basis of considered variables the linear regression equation applied was:-

where,

$Y_m = b_o + b_1 FI + b_2 NF_1 + b_3 Ed + b_4 FS + b_5 D_1 + b_6 D_2 + b_7 D_3 + e$

The log-linear equation of the function was:

$\ln Y_m = b_0 + b_1 \ln FI + b_2 \ln NFI + b_3 \ln ED + b_4 \ln FS + b_5 D_1 + b_6 D_2 + b_7 D_3 + e$

Y_M = No. of migrants from individual household.

FI = Farm Income of the households

NFI = Non-form income of the households

ED = Education of the household (Average completed education years)

FS = Family size of household

D_1 = Health facility available at village level = 1 otherwise = 0 (Dummy variable)

D_2 = Existence of Educational Institution at village level = 1 otherwise = 0 (Dummy variable)

D_3 = Availability of Regular transport facility = 1 otherwise = 0 (Dummy variable)

e = Error Term

Both these models were estimated using ordinary least square (OLS) method. Separate function for socio-facilities such as existence of health facility, educational facility at village and availability of regular transport for daily travelling were estimated in order to capture the role of these facilities in migration check. However, to isolate the contribution of all the considered variables including the social facilities as well, four equations were constructed and regressed considering pooled data of farm and non-farm households.

5. Results of the Study

Results of the study included profile of rural migrants, causes of migration and results of the functional approach.

5.1. Profile of Rural Migrants

To assess village-end considerations with respect to characteristics of rural migrants to urban cities, it is essential to study the basic characteristics of migrants. The profile of the migrants, thus studied, comprises education level, employment pattern, income of the migrants, and distance range of the migrants.

5.2. Education Level of Migrants

It is generally observed that the education and migration are correlated and the better educated are more likely to migrate unconditionally and when conditioned an other motivating factors [Greenwood (1975), T.P. Shultz (1982), Todaro (1969), Benerjee (1983)]. Thus employer prefers to employ people with more education in preference to those with less, even though sometimes extra education may not guarantee better job performance. Similarly ‘educational deepening’, which follows that for any given urban wage, if the probability of success in securing a modern sector job is higher for people with more education, their expected income differential will also be higher and they will be more likely to migrate to the cities (Todaro, 1969).

Godfrey (1973) also argues that education has an effect on migration quite separate from the effect on expected income. The similar situation was observed in results of this study. The data presented in the Table-2 reflected positive correlation between education and migration, since a symmetrical linear increase was observed in migrants with the level of education i.e. primary (10.2 percent), middle (24.2 percent), matric (25.9 percent) and above matric 36.1 percent on overall basis.

The migrants, who were literate, were higher in proportion, 70.3 percent relative to illiterate 29.7 percent on overall basis. In case of non-farm households, the proportion of illiterate migrants was 32.7 percent, while the remaining 67.3 percent were literate. However the education contributed in migration and the trend of migrants was positively affected by education level in case of both the categories of households i.e. farm households and non-farm households. This leads towards acceptance of the hypothesis that education positively contributes in migration from rural to urban areas.

Table 2: Education Level of Migrants

(Percent)

Household Categories	Education Level						
	Illiterate	Literate*	Below Primary	Primary	Middle	Matric	Above Matric
Non Farm	32.7	67.3	4.6	9.8	24.2	23.5	37.9
Farm Household	22.5	77.5	1.6	11.4	24.1	30.7	32.2
Small A	25.9	74.1	2.4	12.4	27.5	27.5	30.2
Small B	11.1	88.9	-	6.4	18.8	37.4	37.4
Medium	25.0	75.0	-	16.7	16.7	33.4	33.3
Large	-	-	-	-	-	-	-
Overall	29.7	70.3	3.6	10.2	24.2	25.9	36.1

*Below primary level (i.e. those who can read or write).

The underlying reason was the availability of more job opportunities at urban areas relative to rural areas in public as well as private sectors especially for educated persons. Moreover, the population growth and inherited distribution of farm land caused the fragmentation of land holdings, because of inheritance distribution, had increased number of sub-marginal holdings. Consequently the income generated from farm land was not sufficient to meet the households' food and fiber requirements. This ultimately pushed the population to leave the place of origin in search of bread and butter.

5.3. Employment Patterns of Migrants

Economic growth and rising per capita income have a dramatic effect on the type of work households do, the income they receive, the way they manage their time, the decision to migrate and choice of work. Economic growth also helps employment creation. Economic growth and structural changes often induce the workers to seek employment in industry and services sectors. The data indicating the employment pattern of migrants was presented in Table 3.

Table 3: Employment Pattern of Migrants

(Percent)

Household Categories	Employment Pattern				
	Government	Self Employed	Private	Daily Wage	Others
Non-Farm	20.9	30.4	38.7	8.4	1.6
Farm	33.8	20.0	41.2	3.8	1.2
Small A	38.2	20.0	34.4	3.6	1.8
Small B	22.2	16.7	55.5	5.6	-
Medium	25.0	25.0	-	50.0	-
Large	-	-	-	-	-
Overall	24.7	27.3	39.5	7.0	1.5

The data in this table shows that the proportion of migrants engaged in private job was the highest (39.5 percent) followed by self-employed (27.3) percent, government service (24.7) percent, daily wage earners (7.0) percent and others (1.5) percent on overall basis. The higher flow of migrants in private sector jobs was due to relatively easy entry as opposed to public jobs. Moreover, the growth of private sector is relatively faster than the public sector over the years. In case of farm households the highest proportion (38.12 percent) of the migrants was deployed in public sector followed by the private sector (34.4 percent). This might be attributed to their comparatively high level of education that was instrumental in getting the job to supplement their livings. No migration took place in case of large farms.

The proportion of self-employed (street vendors, hair dressers, taxi drivers, launderers, employed on tea shops, shop owners, shoe shine boys, car cleaners etc.) was the second highest 27.3 percent. This sector provides jobs for migrants who have come to town to seek work in the urban formal sector but failed to get it. However, studies conducted in several third-world cities indicate that

many of the people, who win their bread and butter this way are long time urban resident and veterans at their particular lines of work (Perkins et. al.).

5.4. Income of the Migrants

Income earned from various sources is an indicator determining well-being of a household whereas its distribution leads an individual as well as a household to a specified standard of living under the prevalent economic environment of the area. Such initial endowments allow the households to exercise comparative advantage in earning sources and the individuals and the households seek for relatively better alternative income generating sources at local level or become migrants. However even at the same location variations or differences in earned income exist due to variations in working capacity, education, skill and mainly the nature of job. The data regarding distribution of migrants on the basis of earned income was presented in Table-4. The data in this table indicates that the highest proportion (42.1 percent) of migrants lie in the income bracket of Rs. 30,000 to Rs. 50,000 followed by the income group of Rs. 15000 to Rs. 30000 (33.2 percent). The migrants having income level above Rs. 50,000 were 21.8 percent. However the migrants who received income upto Rs. 15,000 and less were 3.0 percent.

Table 4: Income Earned by the Migrants

(Percent)

Household Categories	Income Groups (Rs./Year)			
	15,000	**> 15,000 to 30,000**	**> 30,000 to 50,000**	**Above 50,000**
Non-Farm	3.1	34.5	42.8	19.6
Farm	2.6	29.9	40.2	27.3
Small A	1.8	32.7	38.2	27.3
Small B	6.2	31.2	43.8	18.8
Medium	-	25.0	37.5	37.5
Large	-	-	-	-
Overall	3.0	33.2	42.1	21.8

As far as the farm and non-farm households are concerned, the highest proportion of non-farm group (42.8 percent) consists of those who received income of 30,000 to 50,000 followed by the group of 15,000 to 30,000 with households 34.5 percent. This shows that migrants from these income groups were 77.3 percent while the farm households falling in these income groups constituted 70.1 percent of the households of this category of migrants.

Since 70.1 percent of farm and 77.3 percent of non-farm households were between amount > Rs. 15,000 to 50,000. Considering that the average family size in Pakistan i.e. 6.5 persons (Economic Survey-2000) the earning of these income groups was also very low. Such a meager earning could only provide them bread and butter despite leaving their settled locations. Since the cost of living is higher in urban areas as compared to rural areas, this factor can further reduce their consumption level. So the measures should be taken to provide alternative economic opportunities to low income groups by providing them with skill under short courses to adjust them under self-employment schemes at local level by micro-credit arrangement or other alike activities.

5.5. Distance Range for Migrants

Though the migrants settled in Lahore district belonged to various regions of the country, as well as outside the country, the primary data was collected from the households residing within the district boundary to assess the distance range of the migrants working in certain capacities in Lahore. The same is presented in Table 5.

Table 5: Distance Range of Household Migrants to Lahore

(Percent)

Household Categories	Distance (Kilometers)					
	Upto 10	11-20	21-30	31-40	41-50	Above 51
Non-Farm	19.4	20.4	30.6	27.6	1.0	1.0
Farm	12.2	26.8	24.4	35.4	1.2	-
Small A	10.5	21.0	26.3	40.4	1.8	-
Small B	22.2	27.8	22.2	27.8	-	-
Medium	-	62.5	12.5	25.0	-	-
Large	-	-	-	-	-	-
Overall	17.3	22.3	28.8	29.8	1.1	0.7

The data in this table shows that generally the households migrated within the district were from the distance upto 50 kilometers.

The proportion of migrants and the distance range of migrants upto 40 km were positively correlated. This shows that migrants preferred to work at Lahore, the hub of economic activity. Again, migrants felt economically better-off to work at Lahore due to wage difference and other social facilities available to them. Other reasons to migrate could be negligible or zero marginal productivity, depressed average productivity, non-availability of off-farm job or little or non-existence of alternate self-employment at local or nearby locations. In addition, development of Social Overhead Capital (SOC) and access to rapid transportation facilities were the factors might be instrumental for their preference to work at Lahore. The proportion of migrants from the distance of 41-50 Km and above 51 km was (1.1 percent) and (0.7 percent) respectively. After the distance range of 41 km to 50 km and above the correlation between the distances range of migrants is negative that supports our hypothesis. In case of farm and non-farm households, the relationship between migrants and distance range was generally similar.

6. Causes of Migration

There exist various determinants that contribute to migration from rural farm households and landless households to urban localities. These determinants were classified as:

Pull Factors: Certain lucrative and primary economic and social interests associated with urban localities to attract the rural population towards urban localities.

Push Factors: Forces pushing the rural population to move to urban localities resulting from economic environment and non-availability of basic needs.

The results given in Table-6 reveal that non-availability of basic needs was the main push factors causing 39.5 percent of the labour force migrate to urban localities whereas 36.2 percent of the sample households reported family size as the factor pushing the labour force towards urban localities to earn livings indicated by respondents.

Table 6: Causes of Migration Reported by Migrant Workers (Push Factors)

(Percent)

Items	Near	Middle	End	Overall
Family Size	41.3	30.4	37.0	36.2
Average Economic Opportunity	3.3	2.2	2.2	2.6
Non-Accessible Basic Necessities	40.2	39.1	39.1	39.5
Present Position about Employment of Family Members	4.3	2.2	1.1	2.5
Uneconomic Holdings	10.9	19.6	14.1	14.9
Difference in Availability of Social Infrastructure	17.4	8.7	6.5	10.9
Others	14.1	15.2	13.0	14.1

The sample household responses with respect to pull determinants of migration have been presented in Table 7

Table 7: Causes of Migration Reported by Migrant Households (Pull Factors)

(Percent)

Items	Nearby Village	Middle Village	End Village	Overall
Better Job Opportunity	57.6	67.4	83.7	69.6
Better Wage Rate	25.0	23.9	29.3	26.1
Employment Opportunity	63.0	62.0	63.0	62.7
Social Environment	-	-	78.5	26.2
Better Standard of Living	16.3	17.4	78.5	37.4
Bright Future for Children	21.7	20.7	22.8	21.7
Availability of Technical Training	2.2	1.1	3.3	2.2
Recreation	2.2	-	2.2	1.5

The data in this table shows that employment opportunities and better job availability relative to village level were the main pull factors identified by 69.6 percent and 62.7 percent of the sample households respectively. However this determinant reflected positive correlation with distance. Such situation might be attributable to low paid jobs, non-availability of off-farm job at village level to supplement their meager earnings, whereas better standard of living, social environment, better wage rate and bright future of children were the pull determinants causing rural to urban migration of 37.4 percent, 26.2 percent, 26.1 percent and 21.7 percent of the sample respondents respectively.

Uneconomic holdings, difference in availability of social infrastructure and others also emerged as push factors as reported by 14.9 percent, 10.9 percent and 14.1 percent of the sample households. The situation demands attention of self-employment oriented skills training, development of social infrastructure at village level and micro credit for self employment to benefit from acquired skills to impose check on migration from rural areas to urban localities.

7. Results of Functional Approaches

As already elaborated in methodology, two econometric approaches i.e. linear and log-linear were applied in the study. However, six equations were constructed to assess the impact of various economic and social aspects concerning factors on rural to urban migration of the people, considering different dummy variables. All the equations were regressed using OLS method.

All the estimated production functions were judged on prior statistical and economic criteria. The results presented in Table-8, reveals that all the variables bear expected signs with explained variability except farm income to the extent to 46.0 percent in case of simple linear regression and 37.0 percent in ease of log linear regression by the considered independent variables with respect to dependent variable. Though a high R^2 may imply the appropriateness of a regression equation for exploring the movement of dependent variables, yet a relative low R^2 does not necessarily imply that the regression equation is inappropriate or a poor fit. Since R^2 is determined by the nature of dependent and independent variables and the movement of dependent variables in relation to independent variables, the equation's best fit depends upon the choice among well selected and theoretically accepted set of given variables, as the migration phenomenon is related to social characteristics as well as economic characteristics, the captured variability with considered explanatory variables constituted on primary data basis was quite sufficient for best fit for quantifiable variables. However F-ratio is highly significant in the two equations.

In simply linear regression equation all the variables bear positive signs, whereas income from non-farm sources and family size contributed significantly in migration process of rural to urban localities. This indicates that handy cash income earned due to more economic opportunities and diversity of occupations in urban localities results in more prospects of material life and prosperity than the scheduled bounded farm income after a specific gap of five or six months needed for crop harvesting. As far as the family size is concerned, the small unit of land needs less labour for conducting various farm practices. Specifically in this era of increased mechanization even the large farms in certain cases need relatively less manual labour. Thus the incidence of disguised

unemployment and unemployed labour force displaced by mechanization seeks employment opportunity outside the farm in urban areas yet status and prestige phenomenon are of the farm households i.e. they are land owner, inhibited them to do the minor jobs outside their farm fields. So the farm income contributed positively or negatively insignificantly.

The education of households also contributed, though not significantly, to shift the rural population to urban localities.

Table 8: Estimated Coefficients of the Functional Approaches Dependent Variable: Number of Migrants from Individual Households (with all Dummy Variables)

Variables	Simple Linear Regression		Log Linear Regression	
	Coefficient	t-value	Coefficient	t-value
FI	0.00327 (0.07934)	0.0412	-0.003233 (.008403)	-0.385
NFI	0.00545 (0.00095)	5.736*	0.034222 (0.014407)	2.375**
ED	0.01636 (0.011254)	1.454***	0.006622 (0.0142608)	0.464
FS	0.09634 (0.02399)	4.017*	0.381427 (0.080894)	4.715*
D_1	-0.17774 (0.13741)	-1.293	-0.201176 (0.142764)	-1.409
D_2	0.04758 (0.19370)	0.246	0.254281 (0.198776)	1.279
D_3	-0.06313 (0.17237)	-0.366	-0.287501 (0.177361)	-1.621
Intercept	0.55399 (0.023985)	4.118*	0.64981 (0.152104)	4.272*
F-Ratio	10.23		6.1773	
R^2	0.46		0.37	

* Significant at 1.0 percent ** significant at 5.0 percent *** significant at 10.0 percent

The data presented in Table-9 show the results of functional approaches with only health facilities available at rural level used as dummy variable. This factor proved non determinant with respect to change in contribution of considered variables to rural-urban migration. However the results revealed that provision of this facility at appropriate level would prove a check on migration of rural labour force to urban areas, since the contribution of this factor was not only negative but significant at 10 percent confidence level. However the variability captured by the independent variables was to the extent to 36 percent in case of simple linear functional approach and 46 percent in case of log-linear approach. F-ratio was highly significant to make the equation best fit in the two cases.

Table 9: Estimated Coefficients of Functional Approaches (with Health Facility only Dummy Variable)

Variables	Simple Linear Regression		Log Linear Regression	
	Coefficient	t-value	Coefficient	t-value
FI	-0.00344 (0.00831)	-0.414	-0.000420 (.078789)	0.005
NFI	0.3393 (0.01434)	2.366**	0.000551 (0.000094)	5.862*
ED	0.00986 (0.01414)	0.698	0.016892 (0.011085)	1.524***
FS	0.37140 (0.07939)	4.678*	0.095671 (0.023321)	4.102*
D_1	-0.19058 (0.10026)	-1.901***	-0.181558 (0.095027)	-1.911***
Intercept	0.61743 (0.15049)	4.103*	0.538360 (0.127250)	4.231*
F-Ratio	8.10		14.383	
R^2	0.36		0.46	

* Significant at 1.0 percent ** significant at 5.0 percent *** significant at 10.0 percent

The results presented in Table-10 are of the functional approach with existing educational facilities available in rural areas as dummy variables. This revealed shift in movement of dependent variable with respect to independent variables in the two equations. The contribution of explanatory variable remained in similar pattern, as it was in case of pooled function of all dummy variables. However in this case the increase in existing educational institutions also proved a check on rural urban migration. This supports that provision of an appropriate education specifically technical education needs to be experimented at village level as a check of rural urban migration. Variability captured by the independent variable was 45 percent in case of simple linear regression and 35.0 percent in log-linear regression equation. F-ratio was highly significant in the two cases.

Table10 : Estimated Coefficients of Functional Approaches (with Available Education Facility only as Dummy Variable (D2)) Variables

Variables	Simple Linear Regression		Log Linear Regression	
	Coefficient	t-value	Coefficient	t-value
FI	-0.000556 (0.007880)	-0.071	-0.00252 (0.00841)	-0.300
NFI	0.0005487 0.0000938	5.846*	0.03327 (0.01447)	2.299*
ED	0.018182 (0.011102)	1.638***	0.01062 (0.01418)	0.749
FS	0.103100 (0.023287)	4.427*	0.39327 (0.07922)	4.964*
D_2	-0.124321 (0.088635)	-1.403	-0.11951 (0.09459)	-0.732
Intercept	0.505734 (0.125187)	4.040*	0.59814 (0.15087)	3.965*
F-Ratio	13.972		7.643	
R^2	0.45		0.35	

* Significant at 1.0 percent ** significant at 5.0 percent *** significant at 10 percent.

The coefficients of functional approaches estimated considering only availability of regular transport facilities as dummy variable are presented in Table11. This facility proved a main check on rural urban migration and contributed not only negatively but significantly as well. Since this facility provides opportunity for better education for the commuting students, it indirectly had contributed in migration by educational status of the rural households. However even in this case family size and non-

farm income emerge as main push and pull factor respectively contributing in rural-urban migration to the high significant level.

Table 11: Estimated Coefficients of Functional Approaches (with Regular Transport Facility only as Dummy Variable (D3))

Variables	Simple Linear Regression		Log Linear Regression	
	Coefficient	t-value	Coefficient	t-value
FI	-0.000149 (0.007911)	-0.019	-0.00191 (0.00837)	-0.228
NFI	0.000537 (0.000094)	5.716*	0.03454 (0.01437)	2.403*
ED	0.017068 (0.011127)	1.534***	0.00819 (0.01422)	0.576
FS	0.103645 (0.023322)	4.444*	0.40204 (0.07912)	5.082*
D_3	-0.124274 (0.090151)	-1.379	-0.18599 (0.09551)	-1.947**
Intercept	0.527968 (0.130788)	4.037*	0.63042 (0.15170)	4.156*
F-Ratio	13.956		8.141	
R^2	0.45		0.36	

* Significant at 1.0 percent ** significant at 5.0 percent *** significant at 10 percent

8. Conclusions

The total population of the Lahore district was 6.32 million, while the migrants among them were 1.03 million which constitute about 16.4 percent of the total population. A relatively higher proportion (70.3 percent) of migrants was literate, while 62 percent from them matriculate or higher qualified. Self employed and those engaged in private jobs were 67.1 percent of the migrants. About 75.3 percent of the migrants household's earned income was in the range of Rs. >15000 to 50000, which reflected their low consumption level. Better job opportunities and employment opportunities emerged as the main pull factors of rural to urban migration among others. Average family size and non-accessible basic necessities were the principal push factors for such migration.

- Income from non-farm sources and family size contributed significantly in migration process of rural to urban localities, since handy cash income earned due to more economic opportunities and diversity of occupations in urban localities result in more prospects of prosperity than the schedule bounded farm income. However, farm income contributed positively as well as negatively but insignificant in both the cases which could be attributed to status quo of farm families.
- Transport facility contributed negatively, since it becomes a source of commuting for the workers performing jobs in nearby villages or even remote urban localities.
- The existing inappropriate education facilities had emerged as a push factor for the rural unskilled labour force to migrate to urban areas to increase pressure on employment.
- Provision of health facilities at appropriate level would prove a check on migration of rural labour force to urban areas, since the contribution of this factor was not only negative but significant at 90 percent prevision level.

9. Policy Implications

On the basis of conclusions derived from study results the following policy implication are proposed:

- To impose check on rural-urban migration, reduction in family size is essential. Family planning is necessary in this regard.
- Involvement of the rural population in non-farm activities to reduce pressure on farm lands by provision of income generating activities out of farm enterprises, is equally essential.
- Technical training which could involve the labour in self employment activities needs to be extended.
- The expansion of technical education by establishing technical training wing at high school level would prove an effective measure to initiate self employment activities to earn living. However the preference needs to be given to the high schools of rural areas in this regard.
- A micro-credit scheme needs to be introduced at village level to initiate small business/enterprise to earn livings at local level. However, to make the small enterprises and small business successful, workshop concerning relevant knowledge to be arranged at rural level

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The Impact of Budget Deficit on Inflation in Pakistan: (1970-2004)

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Abstract

In this paper, the impact of budget deficit on inflation has been analyzed for Pakistan. After briefly reviewing the theoretical background and literature review, the time series data stationarity has been checked by Augmented Dickey-Fuller test and then OLS technique has been used to find the impact of budget deficit on inflation. The analysis is based on time series annual data from 1970 to 2004.The results show that budget deficits has positive relationship with inflation rates but do have insignificant impact on inflation rates in the Pakistan.

Introduction

IN ECONOMICS, it is not always apparent that a relationship between budget deficit and inflation exists. After independence, Pakistan has been experiencing both high inflation rates and budget deficits, thus creating an interesting case study for the relationship between the two fundamental indicators. The government has been running persistently with budget deficit. An increase in defense expenditure, oil imports and an increase in subsidies led to revenues declining. As a country, Pakistan has sustained a large deficit (on average 7 per cent of GDP) for a very long time. The size of the deficit which Pakistan sustained was twice as high as the average of the Asian developing countries. So this budget deficit gap is going to be met by barrowing either through borrowing from donor agencies, domestic borrowing or by borrowing from the banking sector. On average 2.5% of GDP are financed from international donors, 3.4% from money creation and 1.2% from domestic borrowing. So ending result is debt accumulation.

The stock of public debt (debt payable in rupees and foreign debt in rupee terms) stood at Rs 155 billion by end of the 1970's and by end of the 80's another Rs 646 billion was added which caused public debt to rise at Rs 801 billion. But by end of the 90's, another Rs 2430 billion was added to the public debt, which stood at Rs 3231 billion. The absolute number of public debt is not much of interest. What is more damaging is the burden of the public debt, which means as percentage of GDP or total revenue. At the end of 70's, the public debt was 56 per cent of GDP or 317 per cent of total revenue. It rose to 92 per cent of GDP or 505 per cent of the revenue by the end of the 80's.It was over 100 per

cent of GDP and 630 per cent of the revenues by the end of the 90's. By any standard, this was horrifying number for any country. It was horrifying because almost two-third of the revenues was consumed for debt servicing alone which forced the government to cut Public Sector Development Program (PSDP).

The country's infrastructure, both physical and human, started deteriorating because allocation to these sectors were started declining as percentage of GDP. Since the private sector and the public sector investments are complementary in nature, the decline in public sector investment also resulted in decline in private sector investment. Therefore, total investment which used to be 19 to 20 percent of GDP in early 90's continued to decelerate and reached 15-16 percent level by the end of the 90s'.

In recent years, Pakistan has made serious efforts to address its macroeconomic imbalances and deep-rooted structural problems. As a result, some of the country's macroeconomic indicators have improved, including a reduction in inflation to single digit figures and a significant increase in foreign exchange reserves, which currently stand at about $ 13 billion (May 2005).

The government has also succeeded in bringing down Pakistan's overall fiscal deficit from 5.4 per cent of GDP in fiscal 1999-2000 to 3.3 per cent of GDP in 2003-04. In 2004-5, however, the fiscal deficit began to creep up again. This trend has continued in 2005-06, with the budget deficit for the year now expected to hit 4.2 per cent of GDP. (Economic Survey 2005-06)

In Pakistan persistent fiscal imbalances have contributed to low national saving and investment, impeding growth performance. Many developing countries have managed to sustain relatively large fiscal deficits, but such deficits are unlikely to be sustainable because government debt cannot grow faster than the economy in the long run.

If we finance the fiscal deficit by external financing, this will cause our external debt to grow and will not only exacerbate our balance of payments problems but increase the interest payments on external debt which in turn worsens the fiscal deficit problem. If we finance from bank borrowing, we have to print money which leads to inflation and our domestic debt will also be higher leading to increased interest payments on domestic debt and back to the fiscal deficit. And if the deficit is financed by nonbank borrowing, this will lead to the crowding out problem and increase domestic debt as well.

Theoretical Background

Western government policy plans concerning budget deficit during the Great Depression of 1930–40 were the subject of leading global economist John Maynard Keynes's book on 'The general theory of employment interest and money' in 1936. Traditional Keynesian economists believe that government responsibility is to create economic equilibrium and not balanced budgets. They feel it is necessary to attain economic equilibrium with long term consistency, and to yield budget deficits in the short run.

From the end of 1970 to the present day, many developing countries have experienced extensive problems in the area of budget deficit, along with increased inflation rates. This issue, together involving unemployment and inflation, has damaged the rules of the Phillips Curve, while the idea of Keynesian have come in for a lot of questions, with monetarism entering a new stage. During the last three decades, there have been claims by supporters of monetarism that inflation is purely a monetary phenomenon.

A well established theory in macroeconomics is that fiscally dominant governments running persistent deficits have sooner or later to finance those deficits with money creation ("seigniorage"), thus producing inflation (Sargent and Wallace, 1981). While this theory does not rule out the importance of other mechanisms through which inflation can be fueled and become persistent, fiscal imbalances have remained central to most models. The "fiscal view" of inflation has been especially prominent in the developing country literature, which has long recognized that less efficient tax collection, political instability, and more limited access to external borrowing tend to lower the relative cost of seignior age and increase dependence on the inflation tax (Alesina and Drazen, 1991; Cukierman, Edwards, and Tabellini, 1992; Calvo and Végh, 1999).

This has been studied in different countries. Many economists have researched the relationship between budget deficit, monetary supply and inflation. Here a few of them are summarized.

Literature Review

One extensive study about the relationship between budget deficit and inflation is, 'Budget deficit and the inflationary process in developing countries', written by Aghavali and Khan in 1977. With the help of an application model, it observes that the relationship between budget deficit policies and inflation has been shown in four countries — Brazil, Columbia, the Dominican Republic and Thailand. The important point here is that, in their estimation, this group of countries has experienced the inflationary process.

In addition, Choudhary and Parai (1991) studied the role of budget deficit against a background of hyperinflation in Peru. With the use of the Keynesian model of price determination, the budget deficit variable was entered into the model and the effect of budget deficit on hyperinflation was analyzed. It showed that the budget deficit in Peru was instrumental in creating hyperinflation.

Chaudhary and Ahmad (1995) studied the issue of monetary supply, deficit and inflation in Pakistan. With the use of an extensive model based on the quantity theory of money, the relationship between budget deficit, monetary supply and inflation was researched. The results showed that financing the budget deficit from internal sources, especially using the banking system, increased inflation in the long run. On the other hand, the results also confirmed the hypothesis of the presence of a positive relation-ship between budget deficit and inflation during the inflationary period seen in Pakistan in the 1970s.

Ozmucur (1996) studied the relationship between the general level of prices and budget deficit in Turkey. With the use of cointegration tests, he showed that budget deficit growth had a positive effect on increased price levels in Turkey.

Piontkivsky et al (2001) studied the impact of budget deficit on inflation in Ukraine. Based on monthly data from 1995 to mid-2000, the major finding was that the fiscal imbalance, apart from other, purely monetary, factors, did play a role in determining inflation. Concerning other research carried out on the relationship, we can point to the studies of Hamburger (1982), Barnhart (1988) and Haan (1990).

Yet, as noted in the quote above, empirical work has had little success in uncovering strong and statistically significant connection between the fiscal deficits and inflation across a broad range of countries and inflation rates. For instance, King and Plosser's (1985) comprehensive analysis of the determinants of seignior age in the United States and 12 other countries, using single equation OLS regressions, indicates no generally significant causality running from fiscal deficits to changes in base money and inflation.

Montiel (1989) and Dornbusch, Sturzenegger, and Wolf (1990) find that fiscal deficits tend to accommodate rather than drive inflations—which instead they relate mainly to a combination of exchange rate shocks and inflationary inertia.

Employing nonparametric correlation measures for 17 developing countries and dividing them into low- and high-inflation groups, de Haan and Zelhort (1990) find that seignior age is weakly related to budget deficits except during very high inflation episodes.

Click (1998) provides OLS estimates of the determinants of seignior age in a cross section of 78 (mostly developing) countries and finds that fiscal variables play no significant role.

Finally, several cross-country studies on the determinants of inflation do not even include fiscal balances in their regressions, implicitly or explicitly assuming that fiscal balances play no role or that their effects are indirectly captured by other variables (Romer, 1993; Lane, 1995; Campillo and Miron, 1997; and Loungani and Swagel, 2001).

The Model

On the basis of theory and research, the relationship between budget deficit and inflation is extensive. Researchers have recently pinpointed different models for the study. Most government budget deficit variables are directly entered into the model and the relationship with inflation has been studied — a few indirectly, and some with proxy variables. Without considering the difference in the working manner, the relationship between budget deficit and inflation is confirmed.

Following the model used in the study of Choudhary and Parai (1991) and Chaudhary and Ahmad (1995), the following model has been used in this study:

$LCPI_t = F (LBD_t, LIPI_t, LM2_t)$

Where

$LCPI_t$ = logarithm of consumer price index (CPI) for period t

LBD_t = government budget deficit for period t

$LIPI_t$ = logarithm of import price index (IPI) for period t

$LM2_t$ = logarithm of liquidity for period t

Where t varies from 1970 to 2004

Objectives of the study

To examine the relationship of budget deficit and inflation in Pakistan.

Hypothesis

Budget deficit has a positive impact on inflation

Methodology and Estimation

In this analysis, we use annual data — the variables comprise the CPI, the IPI, the government budget deficit and liquidity. The information is according to time series, and the duration of the study is 1970–2004. The main source of data related to the model variables is (IFS). The first step in the time series analysis is to investigate the properties of the series individually.

In this paper the impact of the budget deficit on inflation are examined in the following ways: First of all for suitable transformation for the entire four variables log transformation has been uses. All of the four variables show that the suitable transformation for the series is log transformation.

Stationarity of the data

Before estimation of the model stationarity of the data has been checked by Augmented Dickey fuller Test. All the variables are nonstationary at level and stationary at 1st Difference. So OLS method has been used for estimation to check the impact of budget deficit on inflation in first difference as all variable are stationary at first difference. The result shows that all the variables have positive relationship with inflation but they are statistically insignificant except the liquidity term M2 while on all bases these parameters are statistically significant.

Table 1: Augmented Dickey Fuller Test

Variables	Trend and intercepts		Intercepts	
	Level	1st Difference	Level	1st Difference
LNM2	1.819423	4.6599*	0.823945	4.660465*
LNBD	3.51	9.143280*	2.155119	9.312327*
LNCPI	1.062266	4.772445*	2.269082	1.528645**
LNIPI	3.357392	4.270406*	3.292148	3.651807*

*means significant at 5% level of significant. **means significant 10% level of significant•.

After the estimation, autocorrelation has been checked using LM test. The result shows there is no autocorrelation in the model.

D(lnCPI,2) =-0.010409 +0.001761 *D(lnBD) +.071735*D(lnM2) +0.002414 *D(lnIPI)

Table 2(a): Dependent Variable: Dln(CPI,2)
Method: Least Squares
Sample(adjusted): 1972 2004
Included observations: 33 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.010409	0.002991	-3.479646	0.0016
Dln(M2)	0.071735	0.016924	4.238786	0.0002
Dln(IPI)	0.002414	0.007510	0.321397	0.7502
Dln(BD)	0.001761	0.003186	0.552706	0.5847
R-squared	0.410989	F-statistic	6.745017	
Adjusted R-squared	0.350057	Prob(F-statistic)	0.001370	
Durbin-Watson stat	1.890858			

Table 2(b): Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.071117	Probability	0.791672
Obs*R-squared	0.083604	Probability	0.772471

Conclusions

Over the past two decades, issues concerning the relationship between government budget deficit and the inflationary process have been among the most important economic concerns in most developing countries. In Pakistan, after 1948, the government mostly had to contend with budget deficit. It was in this way that inflation became a persistent problem for the Pakistan economy. Some times, in economics, there is a relationship between budget deficit and inflation. This is because dealing with the budget deficit depends on a special manner of financing. In other words, if a government budget deficit requires assistance from the central bank, this can have a knock-on effect for inflation.

The most important conclusion of this paper is that government budget deficit, money supply, as well as import prices have positive effect on inflation but only money supply is statistically significant. It implies that if budget deficit or gape is met by deficit financing i.e. printing money or borrowing, it will accrue to inflation, this result also proves Friedman statement "Inflation is only monetary phenomenon". In fact, this result is in agreement with other researchers' findings, such as Aghevali and Khan (1977), Choudhary and Parai (1991), Chaudhary and Ahmad (1995), Ozmucur (1996) and Pointkivsky et al (2001), which also show that the relationship between budget deficit and inflation in a few developing countries is applicable.

• significant means the data is stationary

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