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# Face Recognition Eigenface and Fisherface Performance

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## Abstract

Face recognition is a vital research area with some important challenges mainly concerning images taken in non-ideal illumination conditions. In this paper the Eigenface and Fisherface based face recognition methods are considered, where the recognition performance of the two methods are compared for Frontal Face Database

**Keywords:** PCA based face recognition, LDA based face recognition, eigenfaces and fisherfaces

## 1. Introduction

The face plays a major role in our social intercourse in conveying identity and emotion. The human ability to recognize faces is remarkable. We can recognize thousands of faces learned throughout our lifetime and identify familiar faces at a glance even after years of separation. The skill is quite robust, despite large changes in the visual stimulus due to viewing conditions, expression, aging, and distractions such as glasses or changes in hairstyle.

Computational models of faces have been an active area of research since late 1980s, for they can contribute not only to theoretical insights but also to practical applications, such as criminal identification, security systems, image and film processing, and human-computer interaction, etc. However, developing a computational model of face recognition is quite difficult, because faces are complex, multidimensional, and subject to change over time.

Face recognition is a task so common to humans, that the individual does not even notice the extensive number of times it is performed every day. Although research in automated face recognition has been conducted since the 1960's, it has only recently caught the attention of the scientific community. Many face analysis and face modeling techniques have progressed significantly in the last decade. However, the reliability of face recognition schemes still poses a great challenge to the scientific community [1].

Falsification of identity cards or intrusion of physical and virtual areas by cracking alphanumeric passwords appears frequently in the media. These problems of modern society have triggered a real necessity for reliable, user-friendly and widely acceptable control mechanisms for the identification and verification of the individual [1].

Facial recognition holds several advantages over other biometric techniques. It is natural, non-intrusive and easy to use. In a study considering the compatibility of six biometric techniques (face, finger, hand, voice, eye, signature) with machine readable travel documents (MRTD). Facial features scored the highest percentage of compatibility.

## 2. Background and Related Work

The human capacity to recognize particular individuals solely by observing the human face is quite remarkable. This capacity persists even through the passage of time, changes in appearance and partial occlusion. Because of this remarkable ability to generate near-perfect positive identifications, considerable attention has been paid to methods by which effective face recognition can be replicated on an electronic level. Certainly, if such a complicated process as the identification of a human individual based on a method as non-invasive as face recognition could be electronically achieved then fields such as bank and airport security could be vastly improved, identity theft could be further reduced and private sector security could be enhanced [2].

Many approaches to the overall face recognition problem have been devised over the years, but one of the most accurate and fastest ways to identify faces is to use what is called the “eigenface” technique. The eigenface technique uses a strong combination of linear algebra and statistical analysis to generate a set of basis faces--the eigenfaces--against which inputs are tested. This project seeks to take in a large set of images of a group of known people and upon inputting an unknown face image, quickly and effectively determine whether or not it matches a known individual [2].

Research in automatic face recognition dates back at least until the 1960's. Most current face recognition techniques, however, date back only to the appearance-based recognition work of the late 1980's and 1990's. Kirby and Sirovich were among the first to apply principal component analysis (PCA) to face images, and showed that PCA is an optimal compression scheme that minimizes the mean squared error between the original images and their reconstructions for any given level of compression. Turk and Pentland popularized the use of PCA for face recognition. They used PCA to compute a set of subspace basis vectors (which they called “eigenfaces”) for a database of face images, and projected the images in the database into the compressed subspace. New test images were then matched to images in the database by projecting them onto the basis vectors and finding the nearest compressed image in the subspace (eigenspace) [3].

The initial success of eigenfaces popularized the idea of matching images in compressed subspaces. Researchers began to search for other subspaces that might improve performance. One alternative is Fisher's linear discriminant analysis (LDA, a.k.a. “fisherfaces”). For any N-class classification problem, the goal of LDA is to find the N-1 basis vectors that maximize the interclass distances while minimizing the intraclass distances. At one level, PCA and LDA are very different: LDA is a supervised learning technique that relies on class labels, whereas PCA is an unsupervised technique. Nonetheless, in circumstances where class labels are available either technique can be used, or LDA has been compared to PCA in several studies [3].

One characteristic of both PCA and LDA is that they produce spatially global feature vectors. In other words, the basis vectors produced by PCA and LDA are non-zero for almost all dimensions, implying that a change to a single input pixel will alter every dimension of its subspace projection. There is also a lot of interest in techniques that create spatially localized feature vectors, in the hopes that they might be less susceptible to occlusion and would implement recognition by parts. The most common method for generating spatially localized features is to apply independent component analysis (ICA) to produce basis vectors that are statistically independent (not just linearly decorrelated, as with PCA). Non-negative matrix factorization (NMF) is another method for generating localized feature vectors [4].

### Related Work

Eigenfaces for face representation was first used by Sirovich and Kirby which was later developed by Turk and Pentland for face recognition. Different techniques have been developed using neural networks. The implementation by Lawrence, Giles, Tsoi and Back showed good results. Taylor and Cootes used Active Appearance Model to design a system for face identification. Some comparison has been done between eigenfaces vs fisherfaces, eigenfaces vs feature based techniques and likewise.

### 3. Description of the Problem

Face recognition is a very interesting quandary. Ideally a face detection system should be able to take a new face and return a name identifying that person. Mathematically, what possible approach would be robust and fairly computationally economical? If we have a database of people, every face has special features that define that person. Greg may have a wider forehead, while Jeff has a scar on his right eyebrow from a rugby match as a young tuck. One technique may be to go through every person in the database and characterize it by these small features. Another possible approach would be to take the face image as a whole identity.

Statistically, faces can also be very similar. Walking through a crowd without glasses, blurry vision can often result in misidentifying someone, thus yielding an awkward encounter. The statistical similarities between faces give way to an identification approach that uses the full face. Using standard image sizes and the same initial conditions, a system can be built that looks at the statistical relationship of individual pixels. One person may have a greater distance between his or her eyes than another, so two regions of pixels will be correlated to one another differently for image sets of these two people.

From a signal processing perspective the face recognition problem essentially boils down to the identification of an individual based on an array of pixel intensities. Using only these input values and whatever information can be gleaned from other images of known individuals the face recognition problem seeks to assign a name to an unknown set of pixel intensities.

In this paper, given a training database of human facial photographs annotated with identity, train an automated system to recognize the identity of a person from a new image of the person.

Pictorially, given database of photos and new picture, can an automatic algorithm be developed that can match the identity of the person from the new picture with a previously stored image in the database

### 4. Calculating Eigenface

Let a face image  $\Gamma(x,y)$  be a two-dimensional  $N$  by  $N$  array of intensity values. An image may also be considered as a vector of dimension  $N^2$ , so that a typical image of size 256 by 256 becomes a vector of dimension 65,536, or equivalently, a point in 65,536-dimensional space. An ensemble of images, then, maps to a collection of points in this huge space.

Images of faces, being similar in overall configuration, will not be randomly distributed in this huge image space and thus can be described by a relatively low dimensional subspace. The main idea of the principal component analysis is to find the vector that best account for the distribution of face images within the entire image space. These vectors define the subspace of face images, which we call “face space”. Each vector is of length  $N^2$ , describes an  $N$  by  $N$  image, and is a linear combination of the original face images. Because these vectors are the eigenvectors of the covariance matrix corresponding to the original face images, and because they are face-like in appearance, they are referred to as “eigenfaces”.

Let the training set of face images be  $\Gamma_1, \Gamma_2, \Gamma_3, \dots, \Gamma_M$ . The average face of the set is defined by  $\Psi = \frac{1}{M} \sum_{n=1}^M \Gamma_n$ . Each face differs from the average by the vector  $\Phi_n = \Gamma_n - \Psi$ . An example training set is shown in Figure 1a, with the average face  $\Psi$  shown in Figure 1b. This set of very large vectors is then subject to principal component analysis, which seeks a set of  $M$  orthonormal vectors,  $\mu_n$ , which best describes the distribution of the data. The  $k$ th vector,  $\mu_k$  is chosen such that

$$\lambda_k = \frac{1}{M} \sum_{n=1}^M (\mu_k^T \Phi_n)^2$$

is a maximum, subject to



$$\mu_l^T \mu_k = \begin{cases} 1, l = k \\ 0, otherwise \end{cases}$$

The vectors  $\mu_k$  and scalars  $\lambda_k$  are the eigenvectors and eigenvalues, respectively, of the covariance matrix

$$C = \frac{1}{M} \sum_{n=1}^M \Phi_n \Phi_n^T = AA^T$$

where the matrix  $A = [\Phi_1 \Phi_2 \dots \Phi_M]$ . The matrix  $C$ , however, is  $N^2$  by  $N^2$ , and determining the  $N^2$  eigenvectors and eigenvalues is an intractable task for typical image sizes. A computationally feasible method is needed to find these eigenvectors.

If the number of data points in the image space is less than the dimension of the space ( $M < N^2$ ), there will be only  $M-1$ , rather than  $N^2$ , meaningful eigenvectors (the remaining eigenvectors will have associated eigenvalues of zero). Fortunately, we can solve for the  $N^2$ -dimensional eigenvectors in this case by first solving for the eigenvectors of an  $M$  by  $M$  matrix e.g., solving a  $16 \times 16$  matrix rather than a  $16,384 \times 16,384$  matrix—and then taking appropriate linear combinations of the face images  $\Phi_n$ . Consider the eigenvectors  $v_n$  of  $A^T A$  such that

$$A^T A v_n = \lambda_n v_n$$

Premultiplying both sides by  $A$ , we have

$$AA^T A v_n = \lambda_n A v_n$$

from which we see that  $A v_n$  are the eigenvectors of  $C = AA^T$ .

Following this analysis, we construct the  $M$  by  $M$  matrix  $L = A^T A$ , where  $L_{mn} = \Phi_m^T \Phi_n$ , and find the  $M$  eigenvectors  $v_n$  of  $L$ . These vectors determine linear combinations of the  $M$  training set face images to form the eigenfaces  $\mu_n$ :

$$\mu_n = \sum_{k=1}^M v_{nk} \Phi_k = A v_n, n=1, \dots, M$$

With this analysis the calculations are greatly reduced, from the order of the number of pixels in the images ( $N^2$ ) to the order of the number of images in the training set ( $M$ ). In practice, the training set of face images will be relatively small ( $M < N^2$ ), and the calculations become quite manageable. The associated eigenvalues allow us to rank the eigenvectors according to their usefulness in characterizing the variation among the images.

## 5. Fisherface

Fisherface was suggested by Peter N. Belhumeur, Joao P. Hespanha and David J. Kriegman of Yale University in 1997. This approach is similar to eigenface approach, which makes use of projection of image into a face space, with improvements on insensitive to large variation in lighting and facial expression.

Eigenface method uses PCA for dimensionality reduction, which yields projection directions that maximize the total scatter across all classes of images. This projection is best for reconstruction of images from a low dimensional basis. However, this method doesn't make use of between-class scatter. The projection may not be optimal from discrimination for different classes. Let the total scatter matrix  $ST$  is defined as

$$ST = \sum_{k=1}^N (T_k - \psi)(T_k - \psi)^T$$

The projection  $W_{opt}$  is chosen to maximize the determinant of the total scatter matrix of the projection sample, i.e.

$$W_{opt} = \arg \max_W |W^T S_T W|$$

$$= [w_1, w_2, \dots, w_m]$$

where  $\{w_i | i=1,2,\dots,m\}$  is the set of  $n$ -dimensional eigenvectors of  $ST$  corresponding to the  $m$  largest eigenvalues.

Fisherface method uses Fisher's Linear Discriminant (FLD) by R.A. Fisher. This projection maximizes the ratio of between-class scatter to that of within-class scatter. The idea is that it tries to "shape" the scatter in order to make it more reliable for classification. Let the between-class scatter matrix be defined as

$$S_B = \sum_{l=1}^C N_l (\psi_l - \psi) (\psi_l - \psi)^T$$

and the within-class scatter matrix be defined as

$$S_W = \sum_{l=1}^C \sum_{T_k \in T} (T_l - \psi_l) (T_l - \psi_l)^T$$

where  $\psi_l$  is the mean image of class  $T_l$ . The optimal projection  $W_{opt}$  is chosen as the matrix with orthonormal columns, which maximizes the ratio of the determinant of the between-class scatter matrix of the projected samples to the determinant of the within-class scatter matrix of the projected samples, i.e.

$$W_{opt} = \arg \max_W \frac{|W^T S_B W|}{|W^T S_W W|}$$

$$= [w_1, w_2, \dots, w_m]$$

## 6. Our Experiments

Data set consists of Frontal Face Database. In summary, this database contains 45 images of 5 persons (9 images a person). The 9 images of a person displays varying facial expressions, see Figure 1.

**Figure 1:** Training images



Figure 2: Eigenface

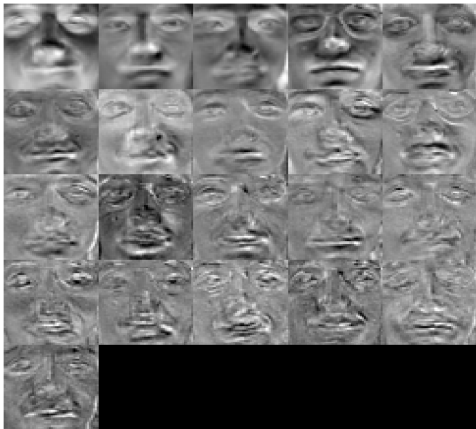
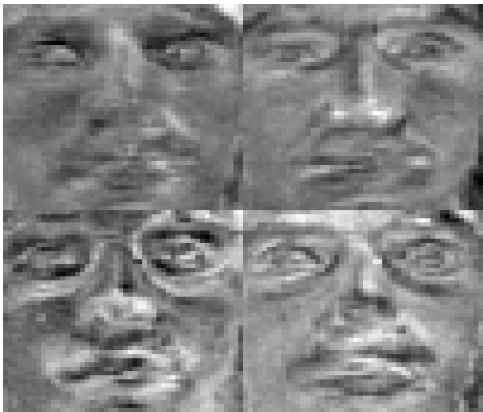


Figure 3: Fisherface



7. Our Comparison

• Eigenface



Input	Match1	Match2	Match3
Dj8	35.2941	36.7647	5.8824
Md7	73.3333	46.6667	32.2222

• Fisherface



Input	Match1	Match2	Match3
Dj8	35.2941	17.6471	27.9412
Md7	42.2222	48.8889	37.7778

## 8. Conclusion

Eigenface is a practical approach for face recognition. Due to the simplicity of its algorithm, we could implement an Eigenface recognition system easily. Besides, it is efficient in processing time and storage. PCA reduces the dimension size of an image greatly in a short period of time. The accuracy of Eigenface is also satisfactory (over 90 %) with frontal faces.

However, as there has a high correlation between the training data and the recognition data. The accuracy of Eigenface depends on many things. As it takes the pixel value as comparison for the projection, the accuracy would decrease with varying light intensity. Besides, scale and orientation of an image will affect the accuracy greatly. Preprocessing of image is required in order to achieve satisfactory result.

Fisherface is more complex than Eigenface in finding the projection of face space. Calculation of ratio of between-class scatter to within-class scatter requires a lot of processing time. Besides, due to the need of better classification, the dimension of projection in face space is not as compact as Eigenface, results in larger storage of the face and more processing time in recognition.

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# **Rotor Shape Optimization of STPM Motors Using RBT Coupled by FEA and DOE**

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## **Abstract**

In this paper, a rotor pole shape optimization method to reduce cogging torque in spoke type permanent magnet (STPM) motors is developed by using the reduced basis technique (RBT) coupled by finite element and experimental design of Taguchi methods. This method is demonstrated on the rotor shape optimization of a 4-poles/24-slots STPM motor. The cogging torque of the motor by the optimized rotor shape has been reduced significantly from the cogging torque of the motor by the conventional rotor shape.

**Keywords:** Spoke-Type Permanent Magnet Motor, Cogging Torque Minimization, Rotor Shape Optimization, Reduced Basis Technique (RBT), Design of Experiments (DOE)

## **1. Introduction**

Permanent magnet brushless motors have been widely used in industrial applications because of their efficiency and power density. In particular, STPM motor has a high torque density per unit volume resulting from its structure which can concentrate flux from permanent magnet. However, this has inherent cogging torque arises from the magnetic coupling between rotor and stator which cause vibration and noise. The rotor iron piece configuration effects on magnetic field distribution on a STPM motor. Cogging torque minimization can be performed using rotor shape design optimization to obtain better magnetic field distributions such that rotor saturation and flux leakage can be avoided. There are some researches in this regard. Table 1 summarizes the literature by showing the type of optimization approach.

K. Y. Hwang et al. [1] used the continuum shape design sensitivity formulation and the FEA method to calculate the flux linkage sensitivity to design variables to determine the shape of iron pole piece. To achieve better performance, they varied and divided the rotor pole shape into three parts. These consist of two end parts of eccentric surfaces and one uniform surface.

J. H. Lee et al. [2] applied response surface methodology (RSM) and B-Spline parameterization during the design process to optimize the design variables in order to provide the back-EMF waveform as close as possible to a sinusoidal form.

Cogging torque reduction in STPM motors was performed using a rotor with flux barriers [3]–[5].

Eccentric pole design was proposed by J. S. Chun et al. [6] to compensate the armature reaction for reducing torque ripple.

The main challenge of current optimization methods, especially for complex one, is the number of design variables required for rotor shape optimization and the generality of the procedure. The presented methods in [1] and [2] are not general solutions to achieve the optimum rotor shape profile. The main limitation of flux barrier design method is poor performance due to loss in flux barriers. Eccentric shape design method is only suitable for motor with one directional rotation.

**Table 1:** Summery of Literature Review

Attributes		Finite Element Analysis		Design Method
Researcher		2D	3D	
K.Y. Hwang et al	[1]	×		(Uniform+ eccentric) pole
J. H. Lee et al.	[2]	×		B-Spline shape
B. Y. Yang et al.	[3]	×		Flux barriers
D. H. Kim et al.	[4]	×		Flux barriers
T. U. Jung et al.	[5]	×		Flux barriers
J. S. Chun et al.	[6]	×		Eccentric pole

A new comprehensive way of rotor shape optimization is demonstrated in this research using an integrated algorithm. The algorithm focuses on the reduced basis technique (RBT) [7] coupled by finite element analysis (FEA) and design of experiments (DOE) method.

RBT method is a weighted combination of several initial shapes, called basis shapes. The aim of the method is to find the best combination using the weights for each basis shape as the design variables until the required objective-cogging torque minimization- is achieved. Therefore, the number of design variables required to define the shape is reduced to the number of basis shapes.

Experimental design of Taguchi method [8] which is the combination of mathematical and statistical techniques used in the empirical study of relationships and optimization, in which several independent variables influence a dependent variable.

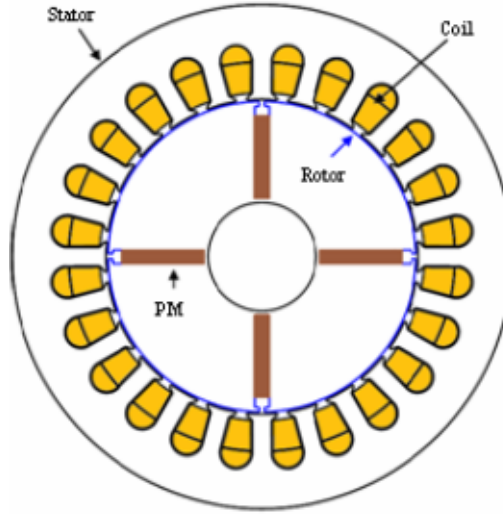
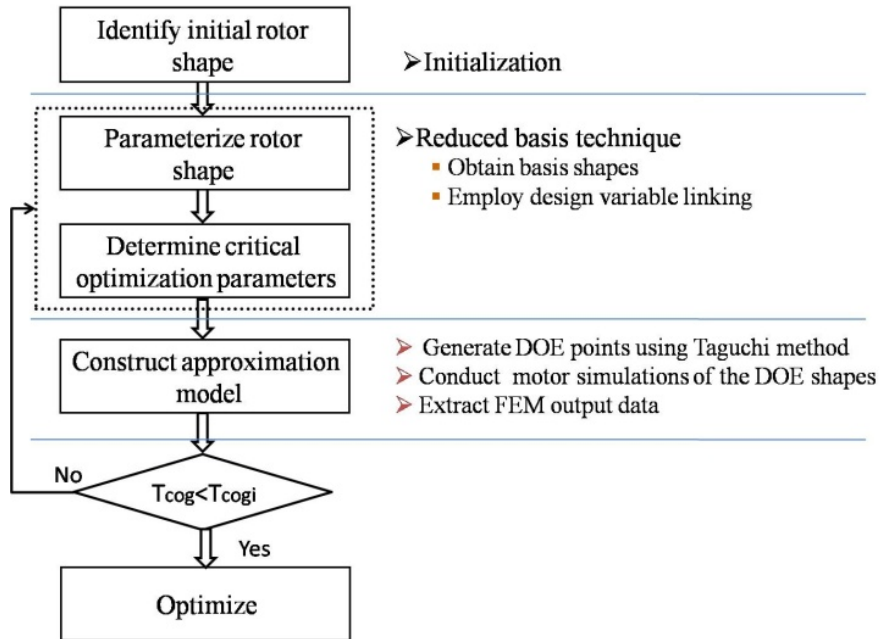
FEA method used to determine weighting factors for each basis shapes and to conduct DOE.

## 2. Shape Optimization Procedure

Rotor shape, as well as stator and permanent magnet shape influence on cogging torque of STPM motors. A cogging torque reduction can be achieved by optimization on shape of rotor. In this section, the procedure of rotor shape optimization using the reduced basis technique coupled by FEA the DOE methods are presented.

### 2.1. Initialization

The rotor pole shape optimization of a 4poles-24slots STPM motor is investigated in this work. A cross-section of the motor is shown in Fig. 1, in which the rotor shape is circular and characteristics of the motor are listed in Table 2. As shown in Fig. 2, the rotor shape optimization can be solved in multi-steps in which the iterative procedure guides the designer in selecting suitable basis shapes.

**Figure 1:** Cross-section of the 4P24S STPM motor.**Figure 2:** Flowchart of design optimization procedure.**Table 2:** Specification of the Investigated Motor

Parameter	Value
Outer Diameter	60 mm
Pole number	4
Slot number	24
PM flux density	1.05 T
Rotor outer diameter	37 mm
Magnet thickness	3 mm
Stator length	65 mm

## 2.2. Rotor Pole Shape Parameterization

The geometrical features of basis shapes can be defined in polar coordinate system  $(r, \theta)$  in which, a point called the center point is considered at center of the rotor  $(0, 0)$  and many radial lines that have

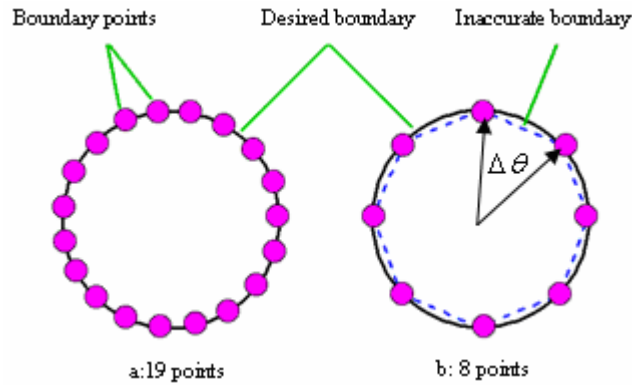
the same angle from each other ( $\Delta\theta = \theta_1 - \theta_0 = \dots = \theta_m - \theta_{m-1}$ ) meet the boundary of basis shape. The number of boundary points should be as plentiful as possible as shown in Fig. 3.

The radial co-ordinates ( $r_0, r_1, \dots, r_m$ ) of these boundary points define the basis vector ( $R$ ) as follow:

$$R = \begin{bmatrix} r_0 \\ r_1 \\ \cdot \\ \cdot \\ \cdot \\ r_m \end{bmatrix} \quad (1)$$

where  $m+1$  represents for the number of boundary points.

**Figure 3:** Basis vectors definition.



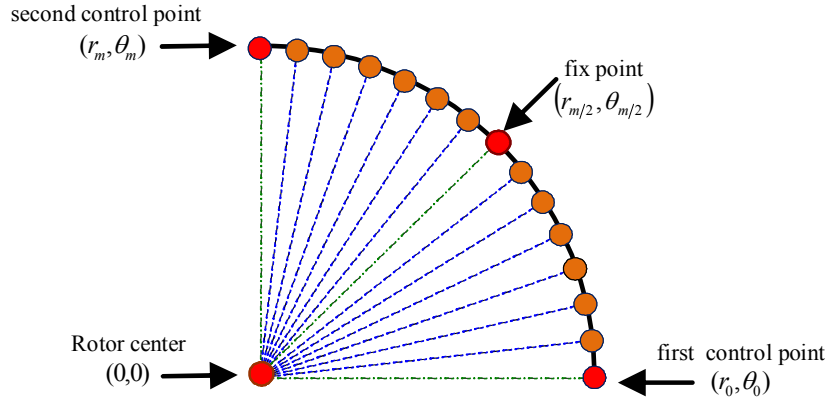
### 2.3. Objective Function and Constraints Determination

The objective function in this research is to minimize cogging torque value. Since this value is not constant respect to rotation angle of rotor, pick to pick value is considered as objective function according to equation (2) and during simulation of the motor, it is assumed that energy error of the system be lower than 0.1%.

$$j(\theta) = (T_{cog.})_{p-p} = T_{P+} - T_{P-} \quad (2)$$

Based on the problem geometry and characteristics, geometrical constraints can be defined for ease of solution. Because of iron pole piece symmetry respect to pole axis, it is enough to consider one iron pole piece. As shown in Fig. 4, a rotor iron pole piece can be defined by three control points. Since the rotation of rotor is bidirectional, the rotor iron pole piece shape should be symmetrical. Midpoint of the quarter rotor segment, i.e.  $(r_{m/2}, \theta_{m/2})$  assumed to be fixed and the two other points, i.e.  $(r_0, \theta_0)$  and  $(r_m, \theta_m)$ , have symmetry respect to the fixed point, therefore, only one point,  $(r_0, \theta_0)$ , is considered in computations.



**Figure 4:** Geometrical definition of one pole piece shape.

Since spline curves are smooth, empirical and can be manufactured by CNC machines, these curves are assumed as basis shapes in this research. A spline curve is defined through following equation

$$r(u_i) = r_0 + (3r_0 + 4r_{m/2} - 7r_m)u_i + 4(r_m - r_{m/2})u_i^2 + 4(r_m - r_0)u_i^3$$

where  $u_i = \frac{\theta_i - \theta_0}{\theta_m - \theta_0}$ ,  $0 \leq u_i \leq 1$  and  $i = 0, 1, \dots, m$ .

Because of symmetry,  $r_0 = r_m$ , so this equation can be simplified as

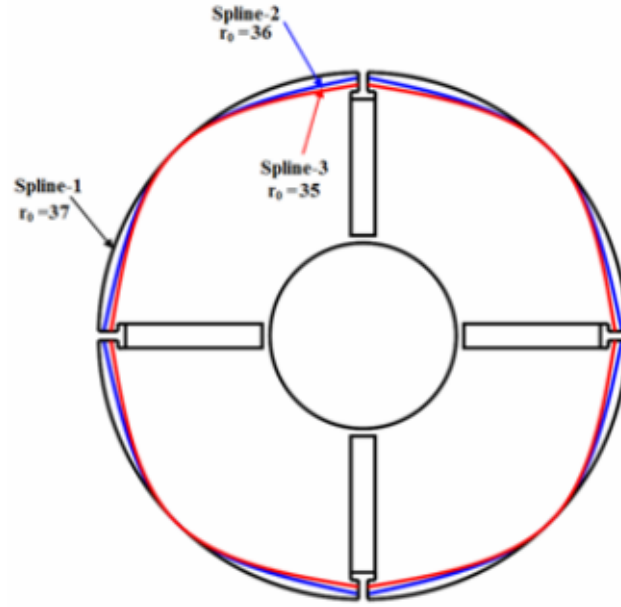
$$r(u_i) = r_0 + 4(r_{m/2} - r_0)[u_i - u_i^2] \quad (3)$$

## 2.4. Reduced Basis Approach

The main objective of the reduced basis approach is to reduce the number of design variables required to define the rotor pole shape. This method is a weighted combination of multiple trial shapes such that the best combination can be found using the weights for each rotor pole shape as the design variables. A multi-level design process is presented to find suitable trial shapes at each step. Each level is considered as a separated optimization problem until the required objectives – minimum cogging torque– is achieved. The process is started with geometrically simple trial shapes that are defined by their boundary points.

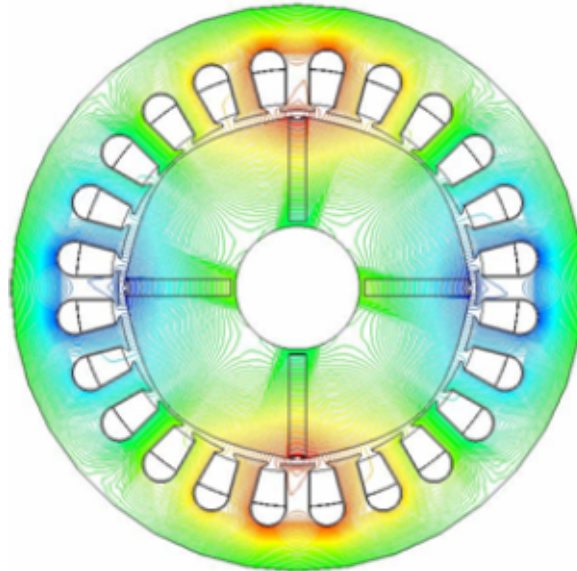
## 2.5. Basis Vector Definition

This step of optimization procedure is to select appropriate basis shapes. Fig. 5 shows three basis shapes assumed as three spline curves. For all cases, the fixed point is on  $(r, \theta) = (37mm, 45^\circ)$  and coordinates of first control point for Basis 1, Basis 2, and Basis 3 are  $(37mm, 0^\circ)$ ,  $(36mm, 0^\circ)$ , and  $(35mm, 0^\circ)$ , respectively. Each basis shapes is defined by 50 radial boundary points and basis vectors of each basis shape,  $R^1$ ,  $R^2$  and  $R^3$  is constructed.

**Figure 5:** The selected Basis shapes.

## 2.6. Finite Element Analysis (FEA)

To find the cogging torque value for preliminary analysis and to determine weighting factor of each basis shape, 2-D FEA simulations of basis shapes are performed. A sample result of FEA is shown in Fig. 6. The peak to peak cogging torque value of the basis shapes are 0.3784, 0.2159 and 0.1768(N.m), respectively.

**Figure 6:** Finite element analysis of the model.

## 2.7. Design Variable Linking

The basis vectors are combined with the weighting factors,  $w_1$ ,  $w_2$ , and  $w_3$  that correspond to each basis vectors by the following equation.

$$R = \frac{\sum_{j=1}^n w_j R^j}{\sum_{j=1}^n w_j} \quad (4)$$

where,  $0 \leq w_j \leq 1$ , and  $n$  is the number of basis shapes.

Since the weighting combination of multi splines is a spline, it is enough to calculate the following data

$$r_0^* = \frac{\sum_{j=1}^n w_j r_0^j}{\sum_{j=1}^n w_j} \quad (5)$$

therefore, equation (3) can be rewrite as

$$r(u_i) = r_0^* + 4(r_{m/2} - r_0^*)[u_i - u_i^2] \quad (6)$$

If the number of shape variables (boundary points) required to define a basis shape is  $m = 50$ , then by applying the reduced basis method, the number of design variables is decreased from  $m = 50$  to  $n = 3$  (equal to the number of weighing factors). By changing these weights, it is possible to obtain various resultant rotor pole shapes in order to find the best combination of these weights.

From the preliminary analysis, it can be said that the basis shape 3 is more successful than the other two shapes in reducing the cogging torque. Therefore, the contribution of basis shape 3 has to be considered in initial weighting factors assumption.

## 2.8. Surrogate Model Construction

The experimental design of Taguchi method [8] is used to build the approximation model and to perform optimization. This methodology, in which several independent variables (here, weighting factors) influence on a dependent variable (here, cogging torque), is the combination of mathematical and statistical techniques used in the empirical study of relationships and optimization. The goal of Taguchi method is to secure an optimal combination. Having performed the analysis of results, the predicted optimum result must be verified through carrying out experiments at optimum combination of factors. If the result of optimum experiment is within the permissible limit, the predicted result will be verified and otherwise, the DOE experiments must be redesigned. 9 DOE points are generated to conduct simulation. Simulations are conducted at these DOE points to find the cogging torque and to build the Taguchi models for optimization. Optimization is performed in QualiTek-4 software to minimize the cogging torque. Weight factors and Levels are listed in Table 3. The optimum weights are 0.5, 0.65, and 0.85 respectively. The cogging torque of the resultant shape is 0.0503 N.m. It is obviously shown that most of the contribution is from Basis 3. There is also a significant contribution from Basis 2. A comparison of peak to peak cogging torque between basis shapes and optimum shape is shown in Table 4.

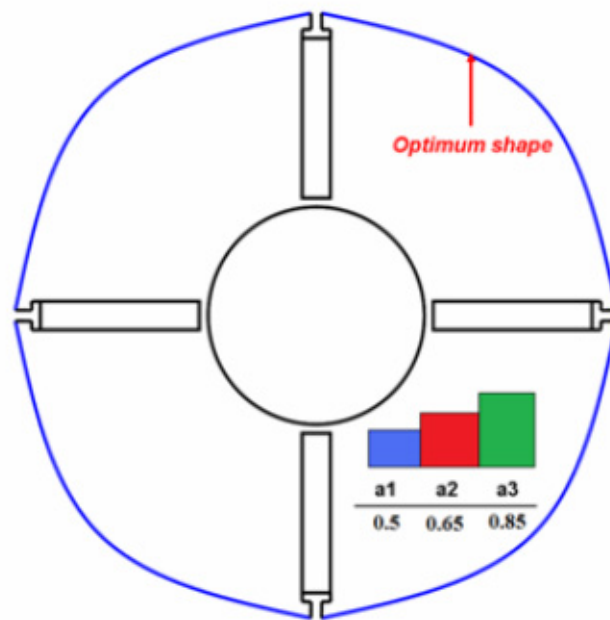
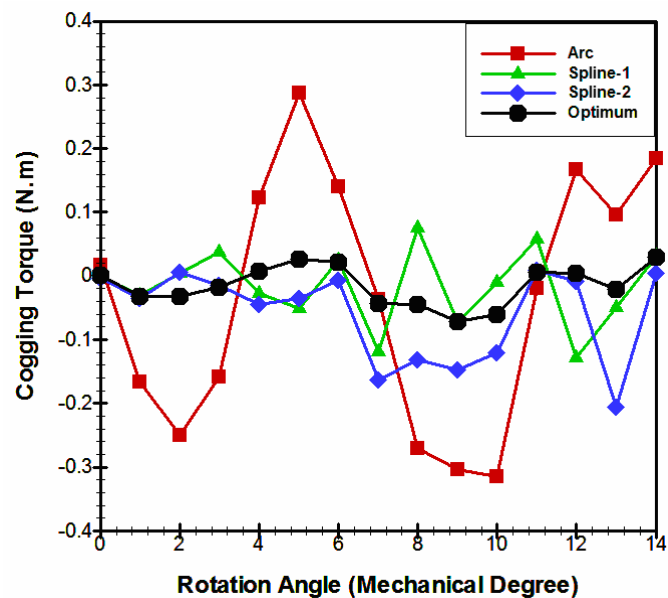
**Table 3:** Weighting Factors and their Selected Values

Factor	Level1	Level2	Level3
w1:r0=37	.3	.5	.7
w2:r0=36	.95	.85	.75
w3:r0=35	.85	.75	.65

**Table 4:** A Comparison of Cogging Torque for Several Curves

Rotor pole shape	Cogging Torque (N. m)
Spline-1	0.3784
Spline-2	0.1768
Spline-3	0.2159
Optimum	0.0503

Optimum rotor pole shape and history of cogging torque reduction are presented in Fig. 7 and 8 respectively.

**Figure 7:** Optimum resultant shape.**Figure 8:** History of cogging torque reduction.

### 3. Discussions and Conclusion

A two-dimensional rotor pole shape optimization method for a 4 poles- 24 slots STPM motor is presented in this paper using the reduced basis technique coupled with DOE method. A multi-level optimization design method is used to reduce the cogging torque of the STPM motor. This optimization technique is started from some trial shapes. If the expert knowledge of machine design is available, then practical basis shapes can be selected in order to reduce the number of FEM simulation required for the process. Increasing the number of trial shapes also enables the designer to obtain a better rotor pole shape, but the computation time also increases to build an approximation model. An optimum rotor pole shape has been achieved by the implemented algorithms, starting from spline-1, spline-2 and spline-3 curves as basis shapes. For the STPM motor, the cogging torque has been reduced significantly from 0.3784 to 0.0503 N.m by this optimization method after 10 iterations.

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## **Emergency Powers Under the Nigerian Constitution: The Plateau State Experience of Year 2004 Revisited**

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### **Abstract**

Emergency powers or emergency rule may be seen as a specie of political arrangement almost forgotten by the people of Nigeria until the 2004 Proclamation of a State of emergency by President Olusegun Obasanjo in Plateau State. Historically and incidentally too, this proclamation came up on Tuesday, May 18, 2004 barely 42 years less 11 days when the first of such proclamation in the political history of Nigeria first befell the defunct Western Region on the same Tuesday, May 29, 1962. The recent declaration has not only come as a surprise to many Nigerians, it has also been trailed by divergent views, opinions and oppositions.

In this article, attempts are made to utilize extant literature, constitutional, statutory and judicial authorities as well as print and electronic media to examine the theories of emergency rule, its historical antecedents in the Nigerian Political Jurisprudence and the implications of the 2004 Proclamation on the nation's democracy.

### **Introduction**

One of the serious problems confronting governments of many nations particularly in the developing world, is that of instability often precipitated by violence, chaos and disorder. In many instances, governments have been expending huge capital, material and human resources to defend their nations from both internal and external violence or aggression. Recently, the spate of violence and civil disorder in Nigeria has increased the rate of insecurity of life and property to the extent that some States of the Federation now appear to be under siege. In Plateau State for instance, protracted ethno-religious crises since 2001, have led to wanton destruction of lives and property. In a bid to put an end to the state of instability, the Federal Government of Nigeria considered no other viable option than to declare a State of Emergency in the State on May 18, 2004.

A lot of political meanings have been read into the action of President Olusegun Obasanjo. Arguments have also been raised as to the proprieties, due process and constitutionality or otherwise of his action. This article focuses on the examination of the meaning of some fundamental theories of emergency powers, the historical and constitutional antecedents of emergency powers in Nigeria; the remote and ultimate causes, constitutional validity and implications of the recent proclamation of a state of emergency in Plateau State on the nation's democracy.

## Meaning, Scope and Theories of Emergency Powers

The word emergency has been defined as a sudden happening which makes quick action necessary.<sup>1</sup> Another dictionary puts the meaning of emergency as a sudden, urgent and usually unforeseen occurrence or occasion requiring immediate action.<sup>2</sup> *The Black's Law Dictionary*<sup>3</sup> also defines the term emergency as a sudden unexpected happening, an unforeseen occurrence or condition, perplexing contingency or complication of circumstances; a sudden or unexpected occasion for action, exigency, or a pressing necessity. An unforeseen combination of circumstances that calls for immediate action. In their own views, Smith and Cotter<sup>4</sup> posited that the term emergency is a generic term suitable to a government, an individual or group situations connoting the existence of circumstances unexpectedly intensifying the degree of extant danger to life or well-being beyond a situation which is accepted as normal. In other words, emergency refers to all instant and overwhelming circumstances which leave no ample room or enough moment for deliberation before decisions or actions are taken to forestall any disaster or further disaster.

In modern Constitutions,<sup>5</sup> the following types of emergencies are often sources of great concern to various governments:-

- (i) Actual conduct or preparations to meet imminent occurrence of war.
- (ii) Threat or presence of internal subversion caused by riots, crises, violence, strikes or natural disasters.
- (iii) Economic recession or serious breakdown in the nation's economy.<sup>6</sup>

The term power, in ordinary grammatical usage, means the energy or force that can be used to do work or the ability to do or act.<sup>7</sup> In law,<sup>8</sup> power connotes the right, ability, authority or faculty of doing something. The authority to do any act which the grantor might himself, lawfully perform. It is also an ability on the part of a person to produce a change in a given legal relation by doing or not doing a given act. In Constitutional Jurisprudence, power includes the right to take action in respect to a particular subject-matter or class of matters, involving more or less of discretion, granted by the Constitution to the several departments or branches of the government, or reserved to the people. In this sense, powers may be classified as legislative, executive and judicial or further classified as enumerated, express, implied, inherent, resulting and sovereign.<sup>9</sup>

Within the purview of this article, the term emergency powers may be expressed as the ability of the President as the Commander-in-Chief of the Nigerian Armed Forces and the Chief Security Officer of the nation, to exercise his executive, legal and constitutional prerogatives by taking a decisive but permissible action to defend the nation or any part of it from any thing capable of threatening peace and stability.

Theories of emergency rule or emergency powers may not be so difficult to remember if conceived from the basic fact that emergencies had formed part and parcel of governance since the ancient times. The need to devise extra-legal means of subjugating all forms of threats to the stability of the State gave the Roman dictators the right to exercise various forms of emergency powers.<sup>10</sup> A Roman dictator for instance, was empowered to use all available instruments of authority to prosecute a war or quell any rebellion.<sup>11</sup> The Greek and Stoic leaders also had the right to adopt any power to deal decisively with any situation capable of imposing threat to the stability of their empires.<sup>12</sup> Over

<sup>1</sup> *The Advanced Learner's Dictionary of Current English* 1965 2<sup>nd</sup> Ed., OUP, London, 324. see also, its 3<sup>rd</sup> ed. at 281.

<sup>2</sup> *The Random House Dictionary of the English Language* 1970 (un-abridged), 467.

<sup>3</sup> 1979 5<sup>th</sup> ed., West Publishing Co., Minnesota, 469.

<sup>4</sup> *Powers of the President During Crises* 1961, De Capo press, N.Y. 14.

<sup>5</sup> *Powers of the President During Crises* 1961, De Capo press, N.Y. 14.

<sup>6</sup> Groves, L.: Emergency Powers, in *Journal of the International Commission of Jurists*, No. 2 Winter, 1961, 1. See also Popoola, A. O. Emergency Powers under the Nigerian Constitution 1983, LL.M. Long Essay, Faculty of Law, University of Ife, Ile-Ife, Nigeria, 68.

<sup>7</sup> *The Advanced Learner's Dictionary of Current English*, op. cit., 757.

<sup>8</sup> *Black's Law Dictionary* (1979); *Supra*, 1053.

<sup>9</sup> *Ibid.*

<sup>10</sup> Rossiter, C.L.: *Constitutional Dictatorship* (1948), Princeton, 15-29.

<sup>11</sup> *Ibid.*

<sup>12</sup> *Ibid.*

the ages, the nature of emergency powers, the use to which they have been put, the extent and procedures of asserting them have served as fertile grounds for many philosophers to research and theorise. Few of the outstanding theories are as follows:

- (a) One theory of emergency powers has been founded on the maxim Salus Populi est Suprema lex, meaning “the welfare of the people is the supreme law.”<sup>13</sup> By this theory, people believe that emergencies, be they of war, economic recession, insurrection, subversion, natural disaster or secession constitute a serious threat to the stability or corporate existence of a nation and so, any extra-ordinary power available to the appropriate authority can be used to deal with the situation. In other words, it is often the desire of the people to give their leaders such modicum of authority sufficient enough to dispel any event that can overturn the peace and stability of their State.
- (b) The Doctrine of necessity is another theory of emergency rule. The word ‘necessity’ has been explained as a force, power or influence which compels one to act against his will.<sup>14</sup> A state of affairs which makes an act or event unavoidable. It is a condition arising out of circumstances that compels a certain course of action.<sup>15</sup> In law, the doctrine of necessity as relates to emergency rule rests on the principle that a government at times, may be confronted with a sudden event of a disastrous nature which compels it to take a decisive action. Thus, a government, though under an obligation to protect civil liberties and rights of the citizen, is equally under the obligation to safeguard the cohesion and integrity of the State. In such circumstances, these obligations may oppose one another while the attempt at safeguarding the interest of the State may derogate from legal or constitutional provisions for the protection of civil liberties. In democratic situations however, it is expected that all actions of government in emergencies must conform to the acceptable conditions recognized throughout the modern world.<sup>16</sup>
- (c) The Democratic Political Theory posits that in plain cases of emergency, constitutional institutions and traditional governmental devices established to cater for the affairs of the State in time of peace may be overthrown or subverted. When this happens, a condition of “constitutional dictatorship” is said to arise. Two major approaches of governments to this kind of situation had been suggested over the ages by early philosophers. According to John Locke,<sup>17</sup> in grave circumstances, positive laws laid down by the legislature may be inadequate or a devile to the immediate action expected to ward-off a danger to the extent that the crown retained a discretionary authority to “act according to discretion for the public good, without the prescription of the law and sometimes even against it”.<sup>18</sup> As to the issue of how a discretion of that nature can be exercised without any abuse, John Locke capitulated by saying that “the people have no other remedy in this as in all cases where they have no judge on earth but to appeal to Heaven.”<sup>19</sup>

In his view, though Jean Jacque Rousseau accepted the need for temporary suspension of democratic process, he was not freely disposed to the postulation of John Locke that in situations where the crown abused the prerogative power offered him by the people to avert any disaster against the State, the people would have no alternative than to “appeal to Heaven”. Alternatively, Rousseau went on to suggest that the crown or any dictator in that circumstance should have a definite tenure of office to avoid perpetuation of the dictatorship. He said:

*“It is wrong therefore to wish to make political institutions so strong as to render it impossible to suspend their operation. Even Sparta allowed its laws to lapse ... if ... the peril is of such a kind that the paraphernalia of the laws are an obstacle to their preservation, ... However, for this important trust to be conferred, it is important that its duration should be fixed at a very brief period, incapable of being ever prolonged. At*

<sup>13</sup> *Black's Law Dictionary* (1979) *op. cit.*, 1202.

<sup>14</sup> *Ibid.* 928.

<sup>15</sup> See *Bykofsky v. Borough of Middletown*, 1924 D.C. Pa, 401 F. Supp. at 1250.

<sup>16</sup> See A.O. Popoola, 1983, *Emergency Powers under the Nigerian Constitution*, *op. cit.*, 3 footnote No. 5.

<sup>17</sup> *Civil Government*, Book II, Ch. xiv.

<sup>18</sup> *Ibid.*

<sup>19</sup> *Ibid.*



*Rome where dictators held office for six months only, most of them abdicated before their time was up. If their term had been longer, they might well have tried to prolong it still further... The dictator had only time to provide against the need that had caused him to be chosen; he had none to think of further projects.*<sup>20</sup>

- (d) The Machiavellian theory argued that in a well-ordered Republic, it should never be necessary to resort to extra-constitutional measures. According to Machiavelli, such measures may for the time be beneficial, yet the precedent is pernicious particularly if the practice is once established to disregard the laws for good objects, then, in a little while, they will be disregarded under the pretext for evil purposes.<sup>21</sup> This theory emphasizes the fact that no Republic will ever be perfect if necessary laws are not put in place to account or cater for everything. On this note, Machiavelli therefore suggested that every Republic must design a system of constitutionalised emergency powers. Under this arrangement, once an incumbent executive authority finds that an emergency exists, he may appoint a temporary but an executive dictator as being practised in ancient Rome. The Constitution should not be suspended while the emergency executive should not be made to enjoin absolute power.<sup>22</sup>

The arrangement, in the opinion of Machiavelli; should be such that gives the emergency executive, a narrow power to be operated under the surveillance of regular constituted legislative and executive officials in his effort at coping with the emergency. He also advocated seriously for a short time of office saying that a year or more is a long time.<sup>23</sup> As far as he was concerned, every Republic must incorporate into its constitution, a regularized or consistent device of a stand-by emergency powers to be invoked with suitable checks and controls in time of national calamity.

- (e) In contemporary political theories, the various theorists have emphasized the doctrine of constitutional dictatorship in handling the affairs of the State in time of emergency with adequate measures of checks and balances in the actions of the dictator. Most of them agreed that in time of emergency, processes of Constitutionalism may be disturbed or trampled upon to pave a way for an authoritarian system provided it “serves to protect established institutions from the danger of permanent injury and is followed by a prompt return to the previous forms of political life.”<sup>24</sup> Carl Friedrich and Clinton Rossiter also asserted in their books<sup>25</sup> that the following main conditions must be met if a constitutional dictatorship is to succeed:

- (i) The period of dictatorship must not be unduly prolonged.
- (ii) The process of enthroning a dictatorship must be legitimate.
- (iii) The overall objective of an emergency dictatorship should be to protect an existing legal or constitutional order.
- (iv) The ultimate authority to determine the need for dictatorship for any emergency must not come from the dictator himself.
- (v) Final responsibility should be maintained for every action taken under a constitutional dictatorship.

The question whether or not the above stated theories are in any way, applicable or relevant to the practice and procedure for the declaration of a state of emergency in Nigeria may be answered by making a survey into the country's history of emergency rule.

<sup>20</sup> *Ibid.* at 124-125.

<sup>21</sup> Machiavelli, *The Discourses*, Bk. I, Chap. xxxiv; See also, A.O. Popoola; *op. cit.* 8.

<sup>22</sup> *Ibid.*

<sup>23</sup> *Ibid.* at Ch. xxxv.

<sup>24</sup> Frederick Watkin, M.: “The problem of Constitutional Dictatorship” in Friedrich J. and Edward. Mason S. 1940, (editors) *Public Policy*, Cambridge University Press, 328.

<sup>25</sup> See Carl Friedrich J.: 1949 *Constitutional Government and Democracy* revised edition, Chap. xxvi; Clinton L. Rossiter, 1948 *Constitutional Dictatorship*, Princeton University Press, 298.

## Historical and Constitutional Antecedents of Emergency Powers in Nigeria

Historical development of emergency rule or emergency powers in Nigeria cannot be completely separated from the colonial tie between her and Great Britain. This is because, Nigeria became a colony of Great Britain when Lagos Protectorate was ceded to the Crown in 1861.<sup>26</sup> One unique characteristic of the colonial government was the exclusive emphasis placed on public order and state security. The British colonial masters were fond of giving apprehension to any form of opposition to their authority and always ready to subdue the rights of the natives in their bid to safeguard the security of their colony. This colonial tendency had led to the enactment of various security laws in all British colonies.

Emergency powers in British colonies especially in Nigeria, began in the early years when many European explorers, historians, scientists and traders made attempts at getting into the shores of their colonies to carry out their socio-economic objectives. The colonial masters and authorities of the Trading Companies faced periodic oppositions and violent attacks since some of their practices conflicted with natives' customs and traditions. In order to protect the colonial interest, it became necessary for the colonial government or trading companies to make laws, maintain their own armed forces, sign treaties and declare war and peace in their territories. Particularly before and after the Berlin Conference of 1885, the British Authority granted Royal Charters to the trading companies empowering them to make laws for peace, order and good government of their territories.<sup>27</sup> When the British Government took up the administration of Nigerian territory, the Consul in Nigeria was also given the Order-in-Council to make laws for peace, order and good government of the territory.<sup>28</sup> In practice, the power to make such laws was later given to the Governors of the Regions. The power was profusely exercised to curb nationalists and agitators of nationalism and representative government from fomenting troubles at the onset of various struggles against colonialism and imperial domination.

Shortly after the beginning of the Second World War, the British Government passed the Emergency Powers (Defence) Act of 1939 which was extended to all British colonies including Nigeria, as the Emergency Powers Order-in-Council, 1939. The 1939 Order empowered the Governor to declare a state of emergency in any part of Nigeria if he thought that there was a serious threat to public order, thereupon, he would acquire virtually autocratic legislative and executive powers over persons and properties.<sup>29</sup> The provisions of the Emergency Powers Order-In-Council vested extraordinary legislative and executive authorities in one single authority so characterized by arbitrary cases of arrest and detention.<sup>30</sup>

When Nigeria attained independence in 1960, the Nigeria (Constitution) Order-In-Council, 1960<sup>31</sup> retained the Emergency Powers Order-in-Council which was in existence between 1939 and 1959. The period of retention was stretched to the 13<sup>th</sup> day of March, 1961. The colonial Emergency Powers Order-in-Council, 1939 was replaced by the Emergency Powers Act, No. 1 of 1961 which became operational on the 30<sup>th</sup> March, 1961. The provisions of the Act were similar to those of the repealed Emergency Powers Order-in-Council, 1939 and it adopted section 65 of the 1960 Constitution which defined a period of emergency as follows:-

- (a) *"the Federation is at war;*
- (b) *there is in force, a resolution passed by each House of Parliament declaring that a State of Public emergency exists; or*
- (c) *there is in force, a resolution of each House of Parliament supported by the votes of not less than two-thirds of all the members of the House declaring that democratic institutions in Nigeria are threatened by subversion.*"<sup>32</sup>

<sup>26</sup> Odumosu, I.O. 1963, *Nigerian Constitution*, Sweet & Maxwell, London, 5.

<sup>27</sup> The Royal Niger Company received its own Charter in 1886.

<sup>28</sup> Akande, J.; 1971 *Emergency Powers in the Newly Independent African States within the Commonwealth* unpublished Ph.D Thesis, London University, cited by Popoola, A.O. *op. cit.*, 21.

<sup>29</sup> See the whole of Section 3 of the Emergency Powers Order-in-Council, 1939.

<sup>30</sup> According to Holland, D.C. (1960) in *Emergency Legislation in the Commonwealth*, 13 *Current Legal Problems* (1960), p. 148; Three of the Emergency Powers Declaration took place in Nigeria between 1949 and 1953 in the whole country, Eastern Region and Northern Region.

<sup>31</sup> Section 6 thereof.

<sup>32</sup> Section 3.

The political intrigues within the rank and file of the Action Group actually degenerated in 1962 when two opposing factions of the Party, one led by Chief Obafemi Awolowo (leader of Action Group) and the other, led by Chief S.L. Akintola (Premier of the Western Region) came out in open confrontations. The efforts of the Governor of Western Region, Sir Adesoji Aderemi and the Rotimi Williams' Peace Committee to resolve the crises proved abortive. The Governor decided to remove Chief S.L. Akintola from office on the ground that he had lost the support of the majority in the House. Even though Chief S.L. Akintola filed a suit against the purported action of the Governor, the Governor proceeded to remove him without awaiting the court's decision and sworn in Alhaji D.S. Adegbenro as the Premier of Western Region.<sup>33</sup> Subsequently, about two attempts were made to hold meetings of the Western State's House of Assembly when political supporters of the two factions clashed in bloody riots that resulted in loss of lives and property. This led to a state of confusion, insecurity and serious breakdown of law and order to the extent that public affairs of the Region could not be conducted.

In response to the political crises which engulfed the Western Region, the Federal Parliament passed a Resolution on May 29, 1962 declaring a state of emergency in western Region of Nigeria. The Resolution, consisting of 13 Regulations<sup>34</sup> provided for the appointment, on the advice of the Prime Minister, by the Governor-General, of an Administrator for Western Nigeria to be responsible only to the Prime Minister, suspension of the Legislature and Constitution of the Region, operation of the existing laws in force until modified, suspended or replaced by the Administrator. Thereafter, the Prime Minister (Alhaji Abubakar Tafawa Balewa) appointed Dr. M.A. Majekodunmi, a Federal Minister and Senator, as the Administrator for Western Nigeria effective from Tuesday, 29<sup>th</sup> May, 1962.<sup>35</sup> That was the first time when Nigerians actually experienced such an emergency declaration by an indigenous regime of the nation. It was also one of the chain of events that facilitated the collapse of the Nigerian First Republic.

### **The Plateau State Experience of Year 2004: Remote and Ultimate Causes**

The crises in Plateau State began in September, 2001 due to protracted boundary disputes and ethno-religious disturbances principally between Christians and Moslems in Yelwa, Langtang, Shendam and Wase Local Government areas of the State.<sup>36</sup> The parties had engaged themselves in fierce battles intermittently between 2001 and 2003. The situation actually degenerated in February, 2004. All along, the parties had been fighting themselves with dangerous charms, arrows, spears and other forms of sophisticated rifles leading to colossal loss of lives. They had also set on fire, their private and public buildings, investment houses, industries, cars and other chattels of great economic values. In the process, thousands of persons were rendered homeless without clothes, shoes and food to eat. Many innocent persons became refugees in other neighbouring States of Bauchi, Benue, Kaduna, Nassarawa and Taraba. Reprisals of the crises were also said to have spread to Kano, Gombe, Owerri, Umuahia and Abuja. Domestic and international news agencies have painted the gloomy and sorry pictures of innocent persons in refugee camps with their debilitating and inhuman environmental conditions, all portraying bad image of Nigeria.

The Federal Government had earlier on, set up at least, three all-embracing peace Committees charged with the responsibility of finding solutions to the crises and means of restoring peace, law and order in Plateau state. In his broadcast to the nation, the President however lamented that:

*"... those committees have been frustrated by vested interests in Plateau State that were clearly not on the side of peaceful coexistence, tolerance and harmony."*<sup>37</sup>

<sup>33</sup> See *S.L. Akintola v. Adesoji Aderemi & Ors.* (1962) W.N.L.R. 185.

<sup>34</sup> Emergency Powers (General) Regulations, 1962 published in the Legal Notice No. 54 of 1962.

<sup>35</sup> By the Legal Notice of June 9, 1962, the Administrator was to hold Office during the pleasure of the Prime Minister.

<sup>36</sup> See *The Comet* (Nigeria) May 19, 2004 1-2, e-mail: mail@cometnews.com.ng

<sup>37</sup> See *The Guardian* (Nigeria) May 20, 2004, 16, e-mail: letters@ngrguardiannews.com

The President also informed all Nigerians that since 2001 when he first visited Plateau State on account of the crises, the situation had degenerated politically due to the failure of governance and the gross inefficiency on the part of Governor Daniel Dariye in managing the rich and robust diversity of the State. The Governor was alleged to have been busy paying visits abroad while his State was on fire.<sup>38</sup>

The situation came to a climax on May 2, 2004 following violent attacks on Yelwa inhabitants in which about 200 persons lost their lives while hundreds of houses were set on fire. This prompted the President to pay another working visit to the troubled spots and refugee camps on May 13, 2004. It was reported that while the Governor and his entourage were piloting the President to the crises-ridden areas, his driver missed the way. This showed that the Governor had not been regular in visiting the areas.<sup>39</sup> The army of refugees were also said to have been unruly on seeing the Governor to the extent that his car was pelted with stones. The President was also reported to have shed tears on sighting the human suffering and promised to restore their dignity.<sup>40</sup> This situation, coupled with what the President described as the lackadaisical, incompetent and nonchalant attitude of the Governor, prompted the invocation of Section 305 of the 1999 Constitution by the President to declare a state of emergency in Plateau State. The questions whether the President has the power so exercised or whether the content of the power and procedures adopted are constitutional or otherwise will now be addressed.

### **Legal or Constitutional Validity of the President's Proclamation**

In exercising his powers, the President did not only declare a state of emergency in Plateau State, he went further to accomplish the following; during his broadcast to the nation on May 18, 2004:

- (a) Remove the Governor of Plateau State from Office.
- (b) Sack the Plateau State House of Assembly.
- (c) Appoint former Chief of Army Staff, General Chris Alli as the Sole Administrator of Plateau State.
- (d) Send 8 Emergency regulations to the National assembly for approval barely one week after the declaration.

In Constitutional Jurisprudence, a declaration of a State of emergency as made by President Olusegun Obasanjo comprises of two major powers, which are: (i) Power to declare a State of Emergency. (ii) Power to make laws and to execute them with regard to issues within exclusive state competence in normal situation, and to overstep, with some exceptions, the limitations on power arising from the relevant constitutional guarantee of fundamental rights as seen in Chapter IV of the 1999 Constitution.<sup>41</sup> The legal or constitutional validity of the above stated actions of the President will now be analysed as follows:

### **Power to Declare a State of Emergency**

Section 130(2) of the 1999 Constitution establishes the office of the President as follows:

*"The President shall be the Head of State, the Chief Executive of the Federation and Commander-in-Chief of the Armed Forces of the Federation."*

The above section envisages that the President shall be the Chief Executive Officer in the country upon whom enormous powers lie in carrying out the day-to-day administration of the nation. As the Commander-in-Chief of the Armed Forces, the President could also exercise any justifiable power tending to portray him as the Chief Security Officer of the nation as well as someone having the overall responsibility to ensure law, order, peace and stability in any part of Nigeria. Hence, the President has the implied power to take any necessary action including declaration of a state of emergency in the nation or any part thereof if any situation calls for it.

<sup>38</sup> *The Comet* (Nigeria), May 19, 2004, 2.

<sup>39</sup> See *Vanguard* (Nigeria) May 19, 2004, 1-3, e-mail: vanguard@linkserve.com.ng

<sup>40</sup> *The Comet* (Nigeria), *supra*, 2.

<sup>41</sup> *Ibid.*

Specifically, Section 305 of the 1999 Constitution explicitly confers certain enumerated and implied powers on the President as regard the issue of emergency. The Section provides:

- (1) *“Subject to the provisions of this Constitution, the President may, by instrument published in the Official Gazette of the Government of the Federation issue a proclamation of a state of emergency in the Federation or any part thereof.*
- (2) *The President shall immediately after the publication, transmit copies of the Official Gazette of the Government of the Federation containing the proclamation including the details of the emergency to the President of the Senate and the Speaker of the House of Representatives, each of whom shall forthwith convene or arrange for a meeting of the House of which he is President or Speaker, as the case may be, to consider the situation and decide whether or not to pass a resolution approving the proclamation.*
- (3) *The President shall have power to issue a proclamation of a State of Emergency only when:-*
  - (a) *the Federation is at war;*
  - (b) *the Federation is in imminent danger of invasion or involvement in a state of war;*
  - (c) *there is actual breakdown of public order and public safety in the Federation or any part thereof to such extent as to require extraordinary measures to restore peace and security;*
  - (d) *there is a clear and present danger of an actual breakdown of public order and public safety in the Federation or any part thereof requiring extraordinary measures to avert such danger;*
  - (e) *there is an occurrence or imminent danger or the occurrence of any disaster or natural calamity affecting the community or a section of the community in the Federation;*
  - (f) *if there is any other public danger which clearly constitute a threat to the existence of the Federation; or*
  - (g) *the President receives a request to do so in accordance with the provisions of sub-section (4) of this section;*
- (4) *The Governor of a State may, with the sanction of a resolution supported by two-thirds majority of the House of Assembly, request the President to issue a proclamation of a State of Emergency in the State when there is in existence within the State any of the situation specified in sub-section (3)(c), (d) and (e) of this section and such situation does not extend beyond the boundaries of the State.*
- (5) *The President shall not issue a proclamation of a State of Emergency in any case to which the provisions of sub-section (4) of this section apply unless the Governor of the State fails within a reasonable time to make a request to the President to issue such proclamation.*
- (6) *A proclamation issued by the President under this section shall come to have effect:*
  - (a) *if it is revoked by the President by instrument published in the Official Gazette of the government of the Federation;*
  - (b) *if it affects the Federation or any part thereof and within two days when the National Assembly is in session, or within ten days when the National Assembly is not in session, after its publication, there is no resolution supported by two-thirds majority of all the members of each House of the National Assembly approving the proclamation;*
  - (c) *after a period of six months has elapsed since it has been in force;*

*Provided that the National assembly may, before the expiration of the period of six months aforesaid, extend the period for the proclamation of the State of*

*Emergency to remain in force from time to time for a further period of six months by resolution passed in like manner; or*

- (d) at any time after the approval referred to in paragraph (c) of this subsection, when each House of the National Assembly revokes the proclamation by a simple majority of all the members of each House.”*

*On the strength of the above cited provisions, no doubt, the President has certain enumerated and implied powers in the first instance, to declare a state of emergency in the nation or any part thereof, for the reasons so stated in the Constitution.*

**(7) Removal of the Governor of Plateau State from Office**

*Under the present democratic dispensation in Nigeria, the Governor of a State is the Chief Executive of the State democratically elected by the people of the State. He is therefore, not a political appointee of the President. Section 176 of the 1999 Constitution provides:*

- (1) “There shall be for each State of the Federation a Governor.*

- (2) The Governor of a State shall be the Chief Executive of that State.*

*Section 177 of the same Constitution provides that:*

*“A person shall be qualified for election to the office of Governor of a State if:-*

- (a) he is a citizen of Nigeria by birth;*

- (b) .....*

- (c) .....*

- (d) .....*

*Section 178(4) and (5) also provides that:*

*“For the purpose of an election under this section, a State shall be regarded as one constituency;*

- (5) Every person who is registered to vote at an election of a member of a legislative house shall be entitled to vote at an election to the office of Governor of a State.”*

In the light of the above cited provisions, the Governor of a State in Nigeria cannot even be subject to the excessive authority of the President let alone being a subject of expulsion or removal at the whims and caprices of the President. In law, the general principle is that ‘he who has the power to appoint also has the power to remove.’ This principle is not applicable in this situation. The Governor of Plateau State was not appointed by the President and so, he could not have been removed by him. By virtue of these constitutional provisions also, there has been a great departure from the usual practice under military regimes in Nigeria when political appointees like Judges and Governors held their office at the pleasure of the Head of State or the President. At that time, the tenure of office of Governors or Judges was often subject to the maxim “Durante bane placito Regis”.<sup>42</sup> Under the present 1999 Constitution therefore, since the Governor of a State does not hold his office subject to the pleasure of the President, the removal of Governor Daniel Dariye of Plateau State by president Olusegun Obasanjo was unconstitutional, illegal and invalid.

Even under Section 11 (3), (4) and (5) of the 1999 Constitution which empowers the National Assembly to make laws when the nation is at war and the House of Assembly of a State cannot meet to make laws for the State, the laws made by the National Assembly are to have effect as if they are laws made by the House of Assembly of that State and until such a time when the House is able to resume its functions. The section does not confer any power on the National Assembly to remove the Governor or its deputy. The Governor can only be removed constitutionally by members of the House of Assembly of his State through a valid process of impeachment enshrined in section 188 of the 1999 Constitution. As far back as 1921 in the case of *Esugbayi Eleko v. Government of Nigeria*,<sup>43</sup> the Privy Council restated the principle that executive acts must be authorized by law. Hence, the Colonial

<sup>42</sup> See Professor Nwabueze’s view in *This Day* (Nigeria) May 21, 2004, 1 & 4, e-mail: editor@thisdayonline.com

<sup>43</sup> Meaning – Judges or Governors to hold office at the pleasure of the King or President.

Governor of Nigeria could not confer any inherent power not given by law or Constitution on itself to deport the then Oba of Lagos.

### **Sacking or Dismissing the House of Assembly in Plateau State**

In support of the argument for non-justification of Governor Dariye's removal by the President, there is also nothing in Section 305 of the 1999 Constitution conferring any emergency power on the President to sack members of the House of Assembly in Plateau State. The position of a House of Assembly even in a period of war is clear under Section 11(3), (4) and (5) of the 1999 Constitution cited above. In that Section, the National Assembly is only empowered to make laws for and on behalf of the State if the State House of Assembly is unable to perform its functions by reason of the prevailing situation which led to the declaration of a state of emergency. The laws made in that circumstance are deemed to have effect as being made by the House of Assembly of the State. According to the Section, the House of assembly shall not be deemed to be unable to perform its functions so long as it can hold a meeting and transact business.

Though, the President alleged that serious threats to life and property coupled with sufficient evidence of breakdown of law and order compelled him to proclaim a state of emergency in Plateau State, empirical reasons were not given to convince members of the Public that the State House of Assembly was unable to meet and carry out their law-making duties. Hence, the President's action was unconstitutional, *moreso*, when there is no express provisions in sections 11 and 305 of the 1999 Constitution specifically empowering the President to sack members of the State House of Assembly. In view of Section 11 stated above, if the Governor and his Deputy cannot be removed from office and a State House of Assembly cannot be disbanded while the National Assembly continues to function even during a war; the proclamation of a state of emergency by the President for reasons of serious ethno-religious and boundary disputes leading to destruction of lives and property, and which were capable of being controlled, can hardly be sustained, tenable and justified. Under the 1999 Constitution of Nigeria, the most popular, just and viable processes of removing any member of a State House of Assembly are impeachment, recall and others stipulated in sections 109 and 110 thereof.

### **Appointment of a Sole Administrator to govern Plateau State**

If the President had no constitutional power to remove the Governor and his Deputy, it follows logically that his act of appointing General Chris Alli as the Sole Administrator of Plateau State was irregular and unconstitutional. Under the present democratic situation in Nigeria, the country is a Federation consisting of States and a Federal Capital Territory of which Plateau State is an integral part.<sup>44</sup> Section 1(2) of the same Constitution provides that:

*"The Federal Republic of Nigeria shall not be governed, nor shall any person or group of persons take control of the Government of Nigeria or any part thereof, except in accordance with the provisions of this Constitution."*

The above cited section envisages that a person or persons who will govern Nigeria or any part of it should emerge in accordance with the provisions of the Constitution. The provisions of the Constitution relating to the emergence of such a person or persons stipulate democratic elections for the President,<sup>45</sup> Governor<sup>46</sup> and other political leaders of the country. As regards the office of the Governor of a State, Section 179(1) states that:

*"A candidate for an election to the office of Governor of a State shall be deemed to have been duly elected to such office where, being the only candidate nominated for the election –*

*(a) he has a majority of Yes votes over No votes cast at the election..."*

<sup>44</sup> Section 2(2) of the 1999 Constitution of Nigeria.

<sup>45</sup> See Section 132 of the Constitution of the Federal Republic of Nigeria, 1999.

<sup>46</sup> Section 178.

The argument is that General Chris Alli was never a political candidate validly nominated and voted for, by the people of Plateau State. He could therefore, not have been a person contemplated by the constitution to govern the State. His appointment as the Sole administrator by the President not being provided for by Section 305 of the 1999 Constitution was therefore, unconstitutional.

### **Sending Eight Emergency Regulations to the National Assembly for Approval**

Barely one week after the proclamation of a state of emergency in Plateau state, the President sent eight Emergency Regulations to the National Assembly for approval.<sup>47</sup> The Regulations have been quoted as laws for the use of the Sole administrator to govern Plateau State. The President believed that this was necessary to enable the Sole Administrator possesses enough legal instruments to handle the affairs of the State since the House of Assembly was already disbanded by him. The regulations are:

- (a) Emergency Powers (General) Regulations 2004.
- (b) Emergency Powers (Procession and Meetings etc.) Regulations 2004.
- (c) Emergency Powers (Reporting of Persons) Regulations 2004.
- (d) Emergency Powers (Control of Arms and Explosives) Regulations, 2004.
- (e) Emergency Powers (Curfew) Regulations 2004.
- (f) Emergency Powers (Detention of Persons) Regulations 2004.
- (g) Emergency Powers (Restriction Orders) Regulations 2004.
- (h) Emergency Powers (Protected Places) Regulations 2004.

The Emergency Regulations were said to have been made pursuant to the Emergency Powers Act, 1961 which was promulgated pursuant to Section 65(1) of the Constitution of Nigeria 1960. Section 65(2) of the 1960 Constitution however provides that:

*“Any provision of law enacted in pursuance of this Section shall have effect during a period of emergency.”*

In the case of *Mongele v. Alawe*,<sup>48</sup> it was also held that:

*“By virtue of section 1(3) of Nigeria (Constitution) Order-in-Council 1960, Emergency Legislation made under Section 65 of the 1960 Constitution are generally efficacious during the period of emergency only”*<sup>49</sup>

Therefore, by the time the Emergency rule ended in the Old Western Region with effect from January 1<sup>st</sup>, 1963, all the Laws, Act or Regulations made for the Emergency rule became non-extant or they ceased to exist by virtue of Section 65(2) of the 1960 Constitution as evidenced by the pronouncement of the Nigerian Supreme Court in the case cited above. It goes without saying that the Emergency Powers Act, 1961 and the Emergency Powers (General) Regulations, 1962 being relied upon by the President as the basis of his Emergency Regulations are no longer existing laws in Nigeria. In fact, the index to the codification of the Laws of the Federation of Nigeria 1990, categorically states on page XLVIII that the Emergency Powers Act, 1961 is “omitted and “spent”. This means that the law is now omitted or left aside in the Nigerian statute book because it had been “spent” like money which someone cannot find any more. It therefore amounted to voidness or invalidity for the President to have derived any power to make regulations from a law that does not exist. It is like putting something on nothing which is bound to collapse. A situation of this nature came up for examination in the case of *M’Cfoy. v. U.A.C.*,<sup>50</sup> where Lord Denning said that:

*“If an Act is void, then it is in law a nullity. It is not only bad, but incurably bad. .... You cannot put something on nothing and expect it to stay there. It will collapse.”*<sup>51</sup>

Apart from divergent opinions on the constitutionality or otherwise of the President’s action, it may also be appropriate at this juncture, to highlight some implications of the emergency declaration on the Nigerian nascent democracy and democratization.

<sup>47</sup> See *Vanguard* (Nigeria) May 19, 2004, 1 – 3.

<sup>48</sup> SC 669/1965 of 11-3-66.

<sup>49</sup> 49. 47.

<sup>50</sup> 1962 AC 152

<sup>51</sup> 51 at 160



### **An Overview of Implications of the Emergency Proclamation**

In order to ensure the brevity of this article, an attempt will be made to highlight the most sensitive implications of the President's proclamation of a state of emergency in Plateau State on the nation's democracy as follows:

1. The proclamation has come as a bitter and sudden reminder to all Nigerians of their unfortunate political experience of the similar incident of May 29, 1962 which was one of the foundation problems that led to the first military intervention in Nigerian politics on January 15, 1966.
2. It has heated up the polity in a more serious dimension by forcing the people to engage in serious debates, agitations and litigations in courts of law.<sup>52</sup>
3. Nigerians have been painfully reminded that the present democratic dispensation has not completely delivered them from the yoke of military rule.
4. The proclamation has further exposed the spate of insecurity of life and property in Nigeria to the international communities whose members may be skeptical about their intention to come and invest in Nigeria. The opposite of this view however, is that foreign investors are always assured of the readiness on the part of the present Administration to give immediate resolution to any problem tending to endanger the security of the nation.
5. It portrays Nigeria as a nation of citizens who have not really appreciated the importance of peace and respect for due process as fundamental ingredients of an enduring democracy.
6. It signifies the executive and legislative authorities in Plateau state as political representatives so incompetent to handle the affairs of the State and perform their public functions satisfactory in the interest of the State and the electorate.
7. The political problems of Plateau State have been compounded further as divisions between supporters and detractors of the suspended Governor and disbanded members of the State House of assembly deepen since the declaration of a state of emergency<sup>53</sup>.
8. Members of the National Assembly who hurriedly ratified the proclamation by the President despite some serious legal, constitutional and procedural irregularities have also been portrayed as peoples' representatives not versed enough in the relevant constitutional and legal issues involved. It has been argued that many of these legislators do not understand the implications of the emergency rule on the rights of the people who voted them into power.<sup>54</sup>
9. The financial implications of the declaration of emergency rule in Plateau State on the nation is equally enormous. For instance, the President had submitted a contingency vote of N2.5 billion (US \$ 704.3 million) to the National Assembly for approval to enable the government meet unexpected emergency situations in Plateau State and other States where reprisals of violence have been noticed.<sup>55</sup> This money should have been judiciously spent on projects capable of improving the standard of living of many Nigerians.

### **Conclusion: Observations and Recommendations**

In every nation whether democratic or otherwise, it is the responsibility of leaders particularly the overall chief executive authorities, to maintain the security of life and property and defend the nation from both internal and external violence or aggression. In Nigeria for instance, the relevant constitutional provisions have been cited in this article which empower the President to exercise emergency powers to protect the security of the State whenever it is threatened in any part thereof. In a

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<sup>52</sup> *Ibid* at p. 160. See the view of Chief Gani Fawehinmi: (SAN) on "The Constitutionality of the Declaration of State of Emergency and the Illegality of Emergency Powers and Regulations (ii)" in *Saturday Tribune* (Nigeria) 5<sup>th</sup> June, 2004 at 5; e-mail: [tribune@skannet.com](mailto:tribune@skannet.com)

<sup>53</sup> Notable Human Rights Activists and some Plateau State's indigenes sued the President for his action. See *The New Age* (Nigeria) May 26, 2004, 1.

<sup>54</sup> *Saturday Tribune* (Nigeria) June 5, 2004, 5.

<sup>55</sup> See *The Guardian* (Nigeria) Thursday, May 20, 2004, 16.  
e-mail: [letters@ngguardiannews.com](mailto:letters@ngguardiannews.com)

democratic situation, the use of emergency power raises some questions regarding its constitutionality, procedure, authorization and exercise. When not in use at the time it is supposed to be used, a democratic order may be rendered asunder. Whereas, if the power is arbitrarily or capriciously applied, it could result into a condition of dictatorship. Therefore, it is the duty of the executive and legislative authorities concerned, to exercise utmost caution whenever any situation calls for emergency.

In an attempt by the President Olusegun Obasanjo to justify the proclamation of emergency powers in Plateau State, a catalogue of systematic incidents that led to wanton destruction of lives and property since September, 2001 was recalled, while a sad picture of the State's executive and legislative incompetence to maintain peace and order was painted to the public.<sup>56</sup> Gleaned from his speech, he was confronted with a sudden peril requiring instinctive action to defend the nation's nascent democracy. Hence, he had no option than to proclaim the state of emergency. As much as someone would like to sympathize with the President, it should also be noted that the President ought to be aware of the constitutional provisions on this matter and the legislative inputs expected of the National Assembly. Also, the spate of crises in Plateau State and its environs had started since September, 2001 leaving a period of over 2½ years during which the Federal, State and Local Government Authorities involved ought to have used every security apparatus at their disposal to bring the situation to normal. It is therefore, difficult to sustain the argument that the climax of the crises in May, 2004 could have posed a sudden peril requiring such an urgent solution.

Hence, the President's hasty actions in exercising his emergency powers by suspending and disbanding the democratically elected Governor and members of the State House of Assembly respectively, have testified to the unconstitutionality of the President's actions. The National Assembly had equally refused to help matters by hurriedly approving the President's proclamation without much restraint and deep reflections on its implications. Whenever the National Assembly is confronted with this kind of situation in future, it is suggested that members' professional competence and legislative experience should further be sincerely explored to protect the rights of the electorate and uphold the Constitution to which they had sworn to defend.

It may be correct to claim that the provisions of the 1999 Constitution of Nigeria dealing with procedure for declaration of a state of emergency are clear to some extent. For the purpose of judicial interpretation however, those provisions may not be seen as elaborate enough. For instance, the Constitution is silent on the fate of the legislative and executive authorities of the state involved during emergency as well as the particular stage at which the President shall make his declaration. Such issues should not be left completely to the utter discretion of the President otherwise, there is bound to be a reckless and misuse of emergency powers. It is therefore, suggested that unelaborate constitutional provisions in this regard be identified and modified by the Presidential Committee on the Review of the 1999 Constitution.

It is also observed that a combination of factors like ineffective security agents, States' incapacity to control the police, neglect of minorities' demands for their rights and the general state of poverty in Nigeria are seriously responsible for the spate of violence and peoples' nonchalant attitude to the preservation of law and order. It is even painful to note that barely three or five days after the proclamation of a state of emergency in Plateau State, fresh violence and cruel attacks had since erupted again in which more lives were lost and properties destroyed.<sup>57</sup> This is part of the incontrovertible evidence that the imposition of a state of emergency might not have provided enduring solutions to most of the crises still being witnessed in the state and other parts of Nigeria. Government must therefore, intensify its efforts at ensuring sound education for all and genuine economic and employment opportunities for the people. It is equally recommended that a Sovereign National Conference being agitated for, by well-meaning Nigerians be allowed to hold in order to resolve all the sensitive national problems of which insecurity of lives and property is most cardinal. The Political Reform Conference that was organized in substitute of the sovereign National Conference was

<sup>56</sup> See *Vanguard*, Friday, May 21, 2004, 1. e-mail: [vanguard@linkserve.com.org](mailto:vanguard@linkserve.com.org)

<sup>57</sup> See *Sunday Tribune* (Nigeria) May 23, 2004, 1 & 6 with the screaming headline "Plateau boils again: Over 74 people killed and 200 houses burnt" [editorsundaytribune@yahoo.com](mailto:editorsundaytribune@yahoo.com)

definitely not able to provide solutions to the lingering social-economic and political problems of the nation.

Finally, the principles articulated by all the major theories stated earlier, in support of the use of emergency powers are believed to be worthy of application whenever any overall executive of the State is faced with a sudden or unforeseen emergency situation. Precisely, that the welfare of the people is the supreme law, that the State has an obligation to take a lawful but decisive action in a perilous circumstance, that in such a situation, some democratic affairs of the State may be subverted, that every Republic must design a system of constitutionalised emergency powers and that the dictator so appointed must not overspend a universally recognized period of six months except otherwise extended by the State. If he refuses to vacate his office at the end of the emergency period, the State may force him to resign and thereafter, he could be prosecuted for illegally prolonging his tenure. Emergencies, in whatever manner should be regarded as a democratic aberration and a threat to the corporate existence of a nation. Hence, extra-legal, constitutional and political cautions must always be adopted in its management for the welfare of the people and the interest of the State.

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## **Farmers' Approach and Access to Information and Communication Technology in the Efficient Use of Modern Irrigation Methods**

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### **Abstract**

Information and communication technology has vastly changed different aspects of people's life especially their economical, social and cultural status and its role will be increased in the near future. Since societies' developments have meaningful relations with the agricultural and rural developments, having access to quick, easy and suitable sources of information seems an important issue in this process. The present study intends to investigate the farmers' attitudes toward information and communication technology and its accurate usage in acquiring modern ways of irrigation.

The study population includes all the farmers who are working in Kohgiluyeh and Boyer-Ahmad Province. The research findings show that most of the farmers in this province do not have access to the modern sources of information such as internet, E-newspapers and magazines. Their access to newspapers, magazines, agricultural brochures, posters, and rural libraries is limited as well. However, they have great access to agricultural professionals and TV and radio programs.

As study findings reveal the farmers have positive attitudes toward media's agricultural programs (TV & Radio) and the agricultural experts' speeches. The results of this research show that the farmers do not trust totally on other mass medias and in the current situation the best option for introducing them the technical information about the new ways of modern irrigation is the Educational Department of Agriculture Organization. According to the research findings, there is a meaningful relation between the age of the farmers, their level of education, governmental facilities and their participation in educational programs and their attitude toward information and communication technology.

**Keywords:** Media, Communication, Information, Agriculture, Irrigation.

## Introduction

One of the essential complexities of the world, especially in dry and semi-dry regions, is the shortage of water for various uses as, drinking, industry, agriculture and natural environment. Therefore, the main thematic message of this paper is that 'Water is one of the rarest and the most precious sources in the world' (Najafipour, 2006).

The countries of the Middle East are characterized by large temporal and spatial variations in precipitation and with limited surface and groundwater resources. The rapid growth and development in the region have led to mounting pressures on scarce resources to satisfy water demands. The dwindling availability of water to meet development needs has become a significant regional issue, especially as a number of countries are facing serious water deficit (Aminmansour, 2007).

The volume of renewable water resources in the country is about 130 milliard cube meter per year that due to the 70 million population of the country, it is assessed to be 1857 cube meter per person in a year. Based on the issued statistics, agriculture utilizes 92% of 938 milliard cube meter of achieved water, and is therefore considered the greatest consumer of water, as well as the greatest demandant of water to use for irrigation purposes (Sayar, 2005).

The modern techniques of irrigation system is highly paid heed to in various parts of the world, especially in regions facing shortage of water, as the water consumed in this system is under control with maximum level of economy (Shangguan, et al, 2002).

In the age of information, due to the new global inclinations, the application of information technology & communication can provide appropriate means for the removal of the present issue and can potentially cause the reinforcement and the development of agriculture and food products (Niknami, 2005).

Information technology is classified into diverse Methods: Traditional Method (mutual negotiation of local leaders), Advanced Method (as internet, radio and TV), Two-way Dialogue (as Tel. & e-mail), and One-way Method (as film, video and mass media).

The present world is rapidly changing into an information community in which wisdom and the level of accessibility of knowledge, plays a pivotal and determinative role (Kiani, Fazelnia, 2004).

Effective communication of new research findings and technologies in agriculture to rural farmers remains a promising strategy for increasing agricultural productivity. Generally, such information may include techniques of applying fertilizers, insecticides and fungicides to crops, improved methods of cultivation and irrigation, soil conservation techniques of planting, maintenance, harvesting and storage of crops (Egbule and Njoku, 2001).

Many factors have and will continue to result in changes in both agricultural communications and agricultural organizations. The importance of determining the preferences of the clientele to be served is paramount in these changing and competitive times. The organizations that work the most diligently to determine the needs and preferences of the intended audiences and most importantly direct resources to meet these expressed needs and preferences will survive and excel (Maddox et al, 2003).

The range of its application as well as its effects on various aspects of today's life and future has been changed to one of the most significant debate in the world and has drawn the attention of many countries to it. Information technology and communication enables production, variety and efficient distribution of agricultural products (IT & CE Web. 2008).

According to the present statistics, at the present time, 16 million people are engaged in the field of agriculture (Country report of the statistical center of Iran, 2007).

Farmers do not have reliable sources of information, even on the most basic, uncontroversial, technical aspects of farming (Wason, 2002). Many papers pertaining to this regard indicate that the more methods and channels are employed in the development of agriculture, the more successful it will be. However, regardless to the intricacies of the method, the efficiency of the message is, to a great extent, based on the person who assumes responsibility of managing the project. The methods of conveying a message relatively determines the behavioral change and consistency. The promoters,

especially in the third world countries, have little knowledge in the exchange of information and knowledge as well as the farmers' capabilities and experiences (Gale, 1995).

In the inception of the third millennium, shortage of food is the most crucial challenge in agriculture. The increasing population of the world demands increasing food. According to the assessments, the world's population will be 8 milliard in 2025, and more than 800 million people are already suffering from chronic hunger and about 2 milliard people are suffering from malnourishment. Increasing the use of basic natural resources as well as the need to agricultural principles for more production are demanded if one wishes to meet the food requirements of the present population.

On the other hand, the present productive systems are not permanent or long-lasting, and consequently, the crisis of the food security is one of the most human challenges at the commencement of the third millennium.

A brief review on the experiences of the other developing countries in the application of information technology in rural and agricultural development indicate that the use of information technology is almost the focus of consideration in all these countries based on their capabilities.

Chinese are actively providing efficient services for the farmers in the development of agriculture through information technology and communication and are already availing more than 100 private companies in the field of agricultural information and various subjects in the application of information technology and communication in this regard and their pertaining teams in the field of plants, irrigation, pesticide and the analysis of the soil. Therefore, many commentators consider China as the innovator of 'the agriculture based on the past 10 years information' (Drom, 2004).

Knowing is capability, and ignorance of the prices and the market status is one of the main issues of sustaining poverty, making poor farmers more dissatisfied. For instance, the producers of cacao and coffee in Africa sell their products less than one-tenth of its actual price in the world market (Matring, 2005).

There is an increasing number of media available for distance education due to technological advances, decreasing costs and increasing ease of use of technologies and the creation of new uses for existing media. Studying by distance education can be a cost effective alternative to full-time study. Distance education eliminates the costs of travel to, and residence in the vicinity of, the study institution and can take place while continuing full-time employment. Truelove (1998) stated for those working in agriculture who are required to continually upgrade their qualifications but are unable to leave their jobs to engage in full-time study, distance learning offers an alternative.

In India small computers, under the name of Simputer, Simple, Inexpensive, Multilingual computer have been designed to publicize the accessibility to network information. Such computers have been designed for illiterate people in rural environments for common use. The software is in local native language and has proved fruitful in the conveyance of information to the local illiterate farmers. In Sri Lanka, based on a common program between UNESCO and the government, radio is used as a link between people and the internet (Emadi, 2004).

Arokoyo studies in 2003 in Nigeria denoted that although video, radio and TV are still the main sources of obtaining information by Nigerian farmers, they can potentially use more advanced means, in case the structural frameworks are provided (Arokoyo, 2003).

The national policy of agriculture in Malaysia (program 1998-2010) in achieving favorable results with the challenges of agricultural and rural development is founded on the knowledge management. Such policy is employed to improve agricultural management affairs, to achieve more efficiency, prevention from repetition, better application of present materials, encouragement to use the best methods of production, improvement of providing agricultural services, as well as complete understanding and perception of needs in agricultural and rural environments (Saadan and Kamarudin, 2001).

A research has been conducted by Jenkins and his colleagues regarding the information technology used by North Californian farmers. Based on this research, it was revealed that news-sheet is the most significant channel of gathering information on agriculture. 60% of farmers read news-sheet and about 45% use the articles of the journals and the bulletins. Friends, meeting the developers

or visiting the local leaders in the farm, reading the newspapers ...etc are the other sources of obtaining information respectively (Jenkins et al, 2003).

The main purpose of this research is scrutinizing the role of information technology and communication in the publication and conveyance of them to the farmers as well as assessing the level of accessibility and the farmers' approaches to the information technology and communication regarding the appropriate and efficient use of new methods of irrigation in Kohgiloye and Boyer Ahmad Province.

## **Materials & Methods**

### **Methodology**

The present research is a descriptive design that is based on the selection and scrutiny of the selected samples in the society, their frequency, distribution of variables as well as the relationship between them.

### **Study Population**

The statistical society of this research includes farmers who are already involved in the agricultural affairs in Kohgiloye and Boyer Ahmad Province, Iran. 240 subjects have been selected based on the random sampling from 4 various cities: Kohgiloye, Sisakht, Dogonbadan and Boyer Ahmad in Kohgiloye and Boyer Ahmad Province.

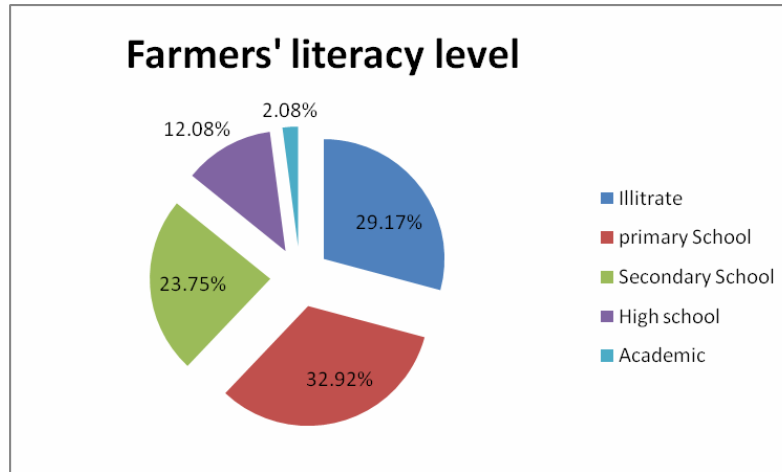
### **Statistical Analysis**

In the analysis of the inputs, different statistical methods have been applied proportional to the measuring levels of the variables and in the framework of the research purpose. In the description of the information certain descriptive terms have been employed as, frequency, percent, mean, mode, standard deviation, variance, and etc. Furthermore, statistical tests of Mann Whitney and Kruskal-Wallis have been employed for the study of variables' level of relationship with each other as well as the study of the differences between various groups. There are four independent variables in this research: age, educational status, application of new irrigation methods and participation in educational classes. Moreover, there are two dependant variables: availability and approach toward the channels and information sources (audio-visual, electronic, written and printed media, face-to-face methods, traditional means of communication, and organizational sources of conveying information) to transfer data and facts pertaining to the appropriate and efficient use of new systems of irrigation.

## **Results**

According to the findings of the research, the mean age of people studied in this study is 45.5 with standard deviation of 12.27. The youngest person was 18 years old and the oldest one 73. The most frequency of farmers' literacy level who participated in the study was belonged to the Primary School (32.92%) and the least one (2.08%) to the academic samples (more than high school diploma).



**Figure 1:** Rate of Respondents' Literacy level

Regarding the accessibility and information of the farmers about information technology and communication in understanding of new methods of irrigation, Likert measurement has been applied and is classified to various branches as low, Medium and high (low = 1, average = 2, and high = 3). The most accessibility of the farmers to information technology and communication belonged to the experts of agricultural teaching and development center with the average score of 2.83, and the least one belonged to internet with 1.21 score status. The rest successive score belonged to the radio (2.81), T.V. (2.58), brochure (2.45), poster (2.24), hand phone (1.92), video (1.71), newspaper (1.54), magazine (1.49) and rural libraries (1.35) respectively. Among the fore-cited media, radio & T.V. were more welcomed (Table 1).

**Table 1:** Distribution of subjects based on access to information resources (AIR)

Access Rank	AIR	Low		Medium		High		Average Score
		Frequency	%	Frequency	%	Frequency	%	
1	<b>Agricultural Experts</b>	12	5	17	7	211	87.9	2.83
2	<b>Radio</b>	7	3	31	13	202	84	2.81
3	<b>TV</b>	9	3.75	41	17	190	79.1	2.58
4	<b>Brochure</b>	48	20	35	14.57	157	65.41	2.45
5	<b>Poster</b>	70	29.16	42	17.5	128	53.33	2.24
6	<b>Hand Phone</b>	95	39.6	70	29.1	75	31.25	1.92
7	<b>Video</b>	105	43.75	98	40.83	37	15.41	1.71
8	<b>News paper</b>	89	37	92	38.33	59	24.6	1.54
9	<b>Magazine</b>	135	56.25	93	38.75	12	5	1.49
10	<b>Rural Library</b>	160	66.7	75	31.25	5	2	1.35
11	<b>Internet</b>	192	80	45	18.75	3	1.25	1.21

The media above are considered separately, however there are many overlaps. For example, with the Internet we see the “convergence” of a number of media that were previously considered quite separate as they involved specialized or dedicated equipment. The Internet has the capability to deliver text, audio and video (many of the strengths, weaknesses and comments for these other media apply to the Internet if these capabilities are utilized).

Regarding the attitude of the farmers about information resource of new methods of irrigation, Likert measurement has been applied and is classified to various branches as very low, low, Medium, high and very high (very low = 1, low = 2, medium = 3, high = 4, and very high = 5). The most acceptable resource for transferring information was agricultural experts (4.16) followed by TV (4.03)

and Radio (4.01) and at least acceptability was belong to internet (0.75). As study findings reveal the farmers have positive attitudes toward media's agricultural programs (TV & Radio) and the agricultural experts' speeches. The results of this research show that the farmers do not trust totally on other mass Medias and in the current situation the best option for introducing them the technical information about the new ways of modern irrigation is the Educational Department of Agriculture Organization (Table 2).

**Table 2:** Frequency Distribution of subjects based on their attitude to Information Resource (IR)

Attitude Rank	IR	Very high		high		Medium		Low		Very Low		Average Score
		F	%	F	%	F	%	F	%	F	%	
1	Agricultural Experts	79	33	140	53.75	24	10	6	2.5	2	0.83	4.16
2	TV	64	27	132	55	30	12.5	12	5	2	0.83	4.03
3	Radio	67	28	125	52	36	15	8	3.33	4	1.66	4.01
4	HandPhone	32	13.33	44	18.33	94	39.16	42	17.5	28	11.66	3.04
5	Brochure	10	4.16	29	12	143	59.58	52	21.6	6	2.54.16	2.93
6	Poster	12	5	36	15	125	52	57	23.75	10	4/16	2.92
7	Video	8	3.33	17	7	97	40.41	112	46.66	6	2.5	2.61
8	News paper	9	3.75	12	5	49	20.41	152	63.33	18	7.5	2.34
9	Magazine	3	1.25	6	2.5	18	7.5	190	79.16	23	9.58	1.97
10	Rural Library	3	1.25	4	1.66	12	5	182	75.8	39	16.25	1.95
11	Internet	-	-	-	-	-	-	12	5	157	65.41	0.75

According to the research findings, there is a meaningful relation between the age of the farmers, their level of education, governmental facilities and their participation in educational programs and their attitude toward information and communication technology.

## Discussion & Conclusion

Information technology and communication are nowadays one of the most significant criterions for the development and advancement of agriculture.

Science, knowledge and information are indispensable means for people's success in confrontation with different opportunities, as well as social, economical and technological changes. Knowledge and information should be conveyed to people as effectively as possible to prove helpful. More than 850 million people in developing countries are deprived of a wide range of knowledge and information. Unfortunately, the poor rural farmers are left detached from both traditional media and new communicative technologies that could otherwise, improve their living conditions and earnings.

To achieve any success in rural development and management completely depends on up-to-date, reliable and sufficient information that ICTs can play key role in this regard (Rama Rao, 2004).

All media available for distance education may best in certain cases, and all may be worst in certain cases, either singly or in combination with other media. There are a number of factors which should be given consideration when selecting a media for distance education in agriculture, including the learners, the circumstances of learners and educators, the subject matter and the desired teacher-student interaction pathways. These factors are highly interrelated.

Based on the research findings, the level of farmer's literacy plays an influential role in the extent of his/her use of media available. The relevant institutes and organizations should provide appropriate grounds for the development of formal and informal education to decrease the level of illiteracy in rural communities.

Sadaqath and Mariswamy (2007) believed that Radio is an electronic audio-medium for broadcasting programme to the audience. This medium is cosmopolitic in approach and is suitable for communication to millions of people widely dispersed and situated in rural areas. Considering the fact that radio & T.V. have good and noticeable educational effect on the farmers, especially on the agronomists of Kohgiluyeh and Boyer-Ahmad Province, it is recommended that Radio & T.V. planners continue producing educational programs with due consideration to the wide range of the farmers' tastes and broadcast them at appropriate time based on the request of the public.

Radio programmes cannot grow more food. However, planned radio campaigns complementing face-to-face advice and extension, with administrative and material support available can motivate, can inform, can entertain, can unify and can contribute towards desirable change (Nakabugu, 2001).

Truelove (1998) recommended that Media can be described with respect to: forms of symbolic representation (text, diagrams, pictures, photographs, voice etc.), common pathways of communication between teacher and students, how they are produced and updated, cost to produce, cost to student, mode of distribution/ delivery, equipment and skills required to use, and dependence on place and time for delivery. Using these characteristics, it is hoped that differences between media are noted.

Egbule and Njoku (2001) mentioned that there is also the problem of widespread illiteracy. The majority of the farmers cannot read and understand the information at their disposal. In addition, the high cost of newspapers, radio and television limits the use of these channels by many present and prospective farmers. Also, the editors and programme directors are more interested in producing programmes that are of high commercial value. Most often, the few agricultural programmes are not timed to suit the farmers. Consequently, most farmers are constrained to rely on third parties for agricultural information, which may often be biased (It is also suggested that producers include appealing and appropriate radio & T.V. items such as, show, contest, comic plays, and etc in their programs under the supervision of the experts in agricultural organization.

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## A Review of the Menopausal Symptoms Management with Herbal Remedies

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### Abstract

**Background:** Women are frequent users of complementary and alternative medicine (CAM) therapies for menopausal symptoms in many countries. Therapies of choice were herbal remedies, chiropractic, and meditation. Recently, dietary supplements and foods containing phytoestrogens have become increasingly popular, despite the lack of data from clinical trials.

**Purpose:** To review randomized, controlled trials of herbal remedies for menopausal symptoms in order to better inform practice and guide future research.

**Data Sources:** MEDLINE and Cochrane Library database (1980- February 2008) were searched for relevant trials that provided data on treatment of menopausal symptoms using 1 or more herbal remedies.

**Study Selection:** All English language, controlled trials and meta-analyses comparing a botanical with placebo or control for relieving menopausal symptoms.

**Data Extraction:** All eligible trials were identified, subjected to inclusion and exclusion criteria, reviewed, and abstracted into evidence tables.

**Data Synthesis:** From 3119 identified abstracts, 85 trials met inclusion criteria, including 50 trials of isoflavones, 15 trials of Black Cohosh, 8 trials of combination of botanicals and other studies were belong to the other herbs.

**Conclusion:** Although individual trials suggest benefits from certain therapies, data were insufficient to support the effectiveness of any botanicals in this review for the management of menopausal symptoms. Many of these potential therapies warrant further study in trials with rigorous scientific designs to determine benefit and safety.

**Keywords:** Herbal Remedy, Management, Menopause, Symptoms.

## Introduction

Menopause is characterized by a rapid and progressive reduction in estradiol, an endogenous form of estrogen. This brings about many changes in a woman's body some of which, like hot flushes, are discomforting but not life-threatening. Others, like loss of bone density and decline in cardiovascular function, have serious life-threatening consequences. Many of these changes can be eliminated or reduced with hormone replacement therapy (HRT). Despite its benefits, however, some women are not candidates for this treatment and many others choose not to take it (Jones, 2000).

Continuance with HRT, at best, ranges between 50 and 80%. Many women stop treatment after a few months because of side effects or fear of long-term complications (Kessel, 1998). As a result, there is growing interest among patients in natural alternatives to conventional HRT. Women throughout the world had been using plant extracts for hundreds of years to treat uterine disorders, menstrual complaints, pregnancy and childbirth, all apparently without toxic effects, although rigorous long term safety trials were rare. (Roemheld-Hamm, 2005; McKenna, 2001).

In the US and Britain, surveys show that 80% of peri and post menopausal women are current or former users of dietary supplements, and 60–70% of users cited the belief that these supplements are good for one's health. Most women report using such treatments largely because they find these alternatives to traditional medicine more congruent with their values, beliefs, and lifestyles, and they believe that use of these herbal products is natural and safe and cannot hurt them. (Albertazzi, 2002; Mahady, 2003; Kass-Annese, 2000; Goldstein, 1998).

The National Center for Complementary and Alternative Medicine had divided complementary and alternative medicine into the following 5 categories:

- 1) biological
- 2) mind–body/behavioral
- 3) energy
- 4) manipulative and body-based, and
- 5) whole medical systems.

(NCCAM, 2005). Biologically based therapies, purchased over the counter or through specialized health professionals, include botanicals, animal-derived extracts, vitamins, minerals, fatty acids, amino acids, proteins, probiotics, whole diets, and functional foods.

There are many therapies used as alternatives to HRT including plant estrogens, herbs, vitamins and minerals and unconventional hormones and steroids. Some of the CAMs most commonly used during the menopause include the following: soy and soy products; red clover (*Trifolium pratense*); black cohosh (*Cimicifuga racemosa*); dong quai (*Angelica sinensis*); chaste tree berry (*Vitex agnus-castus*), ginseng (*Panax ginseng* and other *Panax* species), evening primrose oil (*Oenothera biennis*), motherwort (*Leonurus cardiaca*), and licorice (*Glycyrrhiza glabra*)(ACOG, 2001).

## Botanicals for Menopausal Symptoms

### 1. Soy products

Derived largely from soy products, phytoestrogens are currently the most popular alternative to hormone replacement therapy (Elkind-Hirsch, 2001). They are plant-derived compounds that are structurally and functionally similar to estradiol (Knight, 1996). Isoflavones are one class of phytoestrogens. Genistein and daidzein are the two major types of isoflavones. They are found in soy,

clover, lentils, beans and chickpeas. In humans, gastrointestinal tract enzymes convert isoflavones into heterocyclic phenols that have a structural similarity to estrogen (Setchell, 1988). The beneficial effects of soy supplements in postmenopausal women have been attributed to these isoflavones.

Isoflavones appear to be selective estrogen receptor modulators with modest agonist activity at the beta estrogen receptor, at approximately one-third the potency of estradiol. They also appear to have very weak alpha estrogen receptor activity, with 0.001 the potency of estradiol (Kuiper, 1998). The relative expression of alpha and beta estrogen receptors varies between tissues in the body. Isoflavones appear to have both estrogenic and anti-estrogenic behavior (Cassidy, 1994).

## 2. Black Cohosh

Black cohosh (*Cimicifuga racemosa*) is an indigenous Eastern North American plant that has been used by Native Americans for gynecological conditions since before the arrival of European settlers to North America. Called 'squaw root' because it was used primarily for female disorders, it was first listed in the *Pharmacopoeia of the United States* in 1830 under the name 'black snakeroot.' It was the primary ingredient of Lydia Pinkham's tonic compound for 'female complaints,' which sold widely for more than 50 years in the early twentieth century (Pepping, 1999). In 1989, the German Commission E, an expert panel commissioned by the German government to address herbal products, approved black cohosh as a non-prescription medicine for the treatment of climacteric ailments. The commission recommended, however, that black cohosh be used for no longer than 6 months due to an uncertainty about its possible long-term side effects (McKenna, 2001). The treatment of menopausal signs and symptoms has been the primary therapeutic application of black cohosh. It is the main ingredient in the often-used over-the-counter menopausal preparation 'Remifemin' (Schaper Brummer, Germany, distributed by PhytoPharmica, Green Bay, WI).

The mechanism by which black cohosh may exert its effects is unclear. It was once believed that it may have estrogen-like activity, but the results of various studies have been varied. One study reports that black cohosh binds competitively to the beta estrogen receptor (Duker, 1991), but studies by Remifemin's manufacturer report that it does not perform as a true estrogen (Schaper and Brummer, 1997). The biologically active component of black cohosh is attributed to a number of triterpene glycosides. Remifemin is standardized in respect to triterpene glycoside content.

## 3. Dong Quai

Dong quai is an herb native to Eastern Asia and China. It has been used for more than 1000 years as a spice, tonic and medicine in traditional Chinese medicine. Dong quai is known as the 'female ginseng' and is currently the second best-selling herb in China (Zhu, 1987). It is indicated for dysmenorrhea, irregular menstruation and as a supportive herb for menopausal complaints (Hardy, 2000). In the West, dong quai has become popular as an herb for treating menopausal symptoms. Dong quai was one of the first alternative therapies to which potentially adverse effects were attributed, for it potentiates the effects of warfarin. Dong quai contains furocoumatins, which are coumarin-like substances that act as anticoagulants (Page and Lawrence, 1999).

## 4. Ginseng

The word 'ginseng' is derived from 'panacea,' meaning cure-all. It is said to boost immunity, energy and vigor, and has been reported to have estrogenic properties. There have been a number of studies reported by *Consumer Reports*, the *Los Angeles Times* and Consumerlab.com that have criticized the production quality of ginseng products. One study reported that only 25% of the commercially available products actually contained ginseng (Liberti and Marderosian, 1978). Large quantities of caffeine have also been found in many ginseng products (Taylor, 2001).



### **5. Evening primrose oil**

Evening primrose oil comes from the seeds of the yellow primrose, a North American wildflower. It has a long history of use by Native Americans. The seeds contain oils rich in linolenic acid and  $\gamma$ -linolenic acid, precursors of prostaglandin E. Disorders for which evening primrose oil have been tested include atopic dermatitis, rheumatoid arthritis, mastalgia, breast cysts, premenstrual syndrome and menopausal hot flashes (Kleijnen, 1994).

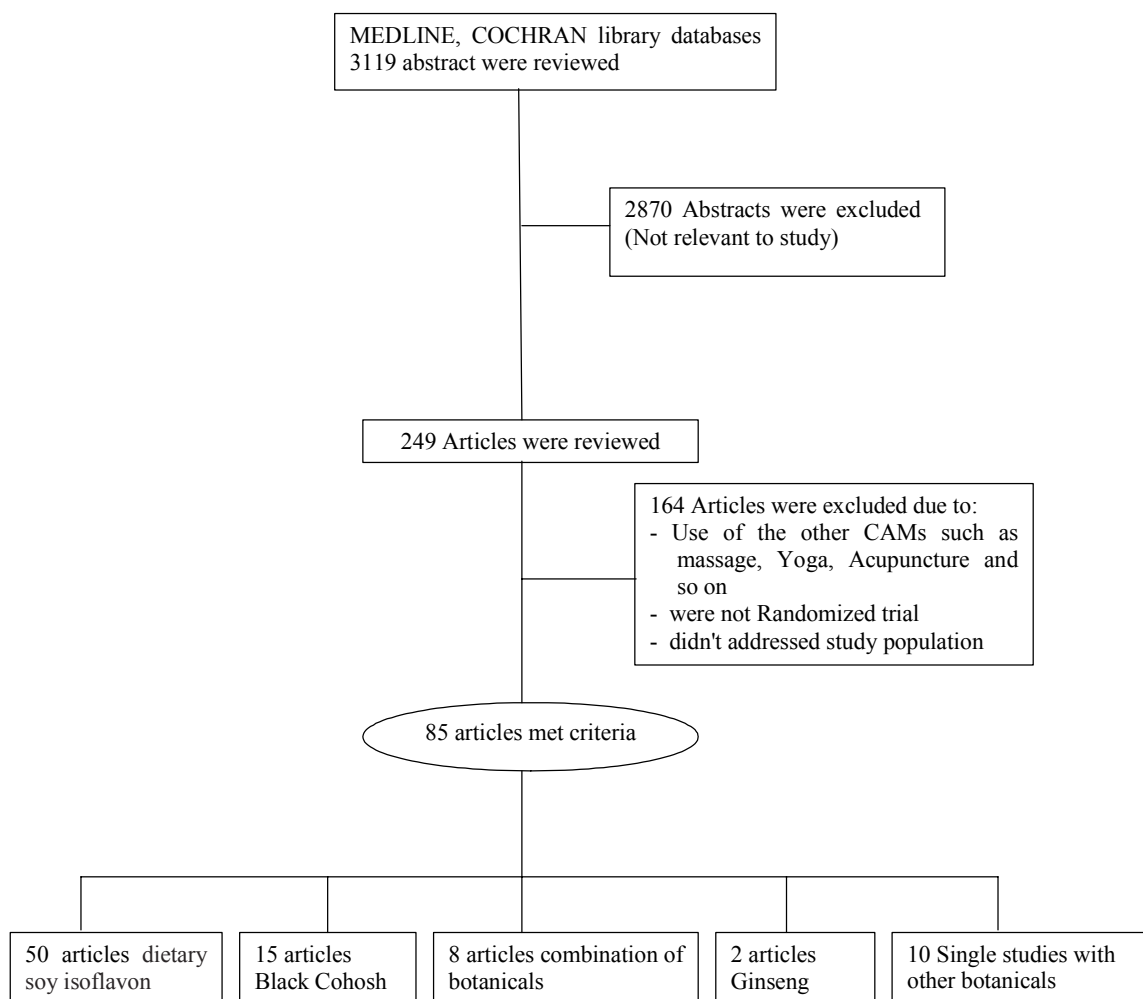
There is a dichotomy between the vast amount of alternative medicine lay literature that women may be reading and the lack of clinical evidence available for physicians on these same topics. Randomized, placebo-controlled clinical trials are just beginning to be performed on just a few of the major, non-traditional therapies, with very little clinical information available on the vast majority of alternative dietary supplements. The purpose of this article is review the scientific literature related to herbal product for treatment of menopause-related symptoms.

### **Methodology**

The MEDLINE, COCHRANE databases from January 1, 1980 through February 2008 were searched using terms related to botanical and herbal supplements and menopausal symptoms. Databases were searched under the terms hot flash/flush, menopause, and climacteric, combined with alternative medicine, herbal medicine, traditional medicine, Traditional Chinese Medicine (TCM), phytoestrogens, isoflavones, soy, black cohosh, dong quai, ginseng, evening primrose oil, kava. Vitex agnus, red clover and black cohosh. The reference lists of published articles and abstracts were searched for relevant articles that were not found in the database searches. Lay literature concerning alternative medicine use was obtained through Internet searches.

Studies were eligible for inclusion if study subjects were peri- or postmenopausal women and were related to menopausal symptoms or postmenopausal symptoms related to aging such as bone density, lipids, cognition, or psychological issues including sleep, anxiety, and memory problems. Randomized, placebo-controlled trials were used when available, although open trials and comparison group studies were also used to gain as much information as possible. Data were abstracted into evidence tables and summarized descriptively (Appendix, Table 1); statistical analysis was not performing, because of the heterogeneity of trials. Outcomes included hot flash frequency and severity, sleep disturbance, vaginal dryness, vaginal bleeding, urinary frequency or incontinence, quality-of-life changes, depression, anxiety, sexual dysfunction, and cognitive function, most frequently measured by the Kupperman Index (Li, 2004) and the Greene Climacteric Scale (Sierra, 2005). This review only considers evidence from studies performed from 1980 to 2008.

**Figure 1.** Search and Selection of Trials. We searched MEDLINE and the Cochrane Library database (from January 1, 1980 through February 2008)



## Result and Discussion

From 3119 identified abstracts, 249 studies which met the inclusion criteria were reviewed. A total of 85 articles met predetermined criteria for inclusion (Figure 1). A majority of eligible studies (50/85) were belong to dietary soy isoflavones (e.g., flour, beverage, powder forms; supplement and extract forms of soy isoflavones; red clover phytoestrogens; and other phytoestrogens). The next largest studies (15/85) was evaluation of Black Cohosh effect's on menopausal symptoms followed by combination of botanicals (8 studies), Ginseng (2 studies) and a single study with other botanicals (Wild Yam, Kava, Evening Primrose Oil, Guar Gum, Dong Quai, Pueraria, Pollen extract, Vitex agnus castus, St. John's wort, Hop extract and Ginkgo Biloba).

In the soy-based study, there were no differences between groups in the number of hot flashes, but some improvement in both groups when compared with baseline levels. The largest study again showed no differences between groups. The remaining trials showed either no differences between soy and placebo or mixed results. In the red clover studies, there were no differences shown between groups when compared with placebo. Results from the other biologically-based studies, looking at black cohosh, kava, guar gum, combination of herbs and others, showed improvements in menopausal complaints only among the black cohosh treatment group (Hernandez Monuz et al, 2003). However, another study, using a different formulation of black cohosh, did not show any improvements when compared with placebo (Lehmann- Willenbrock et al, 1988).

The largest trial enrolled 384 women randomized to either 200 mg/d of a standardized Ginseng extract or placebo for 16 weeks (Wiklund, et al, 1999). Improvement was observed in the treatment group and placebo compared to baseline for a variety of menopausal complaints as measured by the Women Health Questionnaire and included mood, sleep disorders, sweating, and vasomotor symptoms.

The longest trial of women enrolled 241 women for 96 weeks and compared 2 doses of isoflavones in a soy drink (58mg/d vs 42 mg/d) with placebo (Burke, et al, 2003). Hot flush severity and frequency improved within groups compared to baseline, yet no between group differences in frequency or severity of hot flashes or night sweats were observed. The most number of studies have been done in United States with 17 trials followed by Italy (13 trials), Germany (12 trials), Australia (9 trials), and England (5 trials).

The explosion of public interest in alternative and complementary therapies for the treatment of menopausal symptoms will continue to grow and expand in the years ahead. The medical literature examining these therapies needs to grow as well for there is too little clinical evidence currently available. As the number of studies increases, better evidence will become available.

Individual trials suggest a benefit for certain therapies, yet data are insufficient to recommend any complementary and alternative therapy as effective for the management of menopausal symptoms. Of the 50 trials of phytoestrogens, only 6 showed a benefit. This is consistent with a recent systematic review of phytoestrogens as treatment for hot flashes that included 25 trials and 2348 participants (Krebs, et al, 2004).

On the other hand, reaching a definitive conclusion on the efficacy of soy isoflavone extracts is difficult when the products vary so markedly in composition. Additionally, comparison between trials is complicated by variations in dosing and in use of products with different extraction systems. A total of 10 reports in the literature on botanicals used to treat menopausal symptoms reveal equivocal findings, with some studies reporting efficacy for specific products and others reaching opposite conclusions. Differences in findings across studies of the same botanical may be a function of less than optimal trial design, variation in products used, duration of treatment, inadequate dosing, and/or use of small or noncomparable population samples. When comparing products that differ in extraction technique, delivery system, ratio of ingredients, and dose, the question of equivalency must be considered. It also makes the "pooling" of trial data problematic. Many of the trials failed to provide adequate definitions for "postmenopausal" or "menopausal," which also may contribute to varied findings. Some treatments may be more effective in the perimenopausal woman than in the postmenopausal woman, or vice versa.

Not all herbs and dietary supplements are risk-free. Many herbs are being promoted for nontraditional uses. Newly formulated combination herbal products should be avoided until research data are available; currently, no safety or efficacy data on such combinations have been published. Although plant foods are presumed to be safe, the isolated, often concentrated components have not been tested for long-term use. Furthermore, the number of herbal products in the World marketplace is growing rapidly, and recommended dosages are increasing without research supporting the need for these larger doses. Health care providers and consumers should be aware that despite the potential usefulness of many CAM therapies, scientific research is limited. The popularity of CAM therapies and their therapeutic potential necessitate definitive safety and efficacy studies. It is imperative that future research be directed toward safety and efficacy of the CAM therapies used by women to treat their menopausal symptoms.

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## Appendix

**Table 1:** Trial of herbal therapy in menopause

No	Authors, Year (References)	No of Participants (age)	Intervention & Dosage	Duration of Intervention (week)	Design	Outcomes	Findings	Country
1	Cheri, et al, 2002 (34)	123	Soy Beverage 90mg/d vs Placebo	12	RCT Double Blind	Frequency and Intensity of HF	Improved HF frequency & intensity in both groups	Canada
2	Albertazzi, et al 1998 (41)	104	Soy Powder 60g/d vs Placebo	12	RCT Double Blind	KI, HF	Improved HF frequency in both groups but no changes in KI	Italy
3	Albertazzi, et al 1999 (36)	104	Isoflavonoid 76 mg/d vs Placebo	12	RCT Double Blind	KI, HF	Improved HF frequency in treatment 44%, placebo 31%, no change in KI	Italy
4	Bruke, et al 2003	241 (45-55y)	Soy drink IF 42mg/d or Soy drink IF 58mg/d vs placebo	96	RCT Double Blind	HF, Night sweats	Improved HF frequency & intensity in all groups	United States
5	Han, et al, 2002 (32)	80	Soy IF (soy protein 50mg/d & IF 33mg/d) vs placebo	20	RCT	HF, Insomnia, Mood, KI	Improved HF, Insomnia, Mood and KI in soy group	Brazil
6	Knight, et al, 1998 (31)	24	Soy IF powder beverage 60g/d vs placebo	12	RCT Double Blind	HF, General Symptoms Score	Improved HF frequency in both groups	Australia
7	Murkies, et al, 1995	58	Soy Flour 45g/d vs placebo	14	RCT	HF, Mood, Vaginal Dryness, Urinary & Sexual Symptoms, MI	Improved HF & General Scores in both groups	Australia
8	ST Germian, et al 2001 (36)	69 (42-62)	Soy protein (IF 80mg/d) vs Placebo	24	RCT Double Blind	HF	Improved HF in all groups	United States
9	Balk, et al, 2002	27	Soy and Corn Flour (IF) 100mg/d vs Placebo	24	RCT	HF, MSQ	Improved HFs, Night Sweats, Vag Dryness in Placebo group	United States
10	Dalais, et al. 1998	52	Soy Diet (high in IF) or Linseed diet (high in IF)	12+ 12	Cross over	HF	Improved rate of HF with Linseed diet 41% or Placebo 51% but not in Soy diet	Australia
11	Washburn, et al, 1999	51	Soy protein 20g/d	6	RCT	HF, hyperestrogenic symptoms Score (HESS), night sweat, Sleep Disturbance	Improved severity of HF and HESS in soy group No change in Menopausal Symptoms	United States England
12	Duffy, et al, 2003, (57)	36 (50-65)	Soy IF supplement 60mg/d	12	RCT	Menopausal Symptoms	Improved HF in Soy (61%) and placebo 21%	
13	Faure, et al, 2002	75	Soy If extract (genistein & diadzein 70mg/d)	16	RCT Double Blind	HF & Menopausal Symptoms	Improved cognitive test in both groups	France

**Table 1:** Trial of herbal therapy in menopause (cont.)

No	Authors, Year (References)	No of Participants (age)	Intervention & Dosage	Duration of Intervention (week)	Design	Outcomes	Findings	Country
14	Kritz- Silverstein, 2003 (31)	56	Soy Extract Supplement (IF, 100mg/d)	24	RCT Double Blind	Cognitive Test	Improved KI in both groups,	United States
15	Nikander, et al, 2003	62	Phytoestrogen Tab. 228/d	32	Cross over trial	KI, HF	Improved HF in placebo	Finland
16	Penotti, et al, 2003	62	Soy Tab.(IF 36mg/d & Saponin 48mg/d	24	RCT Double Blind Cross over	HF	Improved HF in both groups	Italy
17	Quella, et al, 2000 (38)	177	Soy IF 50 mg/d mg/d vs placebo	12	RCT Double Blind	HF	Improved HF in Soy group	United States
18	Upmalls, et al, 2000, (39)	177	Soy IF extract 50 Mg/d	12	RCT	HF	Improved HF in Soy group	United States
19	Lucks, 2003	52	Vitex agnus castus oil: 2.5 ml dermally	12	Survey of volunteers, no comparison group	Menopausal Symptoms & HF	Improved HF improvement in symptoms, emotional problems and HF	United States
20	Russo, et al, 2003 (18)	50 (48- 54)	Soy based IF 80 mg/d + Black Cohosh 30mg/d	12	RCT Double Blind	HF	Improved HF in soy group	Italy
21	Scambia, et al, 2000	39	Soy extract 400mg/d+ IF 50mg/d followed by CEE .625mg/d for 1 week vs placebo + CEE	12	RCT	HF, GCS	Improved HF with CEE in both group	Italy
22	Tice, et al 2003	252	Red clover IF tab. 82mg/d or 57mg/d vs placebo	12	RCT Double Blind	HF, GCS	Improved GCS and HF in all groups	United States
23	Atkinson, et al, 2004	205	Red clover IF tab. 40mg/d	52	Cross over	Menopausal Symptoms Score GCS, HF	Improved Menopausal symptom and HF in both groups	England
24	Baber, et al, 1999	51	Red clover IF tab. 40mg/d	28	RCT	HF	Improved GCS and HF in both groups	Australia
25	Jeri, et al, 2002	30	Red clover IF tab. 40mg/d vs placebo	16	RCT	HF	Improved HF frequency and severity in treatment group	Peru
26	Van de Weijer, et al, 2002	30	Red clover IF tab. 80mg/d vs placebo Red clover IF tab.	12	RCT	HF, SGS	Improved HF in if group, no changes in GCS	Netherlands
27	Knight, et al, 1999	37	40mg/d or 160mg/d vs placebo	12	RCT	HF, SGS	Improved HF in IF group, no changes in GCS	Australia
28	Crisafulli, et al 2004	90	Genistein 54mg/d vs placebo	52	RCT Double Blind	HF, Estrogen level	Improved Hf 22% at 6 months & 24% at 12 months & improved estrogen in treatment	Italy

**Table 1:** Trial of herbal therapy in menopause (cont.)

No	Authors, Year (References)	No of Participants (age)	Intervention & Dosage	Duration of Intervention (week)	Design	Outcomes	Findings	Country
29	Sammartino, et al, 2003	70	Genistein 36mg/d vs placebo	52	RCT Double Blind	KI	Improved KI in Treatment	Italy
30	Secerto, et al, 2004	262	Isoflavone 80mg/d	12	RCT Double Blind	GCS	Improved GCS in both groups	Italy
31	Brzezinski, et al 1997 (33)	145	Phytoestrogen rich diet (soy 182mg, Lignana 4mg, Genistein 255mg/d)	12	RCT Double Blind	HF, Vag, dryness, MSQ score	Improved MSQ score in both groups	Israel
32	Carranza-Lira, et al, 2001	30	Phytoestrogen Cream 4mg/d	4	RCT	KI	Improved KI in both groups	Mexico
33	Komesaroff, et al 2001	50	Wild Yam Cream I teaspoonful twice daily applied to arms, legs or abdomen vs placebo	12	Cross over	HF, Mood, Libido, Breast tenderness and energy level	Improved HF & energy level in both groups,	Australia
34	Jacobson, et al, 2001 (41)	85	Black Cohosh 1 tab twice daily vs placebo	9	RCT Double Blind	HF, Night Sweat, Irritability, Nervousness, Depression HF, MRS	Improved Mood with Wild Yam cream	United States
35	Osmar, et al, 2005 (44)	304	Black cohosh 2.5 mg/d of Isopropanolic	12	RCT Double Blind	HF, MRS	Improved Sleep, Irritability, Nervousness, Depression, Night Sweating in both groups	Germany
36	Wutke, et al 2005	62	extract vs placebo Black cohosh 40 mg/d or CEE .625	12	RCT Double Blind	HF	Improved HF & MRS in both groups	Germany
37	Hernandez Monuz, et al, 2003 (17)	136	mg/d vs placebo Black Cohosh 1 Tab Twice/daily	9	RCT Double Blind	GCS, Anxiety,	Improved HF In B.C group	Venezuela
38	Cagnacci, et al 2001 (30)	80	Kava 100mg/d or 200mg/d+ 1g Ca vs	12	RCT Double Blind	Depression Score HF	Improved Depression, GCS, & Anxiety Score in both treatment	Italy
39	Chenoy, et al, 1994 (42)	56	Ca 1g/d Evening Primrose Oil 2g/d+ natural Vit. E 10mg/d vs placebo	26	RCT Double Blind		Improved HF in both groups	England
40	Hudson, et al, 1998	13	Combination of botanicals cap 500mg 3 times daily vs placebo	12	Open Trial	HF	Improved HF frequency & severity in both groups	Portland
41	Makkonen, et al 1993	30	Guar Gum 5mg 3 times daily vs placebo	26	RCT	KI	Improved KI score in both groups	Finland.
42	Hirata, er al, 1997 (38)	71	Dong Quai 4.5g/d vs placebo	24	RCT Double Blind	KI	Improved KI score in both groups	United States
43	Wiklund, et al 1999 (39)	384	Standardized Ginseng extract 200mg/d vs placebo	16	RCT Double Blind	KI	Improved KI in both groups	United States
44	Woo, et al, 2003 (47)	136	Puerira Lobata and IF 100mg/d or CEE .625 or MPA 5mg/d vs placebo	12	RCT Double Blind	Menopausal Symptoms, QOL, Lipid & Hormone profile	No differences in QOL, Well-being & other parameters	Hong Kong

**Table 1:** Trial of herbal therapy in menopause (cont.)

No	Authors, Year (References)	No of Participants (age)	Intervention & Dosage	Duration of Intervention (week)	Design	Outcomes	Findings	Country
45	Chen, et al, 2002 (17)	62	JWSYS (combination of 13 Chinese Herbs) or CEE or MPA	16	RCT Double Blind	GCS	Improved GCS in all groups	Taiwan
46	Davis, et al, 2001 (40)	78	ombination of 12 Chinese Herbs vs placebo	12	RCT Double Blind	MSQOL, Vasomotor Symptoms (SRSD)	Improved MSQOL & SRSD in both groups	Australia
47	Hartley, et al 2003 (60)	34	Gensing, Ginkgo Tab 120mg/d vs placebo	1	RCT	GCS	Improved GCS in both groups	England
48	Mac Gergor, et al, 2005	72	Soy extract 235mg+ IF 17.5mg twice/d	12	RCT Double Blind	HF, QOL, MSS	No differences in outcomes	Scotland
49	Winther, et al 2005 (16)	64	Pollen extract (Female tab) vs placebo	12	RCT Double Blind	MRS, HF, QOL	Improved HF, QOL & other menopausal symptoms in treatment group	Sweden
50	Hale, et al, 2001	30 (45-50)	Red Clover IF extract 50mg/d vs placebo	12	RCT Double Blind	Endometrial Biopsy, Bone Marker, Lipid profile	No changes in Endometrial Biopsy, Bone Marker, Lipid profile	United States
51	Wamecke, et al 1985 (11)	60 (45-60)	Black Cohosh 40 drops twice daily vs CEE .25mg/d or Diazepam 2mg/d	12	Randomized open treatment controlled Trial	KI, HAM-A, SDS, CGI and VMI	Improved KI, HAM-A, SDS, CGI and VMI in all therapies	Germany
52	Stoll, et al, 1987 (12)	80 (46-58)	Remifemine tab 8mg/d vs placebo	12	RCT Double Blind	KI, HF, HAM-A, VMI	Sig. Improved in KI, HF, HAM-A, VMI in treatment groups	Germany
53	Lehmann-Willenbrock, et al, 1988 (13)	60 (more than 40y)	Remifemine tab (B,C) 8mg/d vs Estrol or CEE or E/p	24	RCT Double Blind	KI, LH, FSH level	Improved KI in all groups, no differences among groups	Germany
54	Baired, et al 1995, (45)	97 (45- 65)	Soy Diet 165mg/d IF vs usual Diet	4	RCT	VMI, LH, FSH, SHBG	No Sig. changes in outcomes	United States
55	Newton, et al 2006 (40)	351 (45- 55)	M.B+ B.C 200 mg/d or M.B + soy diet or CEE with or without Progesterone	52	RCT Double Blind	Vasomotor Symptoms, Wiklund Vasomotor Symptoms subscale Score	Improved V.S & WVSS only in hormone groups	United States
56	Dodin, Et al 2005	199 (45- 65)	Flaxseed 40g/d vs placebo	52	RCT Double Blind	Menopausal Symptoms, BMD, Lipid Profile	No sig. improvement in outcomes was detect	Canada
57	Haghighian, et al, 2005, (37)	15 (45- 64)	Soy protein 35g/d	12	Open treatment	Weight, BMI, Bone Markers	Improved urinary parameters & alkaline phosphatase but other indexes were not significant	Iran
58	Smolinski, et al 2005, (9)	8 (42- 63)	Herbal Combination (15 herbs)	12	Nonrandomized nonplacebo- controlled study	KI, HF, QOL	Improved KI, HF and QOL	United States

**Table 1:** Trial of herbal therapy in menopause (cont.)

No	Authors, Year (References)	No of Participants (age)	Intervention & Dosage	Duration of Intervention (week)	Design	Outcomes	Findings	Country
59	Liske, et al 1998	152 (40- 60)	B.C 40mg/d or 127mg/d vs placebo	24	RCT Double Blind	KI, Hormone profile, Vag Cytology	Improved KI in treatment groups but no changes in hormonal level or Vag. Cytology	Germany
60	Duker, et al, 1991	110 (52y)	B.C extract tab 8mg/d vs placebo	8	RCT Double Blind	Hormonal profile	Improved LH & estrogen level but no changes in FSH was observed	Germany
61	Petho, 1987	50 (46- 56)	B.C tab 48-140 mg/d vs placebo	24	RCT Double Blind	Mean menopausal Index	Sig, improvement in MMI	France
62	Warneck, et al 1985	60 (54y)	B.C 48-140 mg/d vs CEE or Diazepam	12	RCT Double Blind	MI, Vag. Cytology, HAM-A Scale, Depressio	Improved in Vag. Cytology & MI, in all groups	Germany
63	Vorberg, 1984	50	B.C Drops 48- 140mg/d vs placebo	12	RCT Double Blind	Psychological symptoms, KI, Mood	Significant Improvement in Psychological symptoms, KI, & Mood	Germany
64	Daiber, et al, 1983	36 (45- 62)	B.C Drops 48- 140mg/d vs placebo	12	RCT	KI, CGS	Sig. Improved KI & CGS in treatment groups	Germany
65	Stolze, 1982	629 (51y)	B.C Drops 48- 140mg/d vs placebo	6- 8	Open Study	Menopausal Symptoms	Sig. improvement in neurovegetative complaints and Psychological disorder in treatment groups	Germany
66	Heyerick, et al, 2006 (42)	67	100- 250mg hop extract vs placebo Red Clover extract	12	Prospective RCT	KI & Menopause Symptoms	Improved KI & HF in treatment groups	Belgium
67	Imhof, et al, 2006 (42)	109 (more than 40y)	80mg IF/d vs placebo	24	Cross over	Plasma Testosterone level & Endometrial thickness	Sig, increase Testosterone & decrease Endometrial thickness	Belgium
68	Ingels, et al, 2003	80 (45- 55)	Soy Isoflavonoid 100mg/d vs placebo	16	RCT	KI, Lipid profile, BMI, Hormone profile	Improved in KI in treatment group	Australia
69	Kwee, et al, 2007 (12)	31 (45- 65)	Chinese Herbal Medicine vs HRT or Placebo	12	RCT	QOL, BMI, HF, Night Sweat	Improved HF 29% in CHM, & 50% in HRT	Netherlands
70	Secerto, et al, 2004 (33)	232	IF 80mg/d or IF +Melatonin 3mg/d or Melatonin alone vs Placebo	12	RCT Double Blind	GCS	Treatments didn't show advantages for relief of menopausal symptoms over placebo	Italy
71	JOU, et al 2005 (3)	48	35- 70 mg IF supplement vs placebo	6	RCT	GCS, Lipid profile	Improved GCS in all groups but no change in Lipid profile	Taiwan
72	Haines, et al, 2007	Not Reported	CHM 1.5 or 3 or 6mg/d	16	RCT Double Blind	GCS, HF, MENQOL	Improved HF, Night Sweat, GCS in all doses but medium dose (3g/d) was the most effective	Hong Kong

**Table 1:** Trial of herbal therapy in menopause (cont.)

No	Authors, Year (References)	No of Participants (age)	Intervention & Dosage	Duration of Intervention (week)	Design	Outcomes	Findings	Country
73	Hartly, et al, 2003 (57)	34	Gingko Biloba 120mg/d	1	RCT	Cognitive Test, Mood, Menopausal Symptoms	Improved in Cognitive Test, but no change in Menopausal Symptoms	England
74	Sammartino, et al, 2006 (30)	80	Combination of Botanicals vs Calcium	12	RCT	KI	Improved KI in treatment	Italy
75	Manonai, et al, 2006	36 (52-5y)	Soy protein 25g, IF 50mg/d vs placebo	12	Randomized over	Vag Health Index, Vag PH and vag. Cytology	No changes in outcomes	Italy
76	Bicca, et al, 2004	75 (42- 61)	Standardized Soy extract 33mg/d vs placebo	25	Parallel groups	HF, Night Sweat, Vasomotor Symptoms, Vag PH	Improved HF, Night Sweat, Vasomotor Symptoms, Vag PH in treatment Improvement in HF in placebo more than treatment	Thailand Brazil
77	Campagnoli, et al, 2005	29 (45- 58)	Standardized Soy extract 400mg/d vs placebo	12+ 12	Cross over without Washout period	HF		
78	Hidalgo, et al, 2005	60 (more than 40y)	Red Clover extract vs Placebo	12+1+12	Cross over	KI, HF, Night Sweat Vag. Cytology	No changes in symptoms compare to placebo	Italy
79	Kaari, et al, 2006	68	Soy extract 300mg/d or CEE vs placebo	12	Parallel groups	KI, HF, endometrial proliferation	Improvement in symptomatology but not sig. changes in soy.	Brazil
80	Khaodhiar, et al 2008	166 (38- 60)	Extract of IF 40mg/d & Soy extract 60mg/d vs placebo	12	Parallel groups	HF	Improvement in HF in treatment But not sig.	United State
81	Kotsopoulos, et al 2000	73 (50- 75)	IF 118mg/d vs placebo	16	Parallel groups	Menopause Symptoms	No sig. improvement in MS compare to placebo	Australia
82	Lewis, et al 2006	87 (45- 60y)	Flaxseed 50mg/d or soy 42mg/d vs placebo	4	Parallel groups	Menopause Symptoms & HF	No sig. changes in menopausal symptoms & HF	Canada
83	Tode et al, 1999	12	Korean red ginseng: 6 g daily	12	Non-placebo controlled trial	Menopause Symptoms	Improved fatigue, insomnia and depression.	Japan
84	Grube et al, 1999	111	St. John's wort: 900 mg daily Standardized Soy	24	Non-placebo controlled trial	Menopause Symptoms	Significant improvement in psychological and psychosomatic symptoms of menopause.	Germany
85	Hanachi et al, 2007	37	Soy milk or soymilk +exercise vs placebo	12	Parallel groups	KI, TALP activity & TAS	Improvement in sexual well-being, TAS level and TALP activity in treatment groups	Iran

**Abbreviations:** RCT\_ Randomized clinical Trial; MI\_ Maturation Index; MSQ\_ Menopause Symptoms Questionnaire- HESS\_ Hyperestrogenic Symptoms Score; GCS\_ Green Climacteric Score; CGI\_ Clinical Global Impression Scale; HAM-A\_ Hamilton Anxiety Scale; HDL\_ high-density lipoprotein; LH\_ luteinizing hormone; FSH\_ follicle-stimulating hormone; SHBG\_ sex hormone-binding globulin; VAS\_ visual analogue scale; WHQ\_ Women's Health Questionnaire; BC, black cohosh; CEE, conjugated equine estrogen; GCS, Green Climacteric Scale; HF, hot flash or hot flush; IF, isoflavones; KI, Kupperman Index; MSQ, Menopause Symptoms Questionnaire; NBGD, no between-group differences; NR, not reported; SRSD, self-reported symptoms diary; TAS, Total alkaline phosphatase.

## **A Practical Case Study of Scrubbing Systems for Inert Gas Supply**

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### **Abstract**

Seawater scrubbing is a vital system for the safety of explosive products in maritime transport. The correct performance of this system depends to a great extent on the correct design of the scrubber and the fluegas-seawater flow rate ratio. This is due to the fact that it is here where the seawater removes sulphur dioxide and particles from the gas phase and furthermore produces cooling. It is important to emphasize that an insufficient removal of sulphur dioxide together with water mist in the scrubbed gas causes great amounts of corrosion regimes in the structure of tanks.

We have developed a laboratory plant where fluegas is simulated as an air-sulphur dioxide mixture and seawater is pumped directly from the sea. The scrubber is a counterflow packed tower. Gas and seawater flow rates, sulphur dioxide concentration and packing were changed to study different performance conditions.

The key parameters from experimental tests were compared with those from theoretical models. Results showed that problems in real systems must be related with a great divergence between design and performance and that these results can contribute to setting up the correct guidelines for an efficient sulphur dioxide removal and adequate protection of the structure of tanks.

**Keywords:** Performance, Seawater, inert gas, packed tower, mass transfer.

### **1. Introduction**

The creation of an inert environment inside the tanks of crude carriers is an efficient method for avoiding explosions. In most cases, especially when flow large rates of inert gas are required, combustion gases from main steam boilers are useful, as they have a low oxygen concentration. However, the fluegas must be cooled and washed before being useful for these purposes. This pre-treatment takes place in a seawater scrubber.

Coal and fuel oil used onboard for combustion processes have in their composition mineral sulphur, which is converted mainly into sulphur dioxide, reason why seawater not only promotes cooling and removal of particles from fluegas but has a high absorption capacity of sulphur dioxide by means of its chemical characteristics.



The chemical qualities of seawater also cause the removal of sulphur dioxide in the scrubbing. In this sense, several coastal power plants take advantage of these qualities for fluegas desulphurisation with high levels of efficiency and low process cost.

Seawater scrubbing has demonstrated its efficiency in the prevention of explosion risks onboard, however it is widely recognized that cargo tanks suffer substantial corrosion damages, mainly in the upper side free of cargo. However, inert gas has a low oxygen concentration and so corrosion should decrease to the same extent. These problems can only be related to a lack of sulphur dioxide removal in the scrubber together with the presence of moisture in the fluegas or cargo. A bad design or performance of the scrubber may be the source of corrosion damage.

The analysis of mass transfer parameters in the fluegas-seawater system is essential in order to establish the criteria for scrubber design. There are many theoretical models in the bibliography for predicting these parameters and determining the dimensions and characteristics of the absorption tower. Starting from experimental data, the accuracy of these models was tested in order to study their influence in the corrosion damage previously mentioned.

### 1.1. Fluegas-seawater system

The removal of the sulphur dioxide in the scrubber takes place through a mass transfer process by means of absorption in molecular form until reaching equilibrium according to the Henry's law constant of the system. The process begins with a physical absorption based on a molecular diffusion as a result of a gradient of concentration between gas and liquid phase. Nevertheless, seawater presents dissolved bicarbonates, carbonates and sulphates that react with protons from the ionised sulphur dioxide, increasing the absorption by chemical mechanisms. These are the reactions related with the species of S(IV):



With relation to bicarbonate and sulphate:



As we can see, the removal of the sulphur dioxide is a combined absorption process both physical and chemical, where the reactions can be considered instantaneous [1] and so seawater has excellent qualities as an absorber of sulphur dioxide [2]. Besides it is important to highlight that the final effluent is innocuous as long as aeration and dilution with new seawater are maintained.

It is possible to predict the effluent characteristics by means a chemical model [3, 4] based on the above mentioned reactions; however, this model does not allow us to establish the dimensions and flow rates for an efficient performance of the scrubber.

### 1.2. Mass transfer parameters

It is necessary bear in mind the resistance to diffusion in the liquid and gas phase in order to quantify the sulphur dioxide transference. The available theoretical models make it possible to obtain the mass transfer coefficients for every performance condition and internal geometry of the scrubber. With coefficients obtained from these models and available experimental data, a basic design

$$N_{og} = \int_{y_2}^{y_1} \frac{dy}{y - y^*} \quad (\text{eq. 3})$$

parameter defined as the overall number of transfer units in gas phase,  $N_{og}$  [5], can be calculated:

Where  $y - y^*$  is the drive force of the mass transfer considering the equilibrium concentration in the inter-phase liquid-gas, while  $y_1$  and  $y_2$  are the mol fraction of sulphur dioxide in gas phase before and after scrubbing.

The integral can be simplified by means of the logarithmic mean concept where the inlet and outlet molar relations between sulphur dioxide and gas are taken into account:

$$N_{og} = \int_{y_2}^{y_1} \frac{dy}{y - y^*} \approx \frac{Y_1 - Y_2}{\ln \frac{Y_1}{Y_2}} \quad (\text{eq. 4})$$

The streams in seawater scrubbing can be considered diluted and therefore  $y \approx Y$

According to Whitman's two-film model [6], and equilibrium taking into account concentrations in the inter-phase, a mass balance leads to relate the scrubber dimensions with  $N_{og}$ :

$$N_{og} = \frac{K_g a P Z}{G_g} \quad (\text{eq. 5})$$

The gas side height of an overall transfer unit is the last single parameter related with the transfer unit concept and is defined as the relation between  $Z$  and  $N_{og}$ :

$$H_{og} = \frac{G_g}{P K_g a} \quad (\text{eq. 6})$$

Nevertheless, the prediction of mass transfer efficiency in absorption systems containing random packings involves considerable difficulties because of the complexity of the two-phase flow in such packings. Besides, the available models from the literature are designed for solving any combination of phases and internal structure of the scrubber.

The prediction of mass transfer must take the fluid dynamic behaviour of the column into account. There is a strong dependence on hydraulics of the effective interfacial area,  $a$ , which is related with two key parameters reflected in most of the theoretical models, the pressure drop and the liquid holdup.

Since in the absorption of sulphur dioxide by seawater the main resistance is found in the gas side, the models developed by Dschabagin et al. (1965), Billet and Shultes (1993) and Wagner et al (1997) [7-9], are suitable generalized methods for predicting the mass transfer performance of larger scale packed columns. Dschabagin et al.[7] developed a model to provide volumetric mass transfer coefficients  $\beta g a$ , without considering the specific interfacial area. Billet and Shultes [8] presented a model including a relationship between specific interfacial area and the total surface area per unit of packed volume. Wagner et al. [9], using the less common Higbie's penetration theory (1935) [10], developed equations for the liquid and gas side mass transfer coefficients. They included a pressure drop model for determining the specific interfacial area because, as mentioned earlier, as well as the packing characteristics, this is closely related to the hydrodynamics in the scrubber. A summary of the correlations is given in Table 1.

**Table 1:** Summary of equations for gas and liquid side mass transfer coefficients.

Dschabagin <i>et al.</i> (1965) [7]	$\beta_g a = 5.18 \times 10^4 F_g^{0.67} u_l^{0.46} D_g^{2/3}$ $\beta_l a = 2.17 \times 10^4 u_l^{5/6} D_g^{1/2}$
Billet and Shultes (1993) [8]	$\beta_g a = C_g \frac{1}{(\varepsilon - h)^{1/2}} \frac{a_p^{3/2}}{l_\tau^{1/2}} D_g \left( \frac{u_g}{a_p v_g} \right)^{3/4} \left( \frac{v_g}{D_g} \right)^{1/3} \left( \frac{a}{a_p} \right)$ $\beta_l a = C_l \left( \frac{g}{v_l} \right)^{1/6} \left( \frac{D_l}{l_\tau} \right)^{1/2} a_p^{2/3} u_l^{1/3} \left( \frac{a}{a_p} \right)$
Wagner <i>et al.</i> (1997) [9]	$\beta_g a = \left( \frac{4D_g u_g^3 a^2}{\pi(\varepsilon - h)l_\tau} \right)^{0.5} G_s^{-1}$ $\beta_l a = \left( \frac{4D_l u_l^3 a^2}{\pi h l_\tau} \right)^{0.5} L_s^{-1}$

## 2. Materials and methods

Fluegas was simulated by adding SO<sub>2</sub> to air flow and its concentration and the flow rate of the mixture were varied, as was the flow rate of seawater which was pumped directly from the sea. Experimental values of  $N_{og}$ ,  $H_{og}$  y  $K_g a$  for the system fluegas-seawater have been obtained using a 200x25 cm cylindrical stainless steel scrubber packed to a height of 92 cm with 19 mm Intalox® ceramic saddles. The concentration of sulphur dioxide before and after scrubbing was determined with a Konik KNK 3000 HRGC gas chromatograph.

The experimental values for the overall number of transfer units were calculated from absorption tests using eq. 4. Afterwards, the height of transfer unit and the mass transfer coefficients were obtained from eqs. 5 and 6. The theoretical results from the three models considered were computed for the same experimental conditions. All calculations were developed with Matlab.

## 3. Results and Discussion

Table 2 lists, for each set of performance conditions used in the experiments with 19 mm Intalox® saddles, the experimental mass transfer parameters from equations 3 to 6. High absorption efficiencies were found for the 19 mm saddles. This packing has both greater surface area and better seawater distribution inside the packed bed than larger saddles (38 mm or more). However, as Baaliña *et al.* [2] have shown these high efficiencies, in many cases above 99 %, lead to increases in both the pressure drop and the energy required in the absorption process.

The observation of the behaviour of the mass transfer coefficient in Figure 1, for a given inlet sulphur dioxide concentration and liquid flow rate, shows that the variation in the gas flow rate has little influence on the coefficient values. However, an increase in the liquid flow rate leads to greater values. This means that gas flow has no noticeable effect on the liquid distribution and the interfacial area.

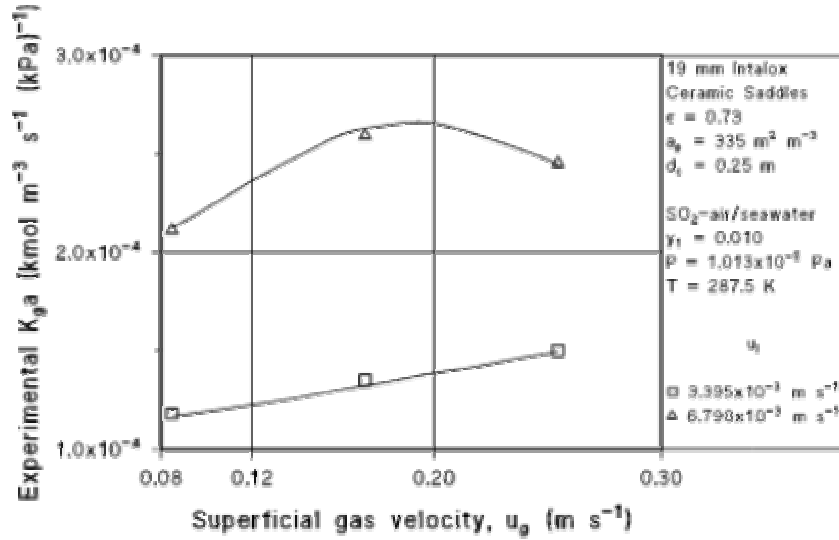
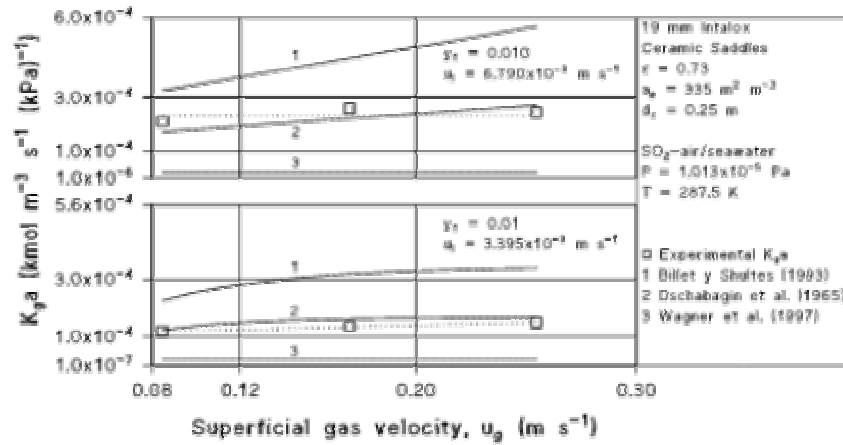
The gas side mass transfer coefficients and the number of transfer units calculated from the three theoretical models experimental data are given in Table 3. Figure 2 shows comparisons between experimental and calculated values at a range of superficial gas velocities. The level of agreement between the three models is poor. Dschabagin *et al.* [7] model shows more accuracy because the proposed correlation is based on chemical systems closer to seawater scrubbing. The other models induce to important deviations as the correlations have a more generalized profile including a wide range of packings and systems.

**Table 2:** Experimental gas-side mass transfer coefficients ( $K_{ga}$  and  $\beta_{ga}$ , in  $\text{kmol m}^{-3} \text{s}^{-1} \text{kPa}^{-1}$  and  $\text{s}^{-1}$ ), overall number and height of transfer units ( $N_{og}$ ,  $H_{og}$  in m) for the scrubber packed with 19 mm Intalox ceramic saddles to a height of 92 cm. Gas and liquid mass flow rates ( $G'$  and  $L'$ , in  $\text{kg m}^{-2} \text{s}^{-1}$ ), gas and liquid molar flow rates ( $G_s$  and  $L_s$ , in  $\text{kmol m}^{-2} \text{s}^{-1}$ ), inflowing sulphur dioxide ( $y_1$ , mol fraction) and percentage of absorbed sulphur dioxide, as indicated. Seawater temperature, 14.5°C; seawater pH, 8.00. Total pressure,  $1.013 \times 10^5 \text{ Pa}$ .

$G'$	$L'$	$y_1 \cdot 10^{-3}$	% absorbed $\text{SO}_2$	$G_s \cdot 10^{-3}$	$L_s$	$K_{ga} \cdot 10^{-4}$	$\beta_{ga}$	$H_{og}$	$N_{og}$
0.10	3.48	9.80	95.40	3.56	0.19	1.18	0.28	0.30	3.05
		5.70	96.30	3.58	0.19	1.27	0.30	0.28	3.28
		1.70	99.60	3.59	0.19	2.13	0.51	0.17	5.51
	6.97	9.80	99.60	3.56	0.37	2.11	0.51	0.17	5.48
		5.70	99.70	3.58	0.37	2.23	0.54	0.16	5.78
		1.70	99.80	3.59	0.37	2.40	0.57	0.15	6.21
0.21	3.48	10.40	82.70	7.13	0.19	1.35	0.33	0.53	1.74
		5.50	87.30	7.16	0.19	1.59	0.38	0.45	2.06
		1.90	97.60	7.18	0.19	2.88	0.69	0.25	3.72
	6.97	10.40	96.60	7.12	0.37	2.59	0.63	0.27	3.36
		5.50	97.30	7.16	0.37	2.78	0.67	0.26	3.60
		1.90	99.70	7.18	0.37	4.48	1.07	0.16	5.80
0.31	3.48	9.90	72.73	10.69	0.19	1.50	0.36	0.71	1.29
		6.00	80.50	10.73	0.19	1.89	0.45	0.56	1.63
		2.20	89.77	10.77	0.19	2.64	0.63	0.40	2.28
	6.97	10.00	88.10	10.69	0.37	2.45	0.59	0.43	2.12
		6.60	92.70	10.72	0.37	2.91	0.70	0.37	2.52
		1.70	98.50	10.78	0.37	4.86	1.16	0.22	4.19

**Table 3:** Experimental mass transfer coefficients ( $K_{ga}$ , in  $\text{kmol m}^{-3} \text{s}^{-1} \text{kPa}^{-1}$ ) and overall number of transfer units ( $N_{og}$ , in m) both based on gas phase compared with those from theoretical models. Packing made up of 19 mm Intalox ceramic saddles to a height of 92 cm. Gas and liquid mass flow rates ( $G'$  and  $L'$ , in  $\text{kg m}^{-2} \text{s}^{-1}$ ), inflowing sulphur dioxide ( $y_1$ , mol fraction) and percentage of absorbed sulphur dioxide (% abs.  $\text{SO}_2$ ), as indicated. Seawater temperature, 14.5 °C; seawater pH, 8.00. Total pressure,  $1.013 \times 10^5 \text{ Pa}$ .

				Experimental data		Billet and Schultes (1993)		Dschabagin <i>et al.</i> (1965)		Wagner <i>et al.</i> (1997)	
$G'$	$L'$	$y_1 \cdot 10^{-3}$	% abs. $\text{SO}_2$	$K_{ga} \cdot 10^{-4}$	$N_{og}$	$K_{ga} \cdot 10^{-4}$	$N_{og}$	$K_{ga} \cdot 10^{-4}$	$N_{og}$	$K_{ga} \cdot 10^{-4}$	$N_{og}$
0.10	3.48	9.80	95.40	1.18	3.05	2.07	2.27	1.14	3.00	0.0091	0.024
		5.70	96.30	1.27	3.28	2.46	6.40	1.23	3.21	0.0111	0.029
		1.70	99.60	2.13	5.51	2.84	7.37	1.41	3.66	0.0185	0.048
	6.97	9.80	99.60	2.11	5.48	3.28	8.59	1.71	4.47	0.0163	0.043
		5.70	99.70	2.23	5.78	3.50	9.11	1.81	4.72	0.0198	0.052
		1.70	99.80	2.40	6.21	3.96	10.29	2.03	5.26	0.0329	0.085
0.21	3.48	10.40	82.70	1.35	1.74	3.04	3.97	1.51	1.97	0.0090	0.012
		5.50	87.30	1.59	2.06	3.40	4.42	1.67	2.17	0.0113	0.015
		1.90	97.60	2.88	3.72	4.06	5.27	1.96	2.55	0.0176	0.023
	6.97	10.40	96.60	2.59	3.36	4.46	5.84	2.29	3.00	0.0160	0.021
		5.50	97.30	2.78	3.60	4.94	6.43	2.51	3.27	0.0201	0.026
		1.90	99.70	4.48	5.80	5.79	7.51	2.89	3.74	0.0313	0.041
0.31	3.48	9.90	72.73	1.50	1.29	3.53	3.07	1.74	1.52	0.0091	0.008
		6.00	80.50	1.89	1.63	3.90	3.39	1.91	1.66	0.0109	0.009
		2.20	89.77	2.64	2.28	4.77	4.12	2.29	1.98	0.0164	0.014
	6.97	10.00	88.10	2.45	2.12	5.66	4.93	2.68	2.34	0.0162	0.014
		6.60	92.00	2.91	2.52	6.14	5.34	2.88	2.50	0.0188	0.016
		1.70	98.50	4.86	4.19	7.96	6.88	3.56	3.07	0.0329	0.028

**Figure 1:** Influence of gas and liquid flow rate on gas-side mass transfer coefficient,  $K_g a$ .**Figure 2:** Comparison between measured and predicted  $K_g a$  values.

#### 4. Conclusions

Despite the fact that experimental data showed that the models for predicting mass transfer in randomly packed scrubbers present a low level of accuracy, which may lead to an incorrect design of the scrubber system and cause the observed corrosion damages in tanks, we showed the guidelines for establishing dimensions and flow rates needed for a safe performance of the scrubber.

The more important factor to reduce the lack of accuracy in the development of future theoretical models could be to obtain only one model for one kind of packing type. This could be a proposed new work.

#### 5. Nomenclature

- a: specific interfacial area per unit packed volume, ( $\text{m}^2 \text{m}^{-3}$ ).
- $a_p$ : total surface area per unit packed volume, ( $\text{m}^2 \text{m}^{-3}$ ).
- C: constant characteristic of the packing.
- D: diffusion coefficient of transferring component, ( $\text{m}^2 \text{s}^{-1}$ ).
- $D_c$ : column diameter, (m).

$F_g$ : gas loading factor, ( $\sqrt{Pa}$ ).  
 $G'$ : gas mass flow rate per unit cross section of the column, ( $\text{kg m}^{-2} \text{s}^{-1}$ ).  
 $G_s$ : gas molar flow rate per unit cross section of the column, ( $\text{kmol m}^{-2} \text{s}^{-1}$ ).  
 $H_o$ : overall height of mass transfer unit, (m).  
 $h$ : liquid holdup.  
 $K$ : overall mass transfer coefficient, ( $\text{kmol m}^{-2} \text{s}^{-1} (\text{kPa})^{-1}$ ).  
 $L'$ : liquid mass flow rate per unit cross section of the column, ( $\text{kg m}^{-2} \text{s}^{-1}$ ).  
 $L_s$ : liquid molar flow rate per unit cross section of the column, ( $\text{kmol m}^{-2} \text{s}^{-1}$ ).  
 $l_t$ : length of flow path, (m).  
 $N_o$ : overall number of mass transfer unit.  
 $P$ : overall pressure, (Pa).  
 $u_g$ : superficial gas velocity ( $\text{m s}^{-1}$ ).  
 $u_l$ : local liquid velocity ( $\text{m s}^{-1}$ ).  
 $Y$ : molar relation in gas phase, (moles of sulphur dioxide per moles of inert gas).  
 $y$ : molar fraction of sulphur dioxide in the gas.  
 $y^*$ : molar fraction of sulphur dioxide in equilibrium with seawater.  
 $Z$ : packing height, (m).  
 $\beta$ : volumetric mass transfer coefficient, ( $\text{s}^{-1}$ ).  
 $\varepsilon$ : void fraction, ( $\text{m}^3 \text{m}^{-3}$ ).

#### Subscripts:

$g$ : gas phase.  
 $l$ : liquid phase.  
 $1$ : inlet.  
 $2$ : outlet.

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# **A Practical Case Study of Relationship between Microbial Air Content and Building Parameters in Humid Climate Flats**

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## **Abstract**

Located in the northwest coast of Spain, the climate of Coruña, population of 280,000, is mild. However, indoors humidity in the area is relatively high over most of the year due to the effect of the Atlantic Ocean winds. Health authorities claim that the level of incidence of respiratory ailments in the area is higher than in the rest of the country, a possible cause being the interior conditions of flats. In order to effectively confirm this claim, a systematic investigation of indoors conditions of homesteads in the area would be needed. There is also a need for improvement and standardization in the tools for exposure assessment of moulds at genus level, fungal antigens, fungal fragments and metabolites.

This need prompted the research reported in the present paper, in which data obtained in several flats in the Coruña area is presented and analyzed. The flats were randomly chosen and data was obtained under every day life of their occupants.

Results showed that northwest of Spain present a high relative humidity as a result of its proximity to the sea. Outdoor relative humidity influences indoor relative humidity, but other household factors can influence mite allergen levels. A statistical study let us associate local humidity problems in walls with fungi growth and the presence of pets with total bacterial in the air.

**Keywords:** Case study; fungi; relationship; humidity; Indoor air; Flats.

## **1. Introduction**

Airborne microorganisms may be responsible for infectious or allergic disorders such as asthma and humidifier fever in exposed people [1]. Numerous epidemiologic studies in the past two decades provide a dose-response correlation between dust mite exposure, with mite sensitisation, and to some degree, asthma [2]. There seems to be insufficient evidence for the associations of indoor mould with asthma [3].

Otherwise, at present there is not conclusive evidence for the role of indoor fungi for allergies in children. Some studies find association, other do not. More than 80 genera of fungi have been associated with symptoms of respiratory tract allergies (Horner et al. 1995) [4, 5]. Results of [3] lead to the conclusion that with current methods for assessing mould exposure and allergy history it remains difficult or impossible to determine causality and attributable health risks.

There is also a need for improvement and standardization in the tools for exposure assessment of moulds at genus level, fungal antigens, fungal fragments and metabolites. Prospective longitudinal and intervention studies are required to further elucidate the role of fungi in environmental hygiene and allergies [3].

Currently, few data are available to guide the clinician for primary prevention of allergies. However, recommendations such as encouraging breast-feeding and allowing the child to grow up in a smoke-free environment remain valid. Allergen avoidance is crucial for treating and preventing disease exacerbation in allergic, already sensitised patients. In addition to recommending allergen avoidance as a therapeutic approach, allergologists have issued recommendations to rigorously avoid contact with potential allergens, such as certain foods during infancy and pets, also for primary prevention of allergic disease, i.e. for prevention of sensitisation [6].

If indoor allergen exposure is a principal determinant of asthma, then at the extremes of allergen exposure, we might expect to find: (1) lower asthma prevalence in locales without mite or pet allergen; and conversely, (2) higher asthma prevalence in locales with high indoor allergen exposure [2].

However, things are more complicated and not the same for all allergens: while increased exposure to house dust mite allergen is paralleled by increased sensitisation rates, the same is not true for cat allergen. One possible explanation for the different effects of different allergens may be their biochemical properties: mite allergens, in contrast to cat and dog allergens, contain proteolytic enzymes. It has been shown that concerning house dust mites a low-allergen environment can be achieved [6]. Other factors like distance of building from the source (a nearby park) and supermicrometre particle concentrations will be associated with the concentration levels of fungi [5].

At the present time, the only way to guarantee lower mite allergen levels in modern homes in the western world is to remove the carpets and to encase the mattress and bedding [7].

Furthermore, to get reduce this exposure we must improve IAQ. The 3 primary considerations in improving IAQ are (1) evaluation of construction failures that allow moisture into the walls of a building, (2) poor ventilation causing excessive humidity and accumulation of gaseous and/or chemical exposure from materials in the living space, and (3) poorly designed or failing HVAC systems that contribute to poor air calculation.

About this two last points, some authors [1] have analysed the massive proliferation of microorganisms may take place in HVAC unit with certain risk factors such as low efficiency filters, cold mist humidifiers using water recycling, areas in which condensation water remains stagnant, large recirculation of air and faulty or deficient maintenance conditions. They demonstrated that, compared to a naturally ventilated building, a HVAC system which is well-designed and well-maintained improves the microbiological quality of indoor air.

Finally, not all indoor allergens are necessarily equal in their propensity to cause asthma. For example, using dust allergen concentration as a proxy for exposure, recent studies have revealed that indoor cockroach allergen exposure, but not mite or cat allergen exposure, is a significant risk factor for asthma [2].

Despite the fact that the data collected on household characteristics varied greatly between the studies and that building materials techniques are very different in different parts of the world, some common themes have emerged [7]. For example, in [3] concentrations of moulds varied hardly between four investigation areas, and neither climatologically conditions nor differences between urban and rural regions exhibited a systematic influence [3]. In another example [8], no association was found between the concentration of mite allergens and the environmental characteristics (geographic



location, floor above ground, type of ventilation) and no correlation were found between indoor humidity and allergen levels [8].

We must consider that house dust mites live in an environment where there is no liquid water, and are dependent upon ambient humidity to absorb water from the atmosphere [7]. To get this water dust mites can gain it by diffusion through the body or extract the water vapour from air via hygroscopic crystals in their supracoxal glands, located at the base of their first pair of legs [7]. The optimum RH for mite growth is 75-95%, at temperatures of 15-30°C, while above 70% RH conditions may be optimal for fungal growth [4]. RH has a major influence on the survival of mite colonies and therefore levels of mite allergens.

Although laboratory and early field studies suggested that there was a strong relationship between RH and mite allergen levels, this had not been conformed by more recent large scale studies when other factors have been considered in a multivariate analysis. For example, freezing and /or dry weather can damage fungi and reduce the spore counts on outdoor sample, but the conditions indoors may be very hospitable to fungal growth non-seasonally [9].

From these studies we can conclude that outdoor RH influences indoor RH, but other household factors can influence mite allergen levels and that mean allergen levels in different geographical areas tend to be influenced by the local climate [7].

As a result of this, novel techniques has been developed recently which allows measurements of RH to be made within the mite microhabitat; that is, where it matters, in the depth of the carpet or mattress. This has revealed that the RH in the carpet may be higher than that in the room air and that with different types of construction, the differences between room RH and floor RH will vary. This suggests that the RH in the room air does not necessarily reflect the RH in the microhabitat of the mite, in the depth of the carpet pile [7].

The objective of this paper is to get information about Spanish flats microbial levels and relate it with flats characteristics. Results will be useful to get in buildings a healthy home taken into account costs versus energy saving and improve health outcomes [10].

## **2. Materials and Methods**

### **2.1. Flats**

Analysed flats present natural ventilation with the only mechanical ventilation consisted of exhaust fans in the toilets in accordance with regulations. In winter, the flats were heated by hot water radiators as in [1]. Normal ventilation conditions were defined as those that had already been established by the resident prior to the researchers arrival (i.e. all windows and doors that are normally open in the residence for this time of year, were open) [5].

To get a good comparison, all the flats present the same walls structures, indoor activities and are located in the city of A Coruña.

### **2.2. Outdoor conditions**

Ambient air was sampled in 25 flats of A Coruña at 1.5 m from the floor during the winter season and the monthly averaged data has been provided by MeteoGalicía [11] with a 10 min frequency and plotted in Figs. 2, 3 and 4.

### **2.3. Indoor relative humidity and temperature**

Temperature and humidity were measured using an Innova 1221 data logger equipped with a temperature transducer MM0034, based on thermistor technology, and a humidity transducer MM0037, made up of a light emitting diode (LED), a light sensitive transistor, a mirror, a cooling element and a thermistor. The accuracies were 70.2 and 70.3 1C (dew point temperature), respectively.

Tinytag Plus 2 dual channel dataloggers with thermistor and capacitive sensors were also installed to record temperature and relative humidity values with accuracies 70.2 1C and 73% HR, respectively.

## 2.4. Microbiological Analysis

Two culture media were used: Trypticase Soy Agar was used for total bacterial flora and malt agar (3% malt extract, 1.5% agar, 0.5 peptone, supplemented with 0.1 mg/ml-1 chloramphenicol) was used for fungi. The Petri dishes were incubated 48 h at 37°C for bacteria and for 5-8 at 27°C for the fungi as [1]. The total number of colonies, total fungi and total bacteria were counted, and the airborne bioburden calculated in terms of colony-forming units per cubic meter air (CFU/m<sup>3</sup>) as is shown in Ec.1.

$$CFU / m^3 = \frac{n \cdot 25}{t} \quad (Ec.1)$$

Where n is the number of colonies and t is the sampling time.

Mean indoor and outdoor relative humidity and temperature and mesophiles and fungi concentration on indoor air are showed in Table 1. In the last column of Table 1 we show some characteristics observed in these flats. We have indicated with “pet” when in that flat there are pets like cats and dogs and “Humidity problems” when some local humidity problems were detected. Other factors like limited space (persons/m<sup>2</sup>) were indicated so. The others flats that do not present special characteristics were called as “Normal”.

## 2.5. Statistics

The relationship between indoor fungal and bacterial concentrations levels with indoor relative humidity, after applying a logarithmic transformation, was done by means a linear regression which is shown graphically in Fig.1.

Once the total number of colonies, total fungi and total bacteria was calculated, a statistical study of the averages of those values was taken. The comparison of averages was carried out by means of analysing the variance of a factor (one-way Anova) using the statistical software SPSS 11.0, for a level of significance of 0.05 to determine if there are groups with the same evolution.

Furthermore, a Duncan and Student-Newman-keuls post hoc analysis will let us recognize groups of flats that present the same fungi or bacterial conditions for a level of significance of 0.05 and associate these concentrations with the characteristics of flats.

### 3. Results

#### 3.1. Indoor conditions

**Table 1:** Indoor/outdoor sampled variables and observed characteristic

Flat	t <sub>indoor</sub> (°C)	RH <sub>indoor</sub>	t <sub>outdoor</sub> (°C)	RH <sub>outdoor</sub>	Total bacterial (CFU/m <sup>3</sup> )	Fungi (CFU/m <sup>3</sup> )	Characteristics
A	20.97	63.45	16.72	74.6	500	50	Pet
B	24.09	65.09	17.76	88.8	200	133	Normal
C	19.42	62.1	14.12	82	316	50	Normal
D	20.38	64.87	17.7	59.6	133	66	Limited space
E	21.46	63.59	17.7	62	300	16,6	Normal
F	23.43	65.03	22.28	66.8	233	183	Humidity problems
G	22.2	70.92	16.24	94	616	183	Humidity problems
H	19.92	63.73	15.64	75	350	50	Limited space
I	21.24	49.62	18.08	45	516	33	Normal
J	23.78	55.7	17.76	47	1116	66	Pet
K	25.11	48.09	17.6	58.8	533	183	Humidity problems
L	23.63	65.58	20.04	73.2	450	133	Limited space
M	22.37	67.19	19.28	78.4	400	17	Normal
N	21.74	63.65	15.6	74.76	1100	133	Humidity problems
O	24.05	50.31	15.2	74.2	300	50	Normal
P	20.29	59.22	12.08	88	1016	50	Normal
Q	20.32	62.23	11.84	88	1566	15	Pet
R	20.1	62.66	14.4	89.2	733	83	Normal
S	17.4	69.88	14.4	87.4	650	33	Normal
T	19.42	64.79	16.6	72	833	116	Humidity problems
U	21.13	61.1	15.8	76	733	116	Normal
V	22.63	65.22	21.4	59.4	300	50	Normal
W	25.12	61.18	21.64	64.4	400	380	Humidity problems
X	19.14	64.56	14.84	78	280	80	Normal
Y	23.83	65.65	21.5	60.8	150	60	Normal

#### 3.2. Outdoor conditions

**Figure 1:** Outdoor temperature.

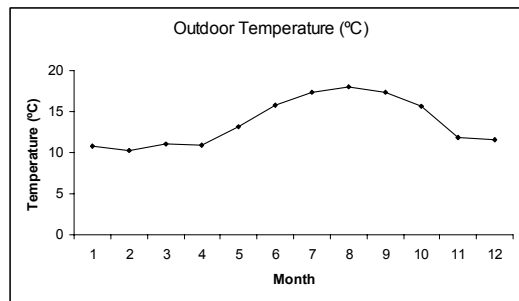


Figure 2: Outdoor relative humidity.

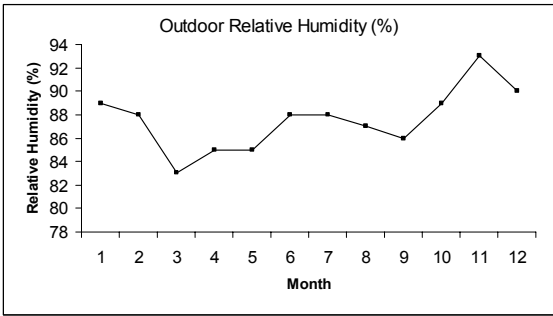
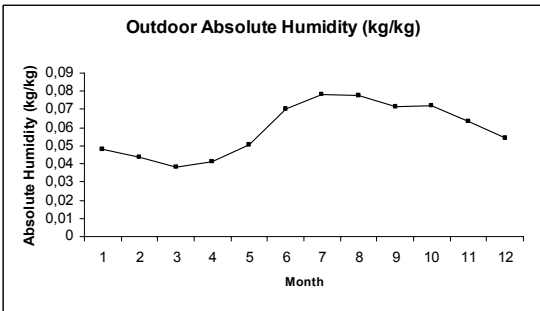
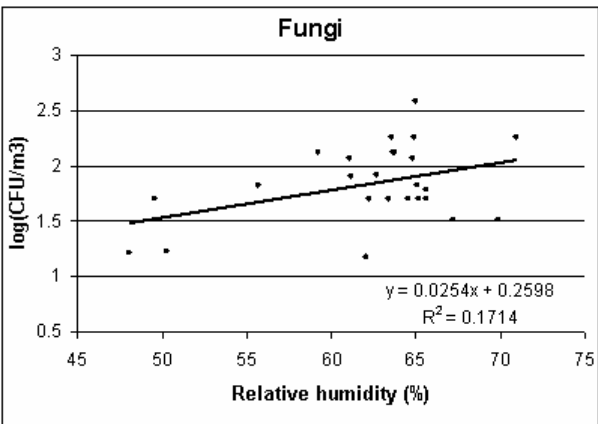


Figure 3: Outdoor absolute humidity.



3.3. Linear regression

Figure 4: Fungi linear regression.



### 3.4. Anova and Duncan post-hoc analysis

**Table 2:** One way Anova and Duncan post-hoc with mean total bacterial (CFU/m<sup>3</sup>).

Groups obtained	Flat	Total bacterial (CFU/m <sup>3</sup> )
Group 1: Pets	A	500
	J	1116
	Q	1566
Group 2: Normal, limited space and humidity problems	B	200
	C	316
	E	300
	I	516
	M	400
	O	300
	P	1016
	R	733
	S	650
	U	733
	V	300
	X	280
	Y	150
	D	133
	H	350
	L	450
	F	233
	G	616
	K	533
	N	1100
	T	833
	W	400

**Table 3:** One way Anova and Duncan post-hoc with mean fungi (CFU/m<sup>3</sup>).

Groups obtained	Flat	Fungi (CFU/m <sup>3</sup> )
Group 1: Normal, Limited space and Pets	A	50
	J	66
	Q	15
	B	133
	C	50
	E	16,6
	I	33
	M	17
	O	50
	P	50
	R	83
	S	33
	U	116
	V	50
	X	80
	Y	60
	D	66
	H	50
	L	133
Group 2: Humidity problems	F	183
	G	183
	K	183
	N	133
	T	116
	W	380

## **4. Discussion**

### **4.1. Indoor conditions**

Northwest Spanish flats present an indoor mean relative humidity of 62 % and a mean temperature of 21.7 °C. These conditions are nearly the optimal conditions for fungal growth but the fungal presence never is greater than the WHO guideline value of 500 CFU/m<sup>3</sup> (World Health Organisation, 1990). In the present study the average fungi was 85.6 CFU/m<sup>3</sup>, which is similar to 198 CFU/m<sup>3</sup> found in California, 189 found in Poland and 105 CFU/m<sup>3</sup> in German, but lower than 549 CFU/m<sup>3</sup> found in Australia. These comparisons suggest that the average fungi exposure levels in northwest Spain homes are similar to those found in many other parts of Europe and the world [3]. The mean total bacterial CFU/ m<sup>3</sup> value was 549 CFU/ m<sup>3</sup> this value is higher than Spanish NTP indications [12, 13]

### **4.2. Outdoor conditions**

Located in the northwest coast of Spain, the climate of Coruña, population of 280,000, is mild. However, indoors humidity in the area is relatively high over most of the year due to the effect of the Atlantic Ocean winds. In Figs. 2, 3 and 4 one can observe that A Coruña has a moderate climate where temperatures are neither too low in winter nor too high in summer. Also, a high relative humidity can be observed as a result of its proximity to the sea.

### **4.3. Linear regression**

The relationship between indoor fungal and bacterial CFU/ m<sup>3</sup> levels with indoor relative humidity, after applying a logarithmic transformation, do not present an optimal regression ( $r^2 < 0.9$ ). This relationship has been obtained in laboratory studies but this had not been conformed by more recent large scale studies when other factors have been considered in a multivariate analysis [9]. Our case study, in real flats, is a clear example of multivariate analysis. These variables were identified and selected by investigators when they are sampling. In this paper we have identified three variables like presence of pets, limited space for persons and humidity problems in walls. These variables must be associated with microbial growth by means an ANOVA and post-hoc analysis.

### **4.4. Anova and Duncan post-hoc analysis**

When we employ fungi post-hoc analysis versus four kinds of characteristics (Limited space, humidity problems, presence of pets and normal conditions) we can deduce that these flats can be divided in two groups for a level of significance of 0.05. The first group of flats is that which presents local humidity problems and the second group is formed with the other flats.

If we employ total bacterial post-hoc analysis versus these four characteristics another two groups can be recognized. The first group is formed with flats that present pets and the second group is formed with the others flats for the same level of significance as before.

Now we can conclude that outdoor relative humidity influences indoor relative humidity, but other household factors can influence mite allergen levels and that mean allergen levels in different geographical areas tend to be influenced by the local climate [7]. In this case, local humidity problems in walls are associated with fungi growth and the presence of pets is significantly correlated with total bacteria in the air.

Once we have detected local microbial origins we can reduce exposure to reduce sensitisation rates [2]. For example; building constructions materials could be a possible solution for humidity local problems [14, 15 and 16] because permeable materials can reduce this humidity during occupied and unoccupied periods. This passive methods solution could be employed as a low energy alternative solution of HVAC [17,18].

This solution could be a new method to detected and correct microbial growth in indoor ambiances and a possible guide to clinician for primary prevention allergies [6].

## 5. Conclusions

A practical case study of indoor microbial growth in Spanish flats has been done. Results showed that northwest of Spain present a high relative humidity as a result of its proximity to the sea. Outdoor relative humidity influences indoor relative humidity, but other household factors can influence mite allergen levels. A statistical study let us associate local humidity problems in walls with fungi growth and the presence of pets with total bacterial in the air.

As average fungi exposure levels are similar to those found in many other parts of Europe. Possible solutions to prevent local microbial growth are proposed as new building construction materials.

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# **Architecture of Simulation Model and Error Rate for Remote Data Transfers Measurement Over Local Area Network (LAN) in Heterogeneous Environment**

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## **Abstract**

We present a novel approach for the measurement of one-way delays and throughput between network nodes in heterogeneous environment over Local Area Network (LAN). This research investigates performance evaluation of remote data transfers on heterogeneous services and technologies environment. We propose an enhanced equation to evaluate the performance of network traffic management via Little Law and Queuing theory to improve the evaluation algorithm. To get accuracy results on the performance of simulation model, we measure (verify and validate) data from lab experiment. We use network management tool to capture those data and Ping Plotter application (network analyzer) to generate traffic. As a result, this simulation model can provide a good approximation of the real traffic (one-way delays and throughput) observed in the real network environment (Local Area Network, LAN). Through laboratory and field experiments, it shows that the model via simulation is capable of approximating the performance of remote data transfers over heterogeneous services and techniques within a minimum error range.

## **1.0. Introduction**

Considerable research has been conducted to model and quantify the performance of heterogeneous services and technologies (e.g [25], [26], [27]). Accurate measurements and analyses of network characteristics (remote data transfers) are essential for robust network performance and management. Queuing theory [3] has been used as an effective tool to model performance in several technical and social contexts. Evaluating the performance of a computer networking usually involves constructing an appropriate model to predict the heterogeneous environment behaviour via simulation model. The heterogeneous environment model is then analyzed and simulated using mathematical techniques. For example, several flow-level network traffic models have been proposed to describe/stimulate [21], [23], [24]. These models have been used to study fairness, response times, queue lengths and loss probabilities under different assumptions and using a variety of mathematical techniques. Queuing theory has been widely used to model and analyze the network performance of complex systems involving services, communication systems, computer networks and vehicular traffic. In contrast to other works in the literature (e.g., [7], [8], [9], [31]), we developed simulation model to measure the performance of heterogeneous environment. Our model can be used to generate representative packet traffic (one-way delays and throughput) in a live network environment or in a simulated environment.

The significant of this study was to develop a simulation model to measure the performance of one-way delays and throughput in heterogeneous network environment using Queuing theory. This model could assist network administrators to design and manage heterogeneous network systems. This simulation model can be used in various services and technologies to measure heterogeneous environment. Therefore, this simulation model is designed to: i) predict the performance of various services (e.g. video, audio, voice and message) in order to aid technology assessment and capacity planning; ii) predict the expected behavior of new services and designs through qualitative or quantitative estimates of network performance; iii) assist network administrator to prepare, propose, plan and design network topology more effective and systematic; and iv) conduct 'What-If' analysis for evaluating heterogeneous network environment performance. Moreover, in the future, the integration of data and communication services, almost every 'Internet Ready' device will be a communicable device [11]. With the availability of this infrastructure, users are now demanding and expecting more services [19], [20]. Convergence is pushing towards an environment that requires new investment in infrastructure and able to support the delivery of rich services (various services), applications and content [17], [21], [5]. Network deployment is growing increasingly complex as the industry lashes together a mix of wired and wireless technologies into large-scale heterogeneous network architecture and as user applications and traffic continue to evolve [2]. The successful evolution of the Internet is tightly coupled to the ability to design simple and accurate models [6]. Many factors may contribute to the congestion of network interface, such as a heavy load in the network that usually generates higher traffic. Once the number of requests exceeds the maximum capability of network, many clients will not be able to receive responses from the network [1]. Thus, this research is critical to be conducted in order to predict and measure of remote data transfers in heterogeneous environment.

## 2.0. Problem Statements

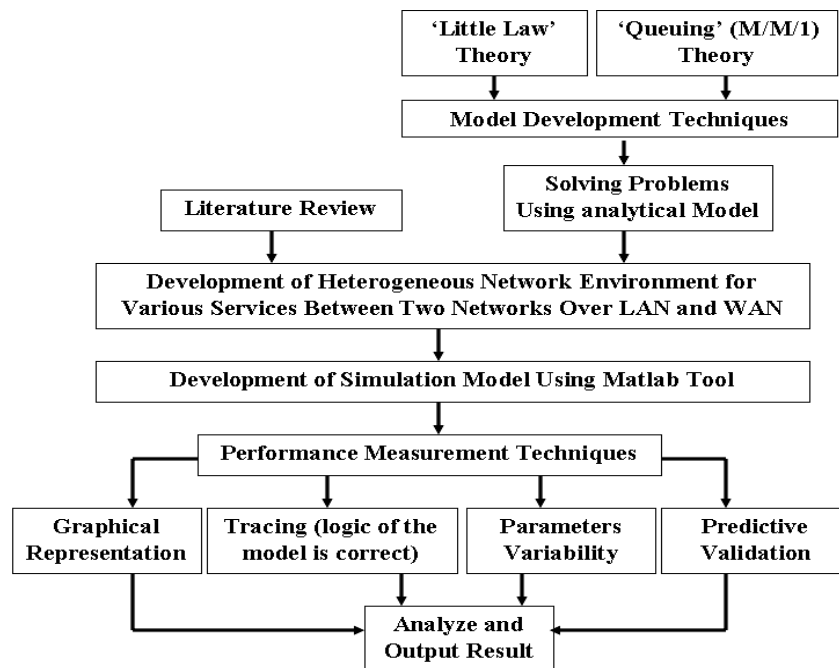
In the 21 century, a network infrastructure is based on multi-service implementation over convergence of network medium such as ISP, PSTN and GSM [12], [15]. Availability of various services has produced multi-traffic in network infrastructure. Therefore, multi-traffic in the network infrastructure has become more complex to observe and analyze [13], [16], [17]. Today, retrieving and sending information can be done using a variety of technologies such as PC, PDA, fix and mobile phones via the wireless, high speed network, ISDN and ADSL lines that are more prone to heterogeneous environment, but unfortunately the optimal capability of technologies are not fully realized. The main factors of network congestion are related to network design and bandwidth capacity [18]. Nevertheless, few studies have been conducted to evaluate the application of computer network technologies and services over heterogeneous environment especially in Higher Education Institutes. Algorithms for actively measuring network physical and available bandwidths have been researched for many years. Many tools have been developed, and only a few tools have successfully achieved a close estimation of network bandwidths [27]. Therefore, retrieving and sending information over heterogeneous environment using convergence of technologies in Higher Educational Institutes should be analyzed and evaluated via simulation model. We have setup a pilot test-bed (real network environment) to analyze and measure of network traffic utilization at University of Kuala Lumpur in Malaysia. This study posits several research questions: i) what is the performance level of the remote data transfers; and ii) Is the simulation model for evaluating and measuring the heterogeneous environment performance effective?

## 3.0. Methodologies

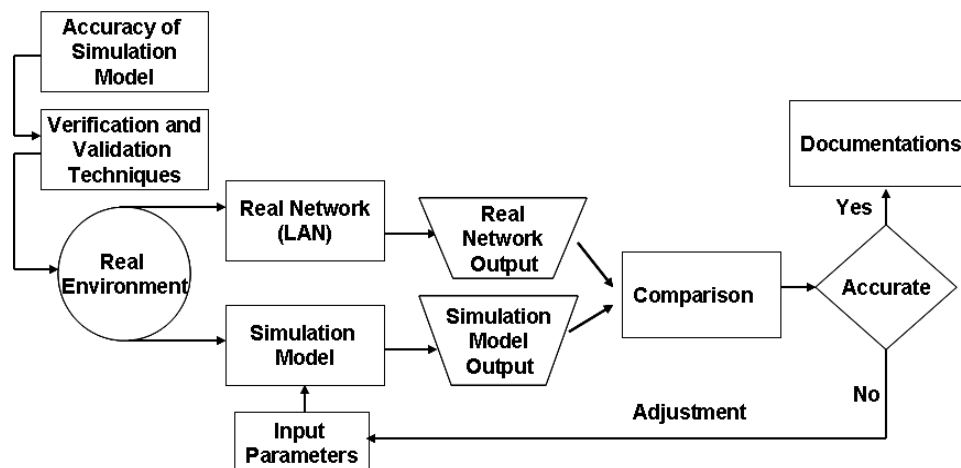
Whatever modeling paradigm or solution techniques in heterogeneous environment model development are being used, the performance measures extracted from a simulation model must be a

good representation of the real network environment. Inevitably, some assumptions must be made about the real network in order to construct the heterogeneous environment model. Figure 3.1 shows the overall framework of the simulation model. There are four performance techniques to validate the simulation model: i) graphical representation; ii) tracing; iii) parameter variability; and iv) predictive validation. In addition, there are two techniques to judging how good a model is with respect to the real network: i) it must ascertain whether the simulation model implements the assumptions correctly (model verification); and ii) assumptions which have been made are reasonable with respect to the real network (model validation). Comparison with a real network is the most reliable and preferred method to validate a simulation model (refer to Figure 3.2). Assumptions, input values, output values, workloads, configurations and network system behaviour should all be compared with those observed in the real network.

**Figure 3.1:** Simulation Model Development Methodology



**Figure 3.2:** Simulation Model Verification and Validation Methodology



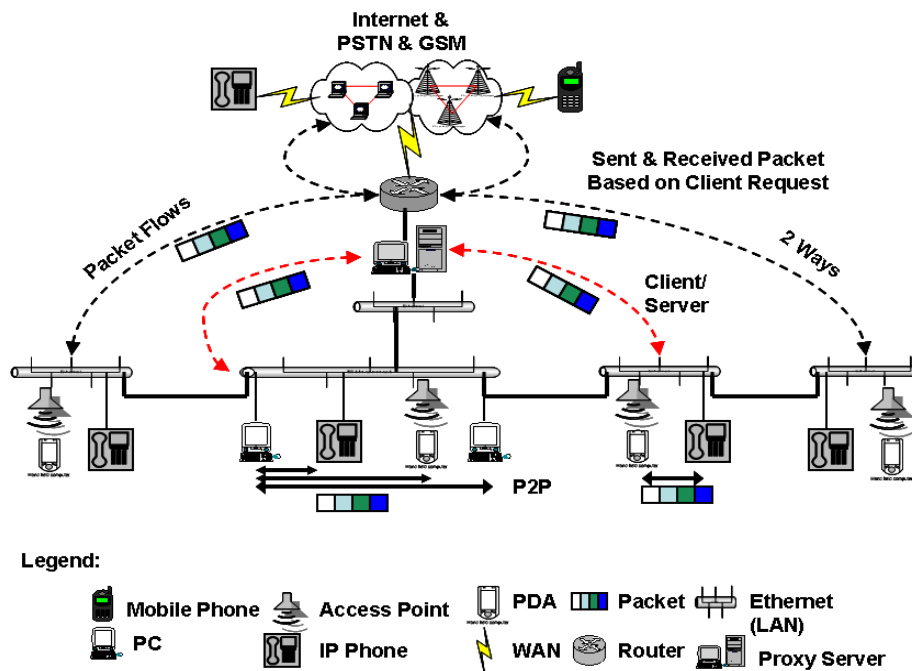
#### 4.0. Propose Simulation Model Development for Remote Data Transfer

Many different types of modeling and simulation applications are used in various disciplines such as acquisition, analysis, education, entertainment, research and training [14]. In the Figure 4.1, theoretical model is based on a random distribution of service duration. “Request” defines the way clients use the computer network to request services, while, “Response” represents the way clients receive services from the server. Simulation model is divided as follows: i) to study physical of real heterogeneous network environment; ii) transform physical of real heterogeneous network environment into logical model; and iii) develop and implement the heterogeneous simulation model.

#### 4.1. Physical Model of Real Heterogeneous Network Environment

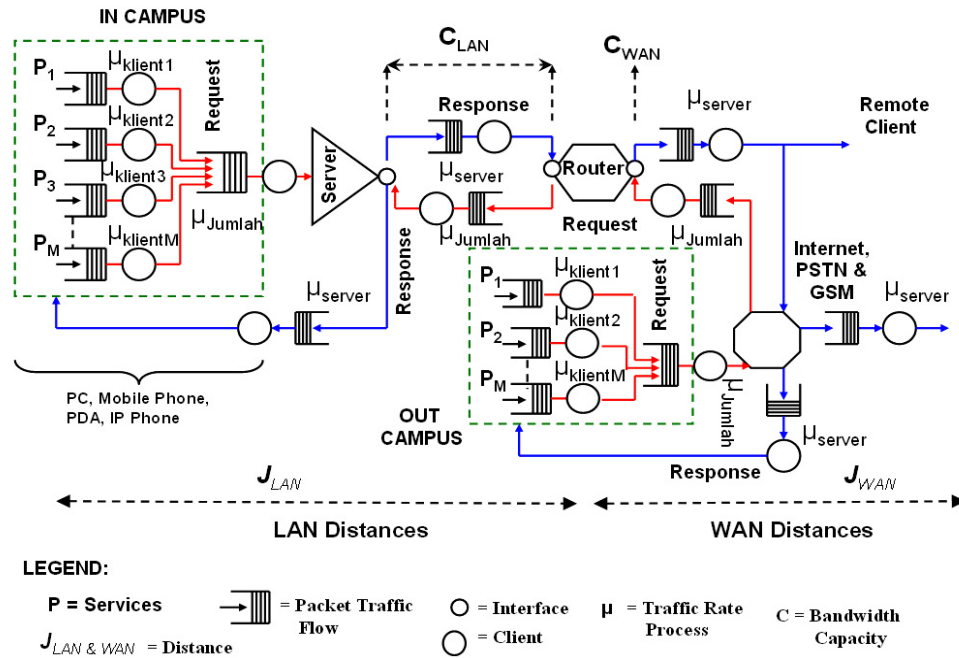
Before we start to develop simulation model of heterogeneous network environment, we need to define the situation of heterogeneous environment in real world. Figure 4.1 shows the network heterogeneous environment in real world. Then we need to transform from heterogeneous environment in real world into logical model. The logical model is the phase where mathematical techniques are used to stimulate heterogeneous environment.

**Figure 4.1:** Real Heterogeneous Network Environment at Main and Branch Campus



#### 4.2. Logical Model of Heterogeneous Network Environment

Figure 4.2 depicts the open queuing network based on M/M/1 will use to develop logical model of heterogeneous network environment for remote data transfers. Queuing theories are powerful enough to include many different combinations [1]. Parameters like bandwidth capacity, size of packet services and distances between two networks are used to ‘characterize’ the application traffic. The logical model is the important area need to define which mathematical techniques should be used in development of heterogeneous environment.

**Figure 4.2:** Logical model of Heterogeneous Network Environment at Main and Branch Campus

### 4.3. Development of Heterogeneous Network Environment Model

This section describes a simple analytical queuing and little law theories that capture the performance characteristics of remote data transfer operations. A link refers to a single connection between routers and hosts. The link bandwidth is the rate at which bits can be inserted into the medium. The faster bandwidth the more bits can be placed on the medium in a given time frame [22]. At this stage, we assume the data are transported between the two network sites (source and destination) as previously shown in Figures 4.1. Table 4.1 shows the parameters that have been used in the model development. In open queuing network, the throughput of the heterogeneous network environment is determined by the input rate in the system. Table 4.2 summarizes all the input and output parameters used in the model.

**Table 4.1:** Notations for Model Development

Model Parameters	Meaning
$L$	Size of packet services
$R$	Bandwidth capacity
$v$	Speed of Light $2 \times 10^8$
$n$	Total of node connected between two networks
$d$	Distances between two networks
$C_{LAN}$ dan $C_{WAN}$	Bandwidth of LAN and WAN interface ports
$P (P_1, P_2, P_3, \dots, P_m)$	Various services
$P_1$	Client uses single service
$J_{LAN}$ dan $J_{WAN}$	LAN and WAN distances
$\mu_{Jumlah}$	Total size of packet services request by clients (traffic)
$\mu_{klientl}$	Size of packet service request by client (traffic)
Trafik_P1	Total size of packet services used by clients (traffic)
Trafik_Heter	Total size of various packet services in heterogeneous network environment used by clients (traffic)

**Table 4.2:** Input and Output Metrics for Model Development

Input Parameters	Output Parameters
Type of Services	Throughput traffic in bit per second (bps)
Size of packet services in bit per second (bps)	Total time taken (delay) in second (sec) due to transmission and propagation delay
Size of bandwidth in bit per second (bps)	
Total of nodes	
Distances in kilometres (KM)	

The original theory [28] is defined as a throughput (variable name is ‘Throughput’) in equation 1. While [29], equation 2 is defined as a delay, time taken for packet transmission depends on size of packets and hop (variable name is ‘Time’). Equation 1 and 2 are derived based on logical model that has been designed to meet requirements for heterogeneous network environment. Logical model is derived and formulated in a single service (homogeneous concept) as in equations 3, 4 and 5. Then, the logical model is derived to the heterogeneous network environment in equations 6 and 7.

(William Stallings, [28]):

$$Throughput = \frac{L}{\frac{d}{v} + \frac{L}{R}} \quad (1)$$

(Darren L. Spohn, [29]):

$$Throughput = \frac{L}{\frac{d}{v} + \frac{L}{R}} \quad (2)$$

Where  $L, d, v$  and  $R > 0$

Equation 1 and Equation 2 are derived

$$Laluan\_Trafik\_Hop = \frac{L}{\frac{d}{v} + \frac{L}{R}(n+1)} \quad (3)$$

**Client uses single service for remote data transfer from LAN to WAN interface ports**

$$Trafik\_P1 = \left[ \frac{P1}{\left(\frac{J_{LAN}}{v}\right) + \left(\frac{P1}{C_{LAN}}(n+1)\right)} \right] + \left[ \frac{P1}{\left(\frac{J_{WAN}}{v}\right) + \left(\frac{P1}{C_{WAN}}(n+1)\right)} \right] \quad (4)$$

$$Trafik\_P1 = \left[ \frac{\mu_{klient\ 1}}{\left(\frac{J_{LAN}}{v}\right) + \left(\frac{\mu_{klient\ 1}}{C_{LAN}}(n+1)\right)} \right] + \left[ \frac{\mu_{klient\ 1}}{\left(\frac{J_{WAN}}{v}\right) + \left(\frac{\mu_{klient\ 1}}{C_{WAN}}(n+1)\right)} \right] \quad (5)$$

**Client uses various services for remote data transfer from LAN to WAN interface ports  
Heterogeneous Environment**

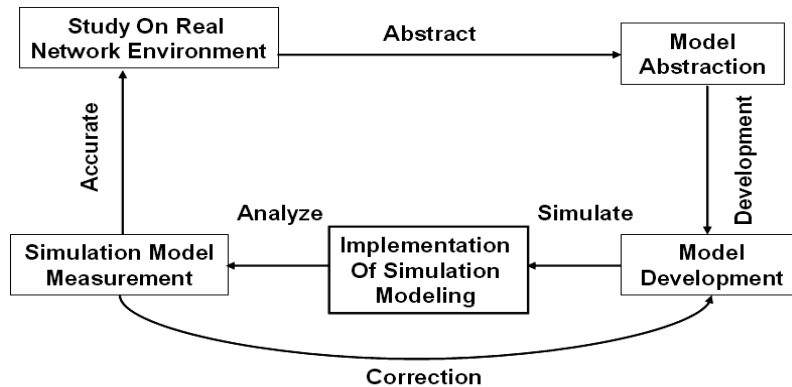
$$Trafik\_P1 = \left[ \frac{\mu_{klient\ 1}}{\left(\frac{J_{LAN}}{v}\right) + \left(\frac{\mu_{klient\ 1}}{C_{LAN}}(n+1)\right)} \right] + \left[ \frac{\mu_{klient\ 1}}{\left(\frac{J_{WAN}}{v}\right) + \left(\frac{\mu_{klient\ 1}}{C_{WAN}}(n+1)\right)} \right] \quad (6)$$

Where  $P_1+P_2+P_3+\dots+P_m = U_{klient1}+U_{klient2}+U_{klient3}+\dots+U_{klientm} = \mu_{jumlah}$

$$Trafik\_Heter = \left[ \frac{\mu_{Jumlah}}{\left(\frac{J_{LAN}}{v}\right) + \left(\frac{\mu_{Jumlah}}{C_{LAN}}(n+1)\right)} \right] + \left[ \frac{\mu_{Jumlah}}{\left(\frac{J_{WAN}}{v}\right) + \left(\frac{\mu_{Jumlah}}{C_{WAN}}(n+1)\right)} \right] \quad (7)$$

Figure 4.3 shows how the model has been formulated from real network environment to simulation model. The main valuable aspects of the simulation study is to explain and understand real world phenomena that are costly to perform in the laboratory or difficult to collect in field experiments. A successful simulation model that is able to provide a sufficiently credible solution that can be used for prediction. Since it is not feasible to construct a simulation model that represents all the details and behaviors of the real network, some assumptions must be made about the real network to construct a simulation model. Therefore, a simulation model is an abstract representation of real network environment.

**Figure 4.3: Model and Simulation Development Phases**



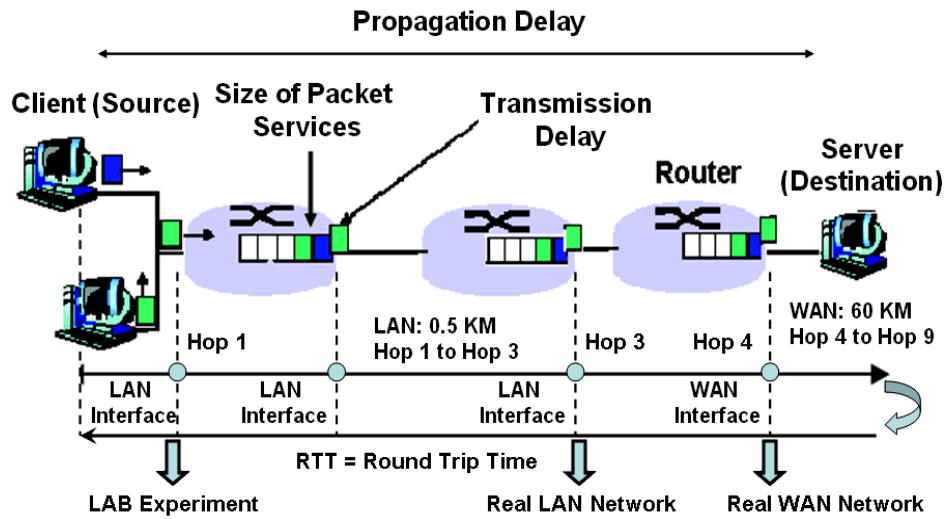
## 5.0. Verification and Validation of Simulation Model with Local Area Network (Real Network) Experimental

In this section, we verify the little law and queuing theories for heterogeneous simulation model environment between two networks through experiments. Lab experiment is based on ideal network in which there is no packet losses, no jitter in delays and network bandwidth is sufficient for all requirements. While, real experiment is based on real network and need to consider as follows: i) network bandwidth is limited and is not enough for all application and users at the same time; ii) delay due to the network overloads; and iii) packet losses.

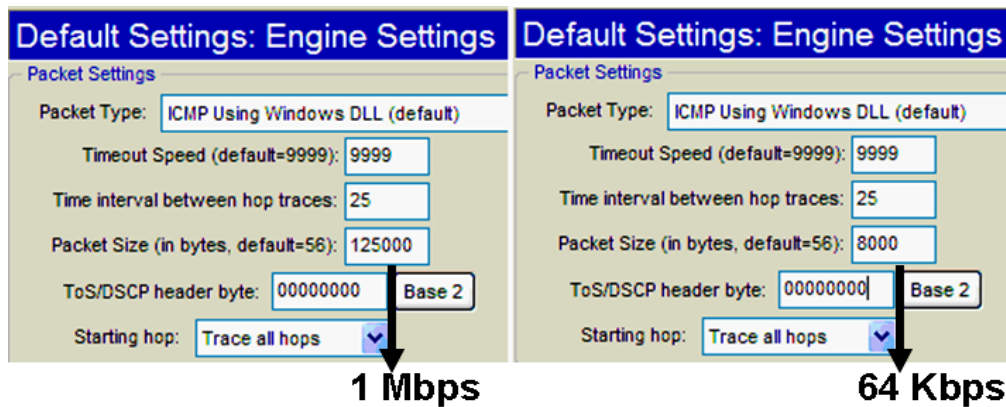
### 5.1. Local Area Network (Real Network) Setup

We used a network management application to capture traffic between two networks link in real network environment. Figure 5.1 shows the experimental setup of real network used in our tests. The real network used switch with Gigabit Ethernet interface, Router interface and Ping Plotter application can be configured to insert size of packet services to generate traffic into the network interface (see Figure 5.2). By using varying number of clients and size of packet services, we are able to simulate network for remote data transfers. Ping Plotter application is based on round trip time (RTT) measurement.

**Figure 5.1:** Real Network Environment Setup



**Figure 5.2:** Ping Plotter Engine Setting for Size of Packet Services



## 5.2. Real Network (LAN) Experiment

We have setup a Local Area Network, LAN (real network) environment of data transfer flow measurement that generates measurement data to analyze network performance at the main campus. Low bandwidth link affects the size of packet services and number of clients access to the network server. The data transfers from source (client: 10.5.1.252) to destination (server: 10.42.1.23) is based on Local Area Network (LAN) with traffic congestion from operational network (see Figure 5.3). Number of hops occurs between source and destination in real network is three hops (see Figure 5.1). Therefore, we run network management application to measure delay (propagation and transmission time) performance (see Figure 5.3).

Four sets of experiments were conducted with different scenarios (see Table 5.1). We used the same input variables that have been used in simulation model (see Figure 5.4, Figure 5.5 and Table 5.1) to estimate our data that must be closely resemble to real network environment (see Table 5.2). We used several variables such as 1 Gbps and 100 Mbps to estimate our data that must be closely resemble to LAN (real network) environment. We conclude that base on our findings, the simulation model is able to predict and estimate data transfers for LAN (real network) environment (Table 5.2).

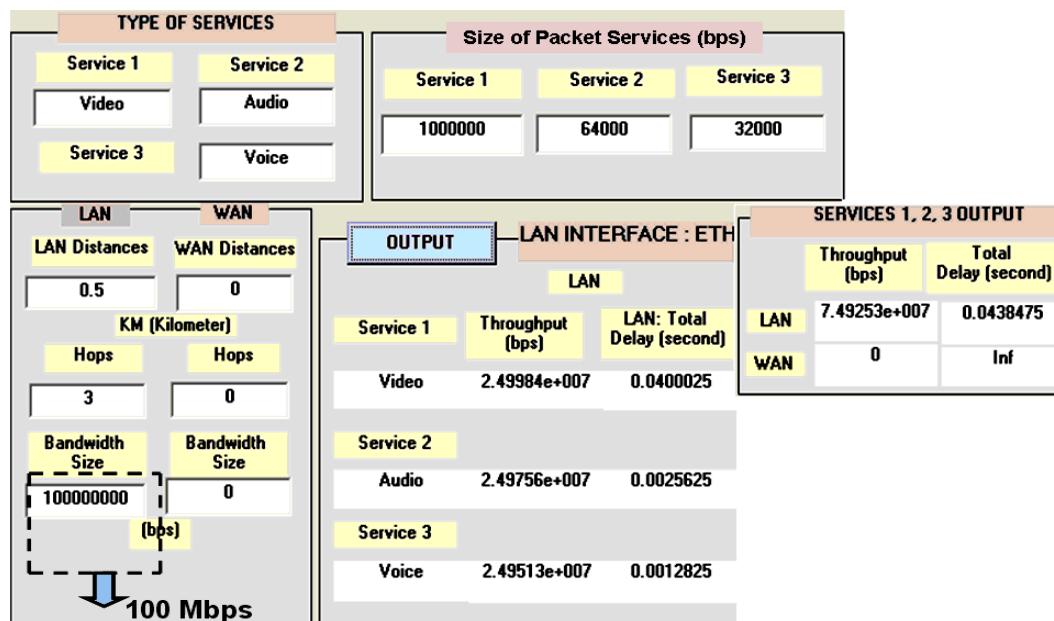


**Figure 5.3:** LAN Experiment (Real Network) Using Network Management Application

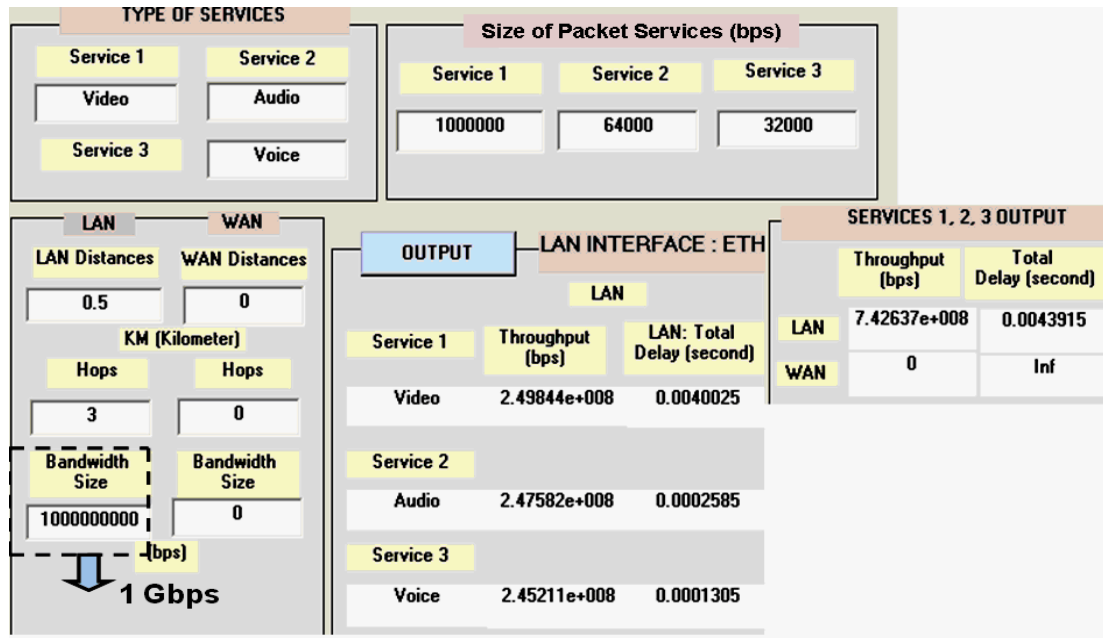
Target Name: <b>www.unikl.edu.my</b> IP: <b>10.42.1.23</b> 10 Samples Timed: 9/11/2007 10:16:45 AM - 9/11/2007 10:17:06 AM										
Hop	Err	PL%	IP	DNSName	Avg	Min	Max	Jttr	Dev	
1			10.6.3.252	-----	2	2	2	0.00	0.0	
2			10.51.1.254	-----	9	9	10	0.67	0.8	
Round Trip:					13	13	13	0.00	0.0	
Target Name: <b>www.unikl.edu.my</b> IP: <b>10.42.1.23</b> 1 Samples Timed: 9/11/2007 11:01:26 AM										
Hop	Err	PL%	IP	DNSName	Avg	Min	Max	Jttr	Dev	
1			10.5.1.252	-----	1	1	1	0.00		
2			10.51.1.254	-----	1	1	1	0.00		
3				-----						
4			10.42.1.23	-----	4	4	4	0.00		
Round Trip:					4	4	4	0.00		
Target Name: <b>www.unikl.edu.my</b> IP: <b>10.42.1.23</b> 1 Samples Timed: 9/11/2007 11:03:23 AM										
Hop	Err	PL%	IP	DNSName	Avg	Min	Max	Jttr	Dev	
1			10.5.1.252	-----	1	1	1	0.00		
2			10.51.1.254	-----	1	1	1	0.00		
3			10.42.1.23	-----	3	3	3	0.00		
Round Trip:					3	3	3	0.00		
Target Name: <b>www.unikl.edu.my</b> IP: <b>10.42.1.23</b> 4 Samples Timed: 9/11/2007 11:07:08 AM - 9/11/2007 11:07:10 AM										
Hop	Err	PL%	IP	DNSName	Avg	Min	Max	Jttr	Dev	
1			10.5.1.252	-----	1	1	1	0.00	0.0	
2			10.51.1.254	-----	0	0	1	1.00	1.0	
3			10.42.1.23	-----	1	1	1	0.00	0.0	
Round Trip:					1	1	1	0.00	0.0	

**Table 5.1:** Type and Size of Services Using in Simulation Model

Data Transfer Flow From Source to Destination Over Network Testbed	
Type of Services	Size of Services
Video	1 Mbps (125000 Bytes)
Audio	64 Kbps (8000 Bytes)
Voice	32 Kbps (4000 Bytes)
Message	8 Kbps (1000 Bytes)

**Figure 5.4:** Prediction and Estimation of 100 Mbps Variables for Remote Data Transfer Using Simulation Model

**Figure 5.5:** Prediction and Estimation of 1 Gbps Variables for Remote Data Transfer Using Simulation Model



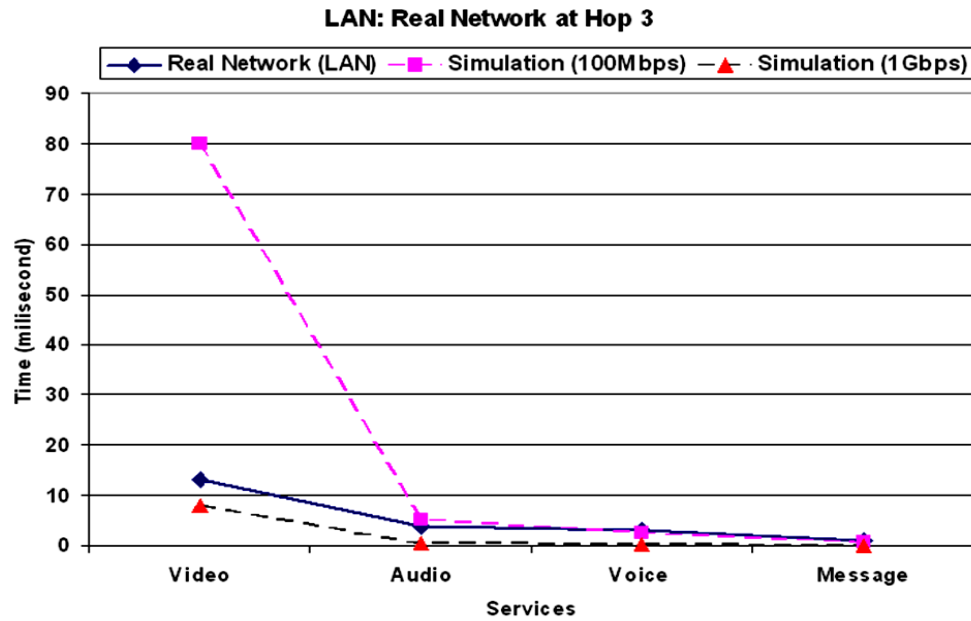
In our experiment using 100 Mbps, it shows that data transfer over video service from source to destination, is not closely to the LAN (real network) environment (Figure 5.6 and Table 5.2). Small size of packet services such as audio, message and voice are closely resemble to the LAN (real network) environment (Figure 5.6 and Table 5.2).

**Table 5.2:** Comparison of Remote Data Transfer between Simulation Model and LAN (Real Network)

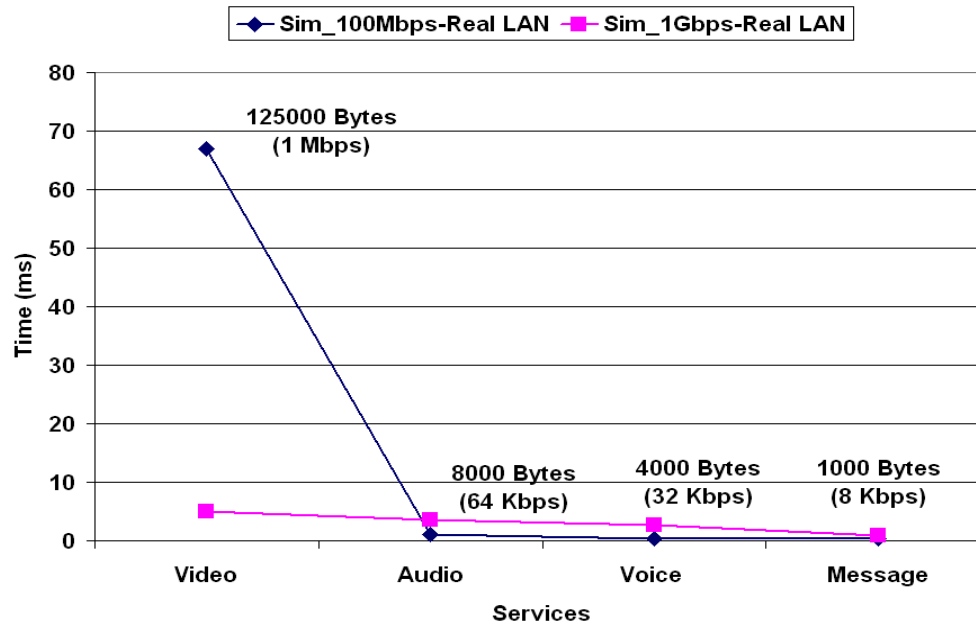
LAN = 100 Mbps and 1 Gbps; Number of Hops = 3; Distances = 0.5 KM			
Type of Services	Real Network for LAN (with network traffic)	Simulation on ideal environment (100Mbps)	Simulation on ideal environment (1Gbps)
Video	13 ms	80 ms	8 ms
Audio	4 ms	5.125 ms	0.517 ms
Voice	3 ms	2.656 ms	0.261 ms
Message	1 ms	0.645 ms	0.069 ms

In real situation our server at main campus is connected with 1 Gbps. The result from our simulation model using 100 Mbps is higher than real network compared to 1 Gbps variable (see Figure 5.6 and Figure 5.7). The reason is simulation model will capture data based on ideal network (no traffic congestion); however in real network environment the data may affect output result caused by traffic congestion from operational network. Simulation model with variable 1 Gbps has shown the result more closely resemble to LAN (real network) for all services (video, audio, voice and message) during data transfer (Table 5.2, Table 5.3, Figure 5.6 and Figure 5.7). As a result, it confirms that our simulation model using 1 Gbps and 0.5 KM variables are closely resemble with real network environment for video, voice, audio and message (see Figure 5.6 and Figure 5.7). Therefore, we will reject 100 Mbps experiment variable and accept 1 Gbps experiment variable in our simulation model. We can conclude and predict that the average of data transfers from source to destination in real network is using 1 Gbps bandwidth link.

**Figure 5.6:** Comparison of Simulation Model Using 100 Mbps and 1 Gbps Variables with LAN (Real Network) Environment



**Figure 5.7:** Comparison of Relative Error Rate between Simulation Model and LAN (Real Network) Environment



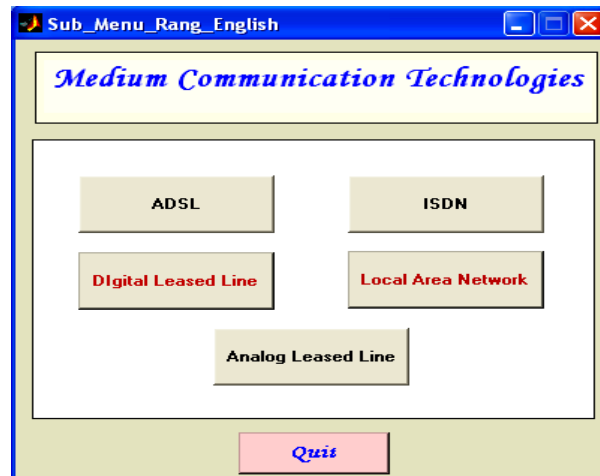
**Table 5.3:** Comparison of Relative Error Rate between Simulation Model and LAN (Real Network)

Type of Services	Sim_100Mbps-Real LAN (ms)	Sim_1Gbps-Real LAN (ms)
Video	67	5
Audio	1.125	3.483
Voice	0.344	2.739
Message	0.355	0.931

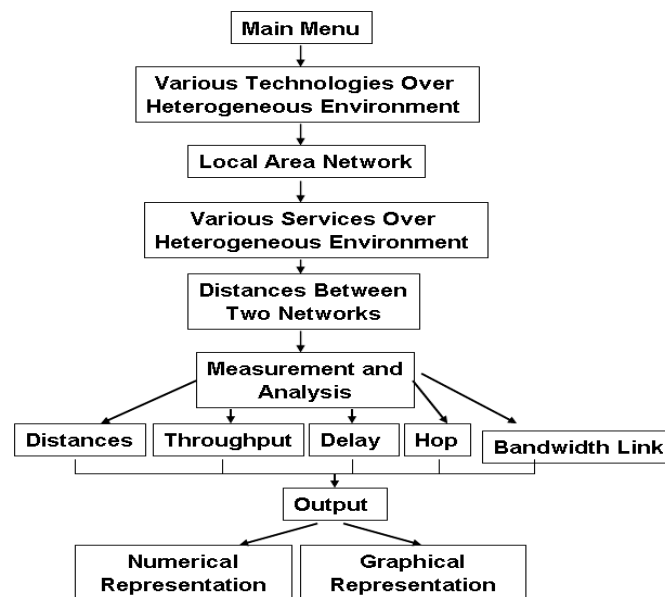
## 6.0. Simulation Model Architecture

A simulation model is set of assumptions concerning the operation of the system, expressed as mathematical, logical and symbolic expressions between the object of interests (entities) of the system. Performance modeling can be done using simulation models or analytical models. Performance modeling is typically used when actual systems are not available for measurement or, if the actual systems do not have test points to measure every detail of interest. Analytical models usually use probabilistic models, queuing theory, Markov models or Petri nets. Figure 6.1 and Figure 6.2 show simulation model architecture, which is used to measure remote data transfers in LAN heterogeneous network environment.

**Figure 6.1:** Main Menu for LAN Remote Data Transfer



**Figure 6.2:** Simulation Model Architecture of Local Area Network in Heterogeneous Environment



## 7.0. Conclusion and Future Work

In this article, we have shown how an analytical queuing network model can be used to understand the behaviors of heterogeneous environment over Local Area Network, LAN (real network). The most apparent aspect is the delay due to the propagation and transmission time. Our simulation model, has

demonstrated that it can measure accurately the performance of heterogeneous services and technologies to transfers data between two networks. Through LAN (real network) experiments, the simulation model is verified and validated for providing accurate performance information for various services. We believe the simulation modeling framework described in this study can be used to study other variations, tunings, and similar new ideas for various services and technologies. In network management, by monitoring and analyzing network delay we can monitor the performance of the network, thus to study whether network is normal, optimal or overloaded. Future work is to develop a simulation model to analyze bandwidth capacity requirement for various services and technologies in heterogeneous environment.

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## **A Software Engineered Voice-Enabled Job Recruitment Portal System**

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### **Abstract**

The inability of job seekers to get timely job information regarding the status of the application submitted via conventional job portal system which is usually dependent on accessibility to the Internet has made so many job applicants to lose their placements. Worse still, the epileptic services offered by Internet Service Providers and the poor infrastructures in most developing countries have greatly hindered the expected benefits from Internet usage. These have led to cases of online vacancies notifications unattended to simply because a job seeker is neither aware nor has access to the Internet. With an increasing patronage of mobile phones, a self-service job vacancy notification with audio functionality or an automated job vacancy notification to all qualified job seekers through mobile phones will simply provide a solution to these challenges. In this paper, we present a Voice-enabled Job Recruitment Portal (JRP) System. The system is accessed through two interfaces – the voice user's interface (VUI) and web interface. The VUI was developed using VoiceXML and the web interface using PHP, and both interfaces integrated with Apache and MySQL as the middleware and back-end component respectively. The JRP proposed in this paper takes the hassle of job hunting from job seekers, provides job status information in real-time to the job seeker and offers other benefits such as, cost, effectiveness, speed, accuracy, ease of documentation, convenience and better logistics to the employer in seeking the right candidate for a job.

**Keywords:** VoiceXML, Web, real-time, Recruitment, Voice and Portal.

## 1. Introduction

Today's competitive business environment has motivated the need for organisations to have the best workforce on their payroll. Employers often receive a large number of applications for an open position due to the strained situation of the labour market. The costs of manually selecting potential candidates have risen and employers are searching for means to automate the selection of candidates (Bizer et al., 2005). Companies therefore must find a more efficient and effective way of recruiting staff into the organisation. In carrying out a recruitment exercise, corporations must offer easy ubiquitous access to enterprise resources and other job information. There should be a flexible means of getting information across to job seekers that have applied for jobs in an enterprise.

Human resources management, like many business transactions, is increasingly taking place on the Internet (Mochol et al., 2007). An Internet based job recruitment portal is one of the conventional means through which job seekers apply for vacant jobs. Using this approach, the job seeker registers and submits his/her Curriculum Vitae (CV) to a web site, while the applicants are expected to periodically check the portal for vacancies that suit the submitted CV. In some cases, a notification is sent by the portal to the email address of the applicant once a vacancy appears. Unfortunately, the only means job seekers (who may be jobless) use in getting information about a vacant job is either through an email or by login into the job portal. In either case, access to the Internet is a necessity.

It is the desire of most organisations to provide self-service solutions. The advent of fast and accurate speech recognition in the late 1990s accelerated the move to self-service systems (Markowitz, 2005). The conventional web portal does not normally offer self-service solutions. There is a large number of online commercial job portals competing to publish job postings for a fee (Mochol et al., 2007), these includes (NigeriaJobsOnline, 2005; CareersNigeria, 2008) amongst others. Most of the existing solutions do not provide an effective mechanism for interactive voice response (IVR) between the job seeker and the system. The conventional practice is a web content with links for navigating from one page to another, using Internet browser. The technology that integrates IVR, VoiceXML and the web is still an open area of research.

A portal is a web system with functionalities to authenticate and identify users as well as provide them with an easy, intuitive, personalized and self-customizable web-interface for facilitating access to information and services that are of primary relevance and interests to the users (Ho, 2002). A portal that is not voice-enabled has limited access to the Internet resources. A voice-enabled job portal is a web based application used by job applicants and employers for managing the profile of job seekers and employers (Voicee-Solutions, 2007).

Voice applications are commonly developed using Voice eXtensible Mark-up Language (VoiceXML), also known as VXML. It is a web-based mark-up language for representing human-computer dialogs, just like Hypertext Mark-up Language (HTML). But while HTML assumes a graphical web browser, with display, keyboard and mouse, VoiceXML assumes a voice browser with audio output (computer-synthesized and/or recorded human speech), and audio input (voice and/or keypad tones) (Gallivan et al., 2002). VoiceXML technology allows a user to interact with the Internet through voice-recognition technology by using a voice browser and/or the telephone. The major goal of VoiceXML is to bring the advantage of web based development and content delivery to Interactive Voice Response (IVR) (Voiceportalwhitepaper, 2001).

The remaining part of the paper is structured as follows: Section 2 discusses the methodology captured by software development life-cycle model. A discussion is presented in section 3. The paper is concluded in section 4.

## 2. Methodology

The system uses a client/server architecture. The client application which can be accessed through a telephone network was developed using VoiceXML. The server logic was implemented with Hypertext



Pre-processor (PHP). Apache was used as the middle-ware and MySQL database as the back-end component. The choice of VoiceXML was due to the fact that it is a foundation platform for developing and operating voice automation applications (Rouillard, 2007). PHP, Apache and MySQL were selected because of their advantage as free and open source software (Siemens, 2003).

After developing the application, the VoiceXML and the PHP code were deployed on a voice network and application servers to make room for dual access using telephony and the web.

The application has dual interface: a) a PHP-based web interface, that provides enrolment and access functionalities to job seekers, employers and the portal/site administrator; b) a VoiceXML-based phone interface, where users call in to get job information. MySQL database was used as the back-end.

### 3. System Design and Implementation

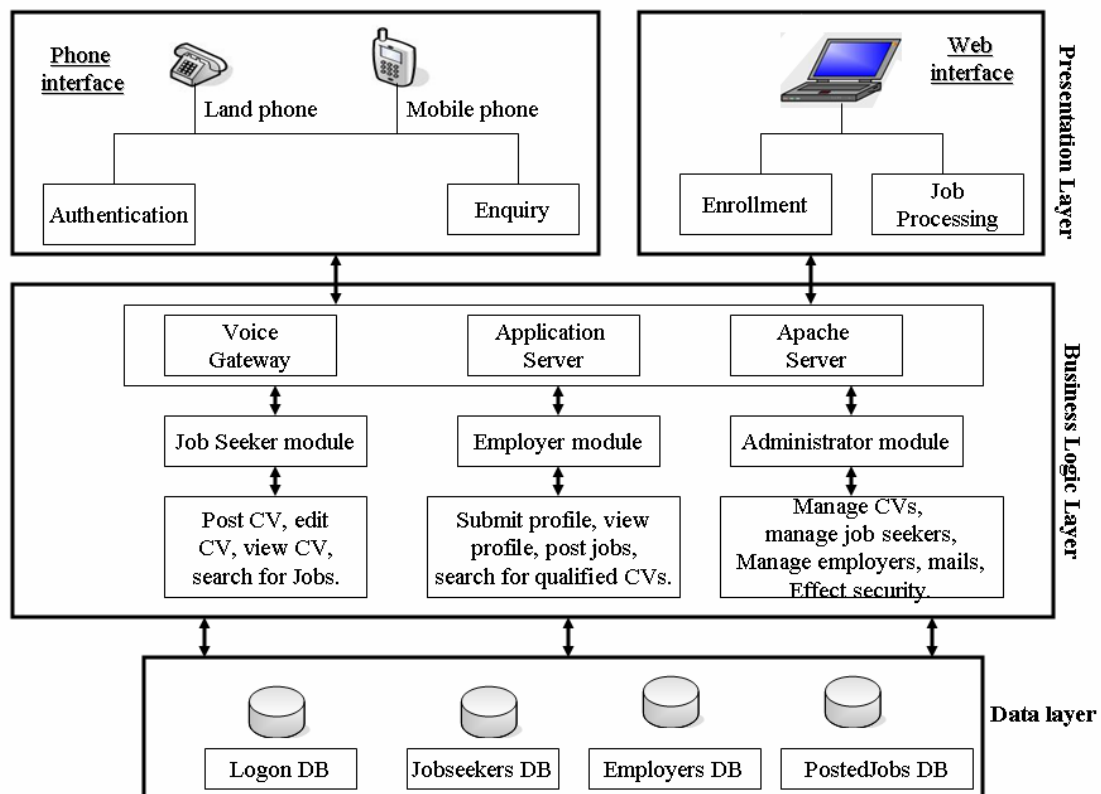
The software and hardware architectures of the system are presented as well as the interaction among the major parties through a collaboration diagram.

The software and hardware architectures are described in this section. The architectures presented allow easy access to vacancy information from any point at any time using either a mobile phone or land phone.

#### 3.1. Software Architecture

Figure 1 gives the logical view of the architecture for implementing the system. The architecture shows the locations of each of the module in the system. It consists of the client interface, middleware and database services. The presentation tier communicates with the voice gateway component of the middle-tier through the voice browser. The middle-tier contains the voice gateway and the application logic. The database is separated from the client by the middleware.

**Figure 1:** Software Architecture for the JRP Application

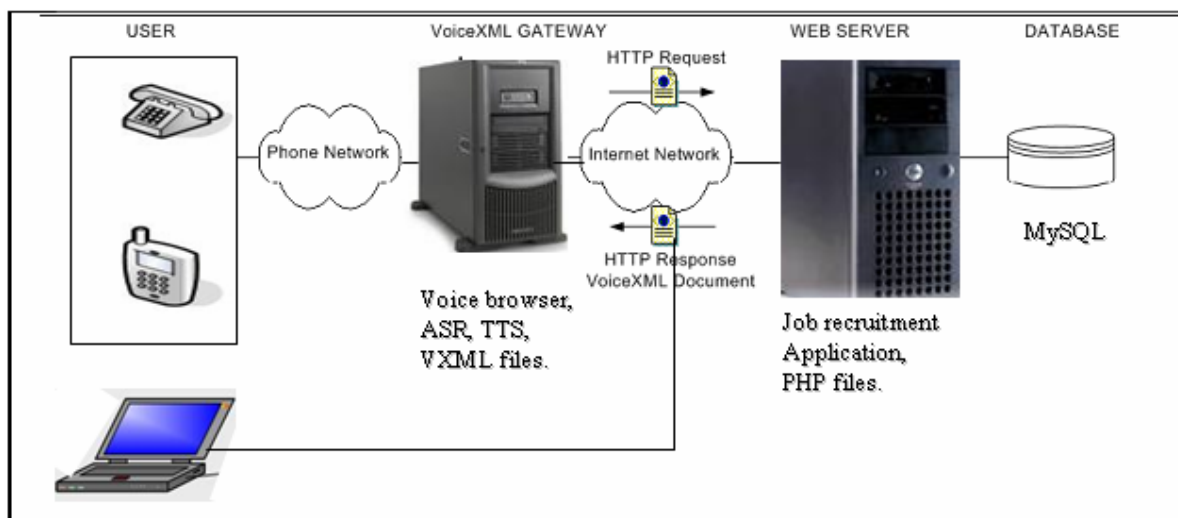


The presentation layer provides client access to the JRP through the middleware. The components of the client phone interface are Authentication and Enquiries, while the web interface has Enrolment and Job Processing. These components do not store or process any form of data, they only serve as interface to the middle layer and the data layer. Data files are not stored on the mobile phones due to resource constraints associated with hand-held devices. The application is designed to use telephone and allows voice browsers (running on the voice gateway) to be used as interface. Users access the application from various mobile telephone devices and land line telephone in real-time. Once a user has been authenticated, the user query is translated by the Automatic Speech Recognizer (ASR) to text and passed to the database server for processing. A Text-to-Speech system provides the reverse of the speech recognition process: that is converting text to speech. The data layer is responsible for uttering, adding, or deleting information in the database within the system. MySQL was used as database for the implementation of the data layer. The information from the database is presented in a compatible form to the client using the voice browser. The database server provides data services and database management system function. The servers hold all the applications. A user can only access the module for which she/ he has authorisation. The client application interfaces to the application layer through the voice gateway.

### 3.2. Hardware Architecture

The hardware architecture is presented in figure 2. It consists of a complete range of robust, high performance clients, voice gateway and web server platforms with the integrated job recruitment application.

**Figure 2:** Hardware Architecture for the Application



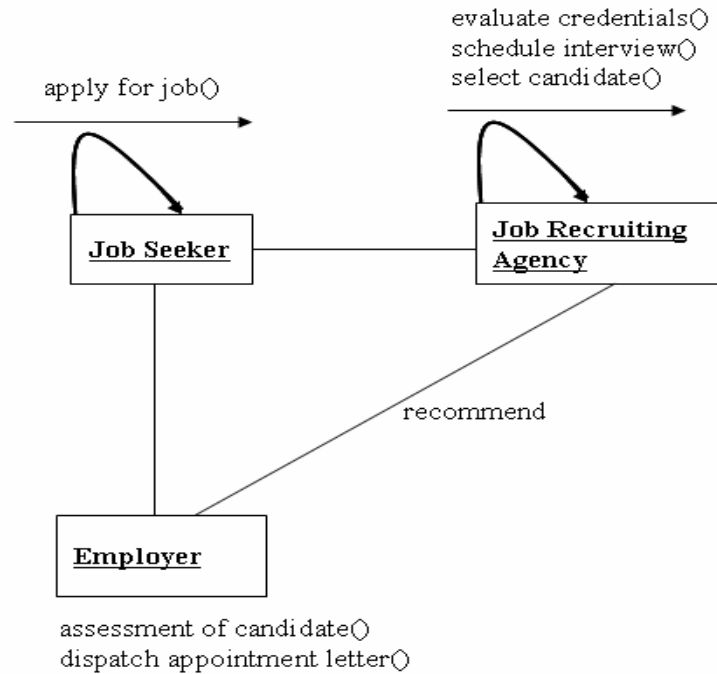
The client systems include land phones and mobile phones such as Personal Digital Assistant (PDA), cell phone and smart phone and other handheld communication devices. The server stores the JRP application and is used to maintain internet connectivity with the voice gateway. The robust web server provides real-time access to the job database.

### 3.3. Requirements and Modeling

The process of applying for a job through an online job recruitment portal involves submitting a CV during the registration process on the portal. The Job portal is either owned by a recruiting agency or an employer. If it is owned by a recruiting agency, the application is processed and the candidate is evaluated, and either recommended to the employers for further assessment, placed on the list or disqualified. The cooperation between the different actors in the job recruitment process is modelled

with Unified Modelling Language (UML) collaboration diagram in Figure 3. The UML is a visual language that provides a means of visualizing, constructing and documenting the artefacts of software systems (Bennett et al., 2005).

**Figure 3:** Collaboration diagram for online job recruitment portal (JRP) application



### 3.4. VUI module design

Every authenticated user of the application will undergo a question and answer session, which will be matched against the database content, and the result received by the user through voice output. The pseudocode in Figure 4 describes a segment of the implementation of the developed JRP application.

**Figure 4:** Pseudocode for online job recruitment portal (JRP) application

```

BEGIN
    SYSTEM PROMPT 'Welcome to our Voice-enabled Online Job Recruitment Portal (JRP) System';
    //Caller supplies a username and password
    SYSTEM AUTHENTICATES CALLER;
    //Caller supplies information requested by the SYSTEM
    WHILE NOT EOF DO
        SYSTEM request for HIGHEST QUALIFICATION from caller;
        CALLER supplies HIGHEST QUALIFICATION;
        SYSTEM request for YEAR OF GRADUATION from caller;
        CALLER supplies YEAR OF GRADUATION;
        SYSTEM request for YEARS OF EXPERIENCE from caller;
        CALLER supplies YEARS OF EXPERIENCE;
        SYSTEM request for AGE from caller;
        CALLER supplies AGE;
        // system check for the rule in database that match the data supplied by caller and display the
        // corresponding information.
        IF HIGHEST QUALIFICATION == database(h_qual) and GRADUATION == database(grad) and
            EXPERIENCE == database(exp) and AGE == database(age)
        THEN SYSTEM PROMPT " vacant position exist for you as an Information Systems Manager in
            Mobile Oil Nigeria Limited. Log into the job portal at http://www.autosp.byethost13.com/jrp-jobs
            to apply. Good Bye.
        ELSE SYSTEM adds enquiry to database;
            SYSTEM process enquiry;
            SYSTEM sends a notification to CALLER;
        ENDIF
    ENDDO
END

```

### 3.5. Testing and Deployment

Testing is a vital stage in the development of any system. A phone emulator was downloaded and used to execute and test the application on a local computer before deploying to the web. The user logs onto the web site using a “userid” and “password” specific to their registration profile. The information on the web is divided into three categories – the author session, employer session and administrator session. To login into the job seeker or employer session, a user must first click on free registration to create his/her profile, and either applies for a job as a job seeker or post jobs as an employer.

## 4. Discussion

The VoiceXML application (phone interface) was deployed on a voice server on the web and accessed from any telephone using the format:<source country code><destination country code><destination area code><generated voice network 7-digit number>.

Simply dial: 009-1-720-2598922 or 009-1-312-4360561 or 009-1-407-9650231 from any mobile or land phone to connect to, and execute the application. The default username is “*admin*” and password is “*admin*”.

Figures 5 and 6 are screen shots of voice interaction between the caller and the system for JRP system accessed through a Nokia 6301 mobile phone.

**Figure 5:** Dialling, request for qualification and caller's response session

The application is launched using a phone by dialling any of the recommended phone numbers. Once connected, the system will be prompt with a welcome message and go ahead to authenticate the user's name and password before any transaction ensues. The system will ask for the services or enquiries demanded by a job seeker or employer.

**Figure 6:** Request for year of graduation, caller's response and a system message.

Similarly the web application (web interface) has been deployed on a web server on the Internet and can be accessed using desktop PCs by visiting the URL - <http://www.autosp.byethost13.com/jrp-jobs>. To access the administrator's module, simply visit the URL <http://www.autosp.byethost13.com/jrp-jobs/admin> and enter "admin" as user id and "admin" as password. The password may be changed after a successful login.

Figure 7 contains a screen shot of the web interface showing *Registration page* of a job seeker.

**Figure 7:** Registration page for a job seeker

Job Recruitment Portal (JRP)

Open a Free account today !

**Job Seekers**

- Login
- Free Registration
- Post Resume
- Edit Resume
- View My Resume
- Search Jobs

**Login**

**Job Seekers**

Username:

Password:

Login

**Employer's**

Username:

Password:

Login

Username: \*  max. 10 symbols (letters and/or numbers)

Password: \*  max. 10 symbols (letters and/or numbers)

Confirm password: \*

Title: \*

First name: \*

Last Name: \*

City: \*

State:

Country: \*

Zip:

Address: \*

Phone: \*

Phone #2:


E-mail: \*

Target company:

**Employer**

- login
- Register Here
- Post Job
- Search

**Advertisement**



job Posting

**Links**

## 5. Conclusion

In this paper, we have successfully designed, developed and deployed on the web, an online voice-enabled JRP system to enhance the speed and convenience of applying for a job and the management of the entire job recruitment process, as it affects job seekers, employers and the administrator (site owner).

The system will assist the job seekers in getting a first hand and timely information regarding the existence of a vacancy to which a CV has been submitted, on a self-service bases. The JRP to a large extent will ensure that the right candidate invited for a job selection is not left out of the recruitment process, by posting vacancy information from the portal to the mobile phones of job seekers. The system will eliminate all form of paper work involving stationeries, logistics, etc, used by the employers or recruitment agency during a recruitment exercise, leading to cost savings, speed and operating efficiency.

Finally, the application will save the recruiting agencies the hassles of recruiting candidates, particularly for large population, since the portal operates on a self-service bases. The portal will widen the scope of job seekers and employers, including those from outside the country. Since most of the developing countries have infrastructural challenges towards providing a problem free Internet services for their citizenry, job seekers within these region will find JRP very useful. The integration of mobile phone further enhances the accessibility of the system.

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## **Ecologie des Sarcelles D'hiver *Anas Crecca Crecca* L. Hivernants Dans L'éco-Complexe de Zones Humides de Jijel (Nord-Est de L'algerie)**

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### **Summary**

The ecological study of the green winged Teal in two humid sites of the eco-complex of Jijel wetlands (North-East of Algeria) showed many similarities. Béni-Belaid Lake, which has water throughout the year and because of its geographical position near the Mediterranean, was firstly visited. The marsh of El-Kennar which dries during the summer season has not been colonized by this species until the end of October. These Anatidae leave chronologically the Lake of Béni-Belaid then the marshes of El-Kennar which hosted the largest numbers (twice than that of Béni-Belaid Lake).

Diurnal time activity budgets were quantified in the both sites and showed that sleeping is the most important activity. It largely dominates their time budget (58.27% in Béni-Belaid Lake and 61.68% in El-Kennar marsh). It is followed by swimming with 21% in Béni-Belaid Lake and 19% in El-Kennar marsh, then preening and grooming (15.93% in Béni-Belaid Lake and 08.96% in El-Kennar marsh). Food is, however, noted with very low rates in Béni-Belaid Lake (01.43%) and is sporadically high in El-Kennar marsh (09.5%). At the end, the flight characterizing regrouping occurred following a disturbance; however, it is the lowest represented activity. As a result, the two studied wetlands sites play clearly the role of roosting area of diurnal time-activity budgets for the wintering populations of green winged Teal.

**Keywords:** Teal, Anatidae, *Anas crecca crecca*, diurnal time-activity budgets, wetland, Jijel, Algeria, *focus*, sleeping area, feeding area.

### **Introduction**

Parmi les 256 sites d'importance internationale pour les canards en Afrique et en Eurasie 190 soit 74%, sont protégés (Scott et Rose 1996 in Guillemain *et al.*, 2002). La définition des rythmes d'activités d'un oiseau d'eau et principalement celui d'un canard constitue une base fondamentale dans l'analyse de l'écologie et de l'occupation spatio-temporelle d'une zone humide par cette espèce. La Sarcelle d'hiver *Anas crecca crecca* qui constitue avec le Canard Siffleur *Anas penelope* le Canard Souchet



*Anas clypeata*, le Canard Colvert *Anas platyrhynchos*, le Fuligule Nyroca *Aythya nyroca*, le Fuligule Milouin *Aythya ferina* et la foulque macroule *Fulca atra* les sept espèces les plus habituées des écosystèmes aquatiques méditerranéens. Elle a fait l'objet d'innombrables travaux en Europe qui ont montré son caractère nyctéméral (Tamisier 1966, 1974, Gauthier-Clerc *et al.* 1998, Guillemain *et al.* 2002, 2005), en Amérique (Rave et Baldassarre 1989, Paquette et Ankney 1998) en Afrique du nord et principalement dans l'éco-complexe de zones humides du Nord-Est de l'Algérie (Samraoui et De Belair 1998, Houhamdi 2002, Houhamdi et Samraoui 2001, Mayache *et al.* soumise). Ainsi, cet anatidé fréquente régulièrement deux sites différents pendant son hivernage; les terrains de remises durant les journées et les terrains de gagnages pendant les nuits. Les lieux de remise sont habituellement pauvres, saumâtres mais offrent une grande sécurité, tandis que ceux du gagnage sont généralement riches en végétation hélophytes et en graines (Thomas 1976, 1982, Tamisier 1972a, 1972b, Tamisier et Dehorter 1999). Le suivi des rythmes d'activités de la Sarcelle d'hiver *Anas crecca crecca* dans deux sites du littoral Algérien; le lac de Béni-Bélaid et le marais d'El-Kennar. Ces deux milieux par leurs caractères peu saumâtres et riches en végétation aquatique présentent des similitudes et des différences avec les autres sites humides méditerranéens. Cependant, ils n'ont fait l'objet d'aucune étude scientifique mise à part celle de De Belair et Samraoui (2000) représentent d'une part un quartier d'hivernage important pour de nombreuses espèces avifaunistique et d'autre part des lieux de stationnement habituels pour cette espèce d'Anatidés.

## Matériel et Méthodes

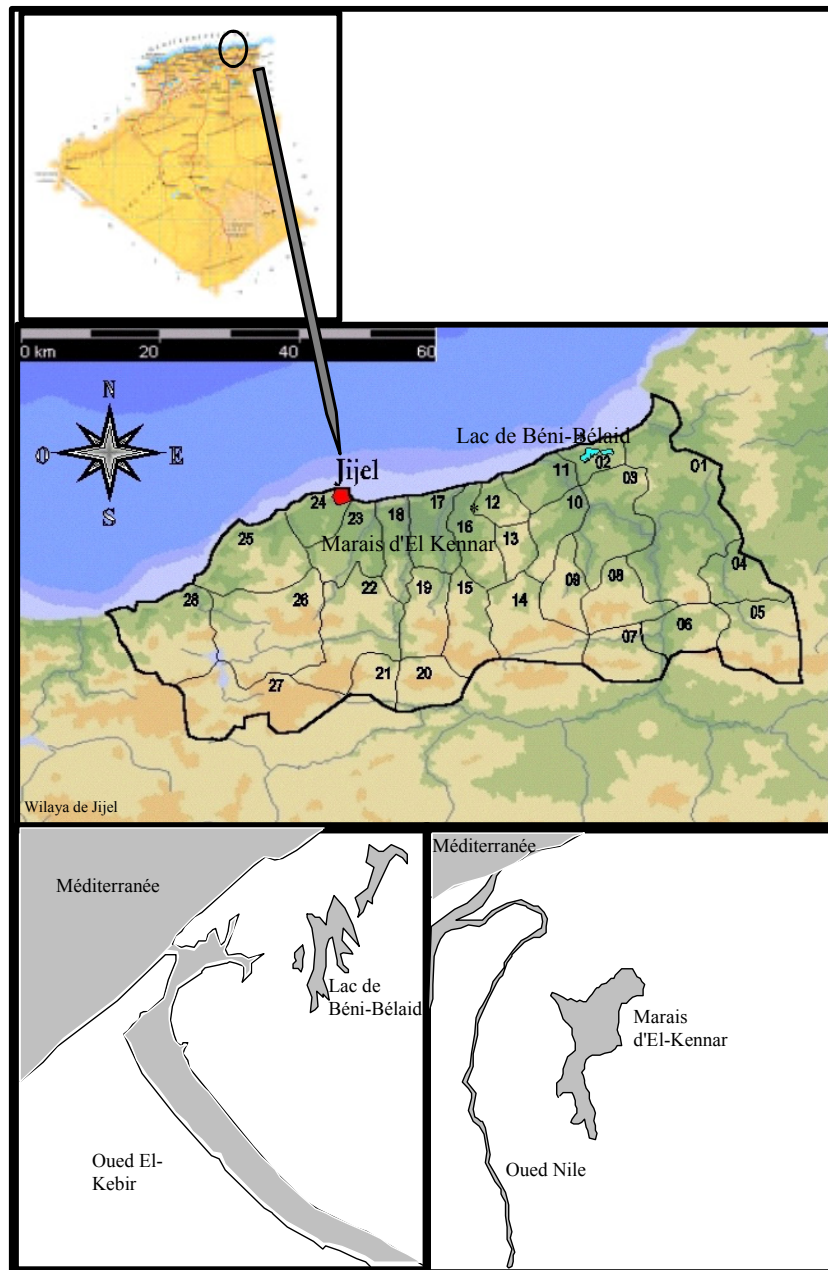
L'hivernage de la Sarcelle d'hiver *Anas crecca crecca* dans les zones humides du Nord-Est Algérien et en particulier dans la région de Jijel constitue une étape importante dans le déterminisme du rôle écologique de cette espèce. Dans cet objectif un dispositif de deux années consécutives a été mis en place depuis octobre 2000 afin d'étudier et de suivre cet Anatidé dès son arrivée et sa colonisation des deux milieux jusqu'à sa disparition totale (migration prénuptiale) vers la fin du mois de février début mars. Ce dispositif vise à déterminer approximativement l'effectif hivernant et au même temps suivre les rythmes d'activités diurnes manifestés par la sarcelle d'hiver (canard de surface) à l'aide d'une paire de jumelle *Konus* 7x50 et d'un télescope *Meopta* 20x60. Le dénombrement s'est effectué systématiquement dès leur observation dans les deux sites à raison d'une sortie par semaine, en procédant à un comptage individuel; si l'effectif total ne dépasse pas les 200 individus ou à une estimation visuelle; si le nombre total est supérieur à 200 individus, ou si le groupe d'oiseaux est situé à une distance très éloignée (Lamotte & Bourlière 1969, Blondel 1975). Ces dénombrements plus ou moins structurés s'accompagnent d'une localisation spatiale de ces groupes d'effectifs sur une carte à l'endroit où ils sont observés afin de déterminer le rôle que joue la végétation aquatique dans le maintien de l'espèce ainsi que les interrelations existantes entre Sarcelle d'hiver et plantes aquatiques.

Nous avons aussi procédé à un suivi rythmé du comportement de ces groupes de Sarcelles ayant colonisés les deux plans d'eau suivant la méthode *focus* (focal animal sampling) (Altman 1974, Baldassarre *et al.* 1987, Lositho *et al.* 1989). Cette opération a été réalisée hebdomadairement dès débuts des matinées, soit de 8h jusqu'à la fin de la journée afin de mieux caractériser les variations journalières du budget temps et mieux suivre le bilan des rythmes d'activités pendant tout leur séjour dans les deux zones humides. Ainsi, dans cet objectif, nous nous sommes basés de suivre pendant 10 minutes un individu bien déterminé et noter toutes ces activités manifestées dont la nage, le sommeil, l'alimentation, la toilette (entretien du plumage) et le vol. Les données récoltées sont ensuite exploitées par analyse multivariée (AFC) grâce au logiciel ADE-4 (Chessel et Doledec 1992).

### **Description de L'éco-Complexe de Zones de Jijel**

L'éco-complexe de zones humides de la wilaya de Jijel (Nord-Est de l'Algérie) renferme un nombre appréciable de zones humides dont les plus importantes sont le lac de Béni-Bélaid ( $36^{\circ}52' 28''N$ ,  $6^{\circ}6'7.42''E$ , 46 ha), le marais de El Kennar ( $36^{\circ}49' 26''N$ ,  $6^{\circ}56'52''E$ , 10 ha), le marais de Redjla, (Taher); les retenues collinaires de Chekfa et de El-Aouana (Fig.1). Sur le plan ornithologique, ces écosystèmes aquatiques ont été depuis longtemps ignorés et ce n'est qu'en 1992 que le Parc National de Taza (Jijel) a commencé des opérations annuelles de comptage des oiseaux d'eau de la région. Durant l'année 1997, dans le cadre d'un projet *MedWet2*, une étude écologique de cet éco-complexe de zones humides a été réalisée par le Laboratoire de Recherche des Zones Humides (LRZH, Université de Annaba). Elle est basée sur un inventaire intensif de toutes les espèces végétales et animales de la région (De Bélair et Samraoui, 2000). L'inventaire de la faune a montré la présence de deux espèces de mammifères, trente trois espèces d'oiseaux d'eau, trois espèces de poissons, deux espèces d'amphibiens, deux espèces de reptiles et dix huit espèces d'odonates. La présence d'une espèce rare la loutre *Lutra lutra*, du fait d'une forte persécution humaine a mérité d'être soulignée.

**Figure 1:** Situation géographique des zones humides de l'éco-complexe de Jijel (Nord-Est de l'Algérie).



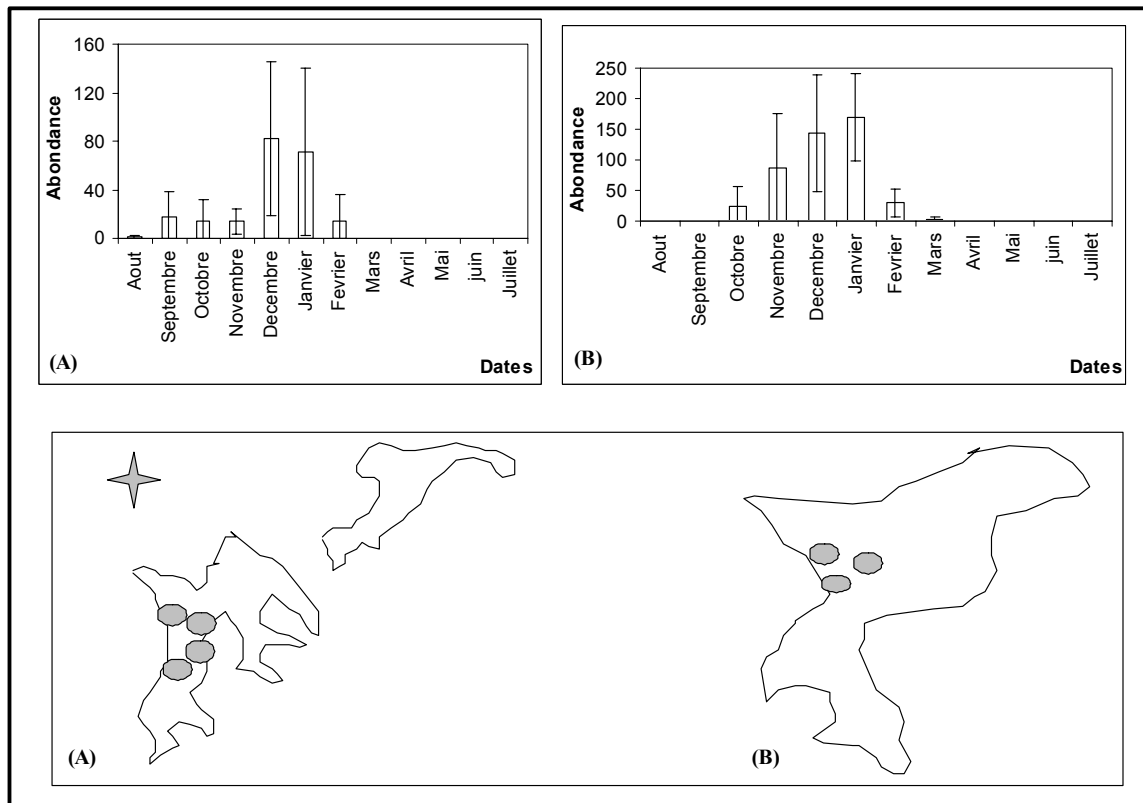
## Résultats et Discussion

### 1. Phénologie et structure de la Sarcelle d'hiver

La Sarcelle d'hiver *Anas crecca crecca* après deux années d'étude et d'observations s'est caractérisée par sa colonisation précoce du lac de Béni-Bélaid (Fig.2). Les premiers hivernants sont enregistrés vers la fin du mois d'août. Leur effectifs demeure faible (2 à 4 individus) puis augmente progressivement suite à l'arrivée de petits groupes durant les mois de décembre et janvier amenant l'abondance totale à 80 individus. L'espèce quitte définitivement le plan d'eau vers la fin du mois de février. La fréquentation du marais d'El-Kennar par cette espèce est liée à sa mise en eau souvent tardive. Les premiers colonisateurs du site sont enregistrés dès la mi-octobre avec des effectifs plus nombreux qui augmentent progressivement pour atteindre un maximum de 169 individus durant le mois de janvier. Des effondrements successives, traduisant des migrations pré-nuptiales sont aussitôt observées ramenant l'abondance totale à néant durant le mois d'avril. Au total la Sarcelle d'hiver *Anas* sept à huit mois allant du mois d'août au mois de février dans le lac de Béni-Bélaid et du mois d'octobre au mois

de mars dans le marais d'El-Kennar, exhibant des phénologies et des structures très variés. Les populations de cette espèce se sont généralement concentrées dans les régions centrales des deux plans d'eau (Fig.2). Ces régions sont peu profondes et loin de tous dérangements sont cependant riches en végétation aquatique principalement *Myriophyllum spicatum* et *Potamogeton pectinatus*.

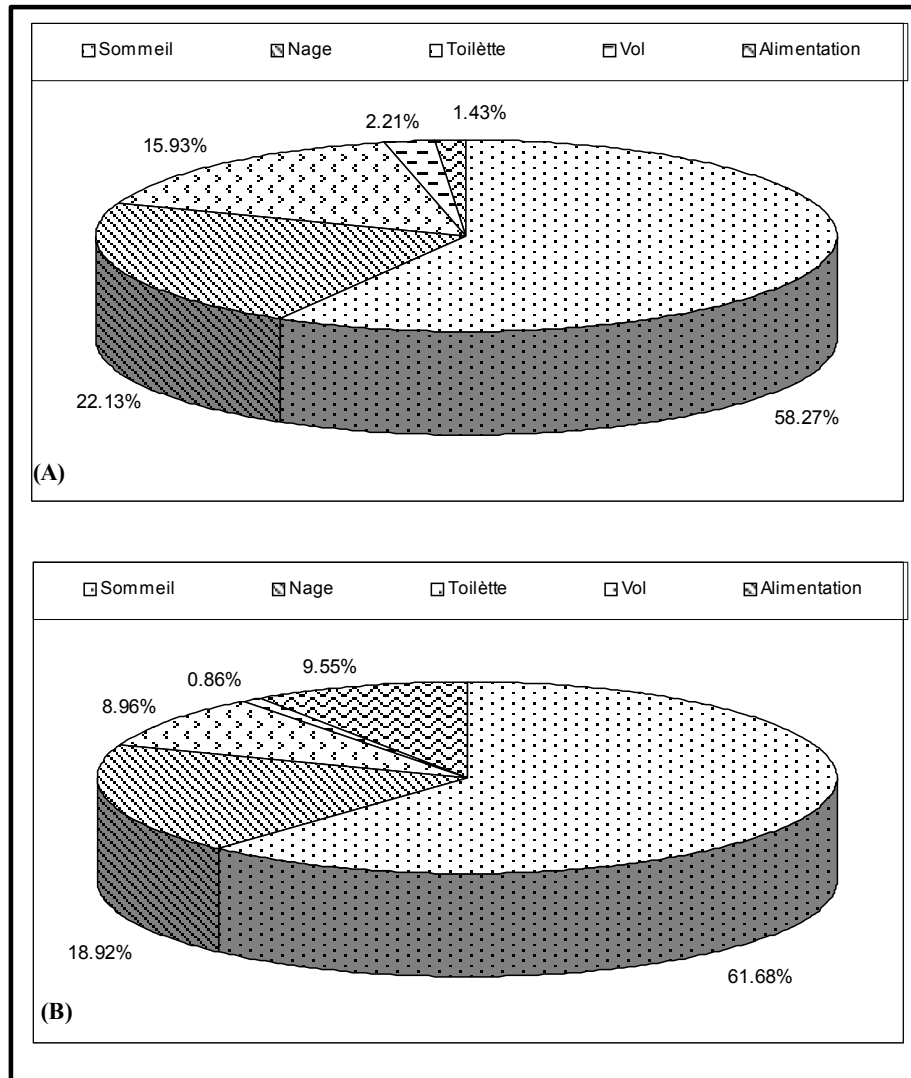
**Figure 2:** Évolution des effectifs de la Sarcelle d'hiver dans le lac de Béni-Bélaïd (A) et dans le marais d'El-Kennar (B).




## 2. Comportement diurne de la Sarcelle d'hiver

Le suivi de leurs activités diurnes dans ces deux zones humides classées réserves de la biosphère (34h dans le lac de Béni-Bélaïd et 37h dans le marais d'El-Kennar) nous expose que le repos diurne représente l'activité principale de cette espèce avec une dominance dépassant largement les 50% (Fig.3). Il est suivi de l'activité de la nage avec des taux avoisinants les 20% puis des autres activités avec des taux plus ou moins variables.

**Figure 3:** Budget temps des Sarcelles d'hiver hivernant dans le lac de Béni-Bélaïd (A) et le marais d'El-Kennar (B) (Jijel, Algérie).



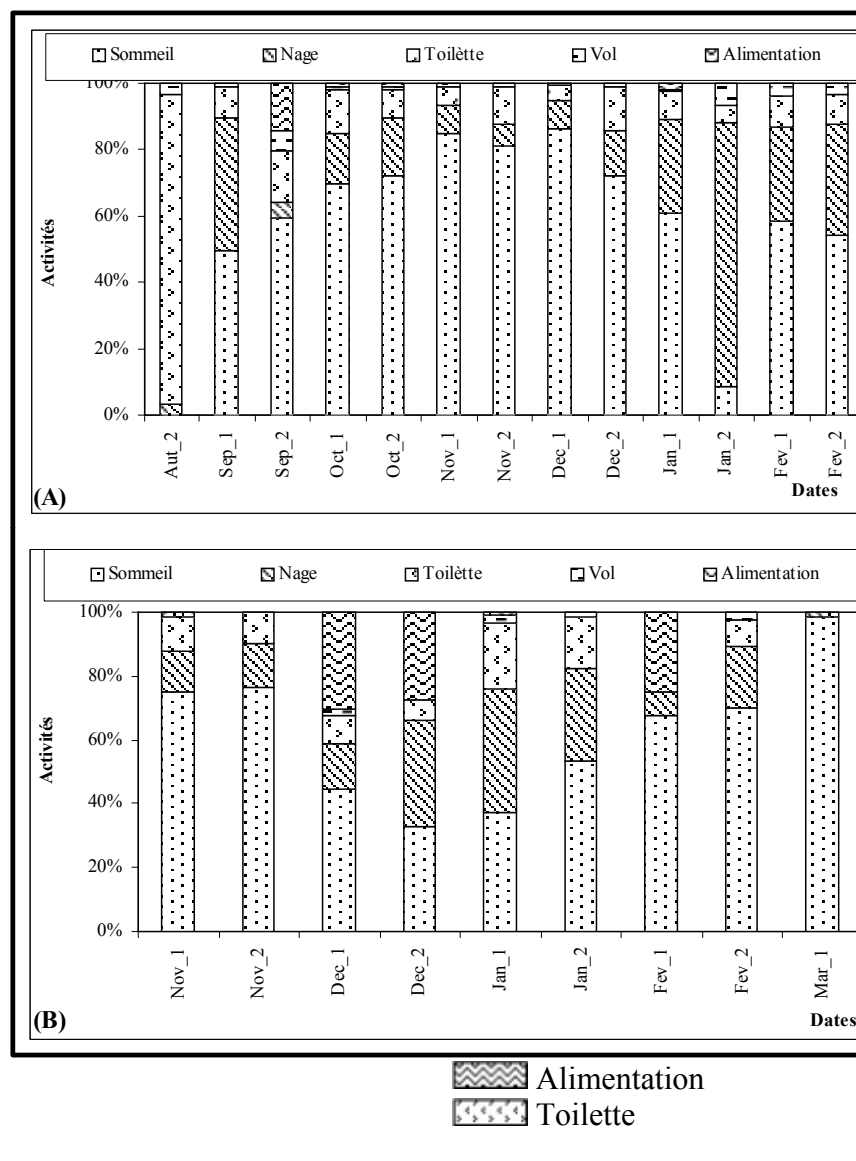
 Sommeil  
 Nage  
 Vol

 Alimentation  
 Toilette

Le sommeil dominant ce bilan total de ces rythmes d'activités est noté avec 58% dans le lac de Béni-Bélaïd et 62% dans le marais d'El-Kennar (Fig.4). Dans le premier site, cette activité qui est notée avec des taux très faibles chez les premiers hivernants (individus éclipses) augmente progressivement pour atteindre un taux de 86% observé durant le début du mois de mars. Elle diminue aussitôt après et ce jusqu'à leur disparition totale du site. Dans le marais d'El-Kennar, où l'espèce n'est observée qu'à partir du mois de novembre, autrement dit juste après sa mise en eau, l'activité du sommeil est notée avec des taux très élevés durant le début et la fin de la saison d'hivernage, soit pendant les mois de novembre, février et mars. Des légères diminutions sont observées pendant le mois de décembre. Elles se résument à l'observation de l'activité d'engraissement chez les populations de passage. Ainsi, ces sarcelles ont manifestées leur activité de sommeil en groupes (grégarisme caractéristique de l'espèce) dans les lieux dégagés des deux plans d'eau, sur les berges, sur les branches de Tamarix et près des juchées sur des touffes de végétation (*Sirpus maritimus*, *typha*

*angustifolia*, *Iris pseudoacorus*). En effet, le sommeil exprime une phase de moindre dépense énergétique; les déperditions de chaleur sont ainsi réduites et la durée prolongée du sommeil permet à cette espèce de maintenir leur stock de réserves (principalement lipidiques) impératif pour résister aux températures basses du milieu (Tamisier 1972a). La conservation des réserves lipidiques à la fin de la saison est aussi essentielle pour préparer les longues migrations prés-nuptiales. Il est néant moins important de signaler que chez cette espèce, les quartiers d'hivernage sont généralement composés de deux types de milieux: les remises diurnes et les gagnages nocturnes (Tamisier 1978/1979, Quilan et Baldassarre 1984, Rave et Baldassarre 1989, Houhamdi et Samraoui 2001). Cette activité dominante est souvent interrompue par la présence des prédateurs tel le Goéland leucophée *Larus michahillis* et le Busard des roseaux *Circus aruginosus* nécessitant une grande vigilance: sommeil vigilant (Gauthier-Clerc *et al.* 1998).

**Figure 4:** Évolution des activités diurnes des Sarcelles d'hiver *Anas crecca crecca* hivernant dans le lac de Béni-Bélaid (A) et le marais d'El-Kennar (B) (Jijel, Algérie).



La nage occupant le deuxième rang dans le bilan de ces rythmes d'activités avec des taux avoisinants les 20% est observée le plus souvent chez les petits groupes de Sarcelles d'hiver. Elle est observée avec un taux de 19% dans le marais d'El-Kennar et 21% dans le lac de Béni-Bélaid (Fig.3). L'évolution de cette activité présente des graphiques différents dans les deux hydrosystèmes. Ses valeurs les plus élevées sont enregistrées vers la fin de la saison d'hivernage dans le lac de Béni-

Bélaïd, soit pendant les mois de janvier et de février et au milieu de la saison dans le marais d'El-Kennar, soit durant les mois de décembre et de janvier (Fig.4). Cette activité est notée au détriment de l'activité du sommeil qui exhibe pendant ces périodes ces taux les plus faibles. Les taux enregistrés sont largement supérieures à celles de ces congénères hivernants en Louisiane: 08.6% de nage (Rave & Baldassarre 1989) et au Texas: 09.5% (Quilan & Baldassarre, 1984, Quinlin & Bolen 1988). Cette activité est souvent considérée chez les Anatidés comme un comportement non typique, essentiellement collectif (grégaire) et permettant un déplacement progressif du groupe afin de faire face à la dérive occasionnée par le vent (Tamisier 1972a). Elle correspond dès fois à un moyen de revenir à une activité normale après des dérangements (Klima 1966 in Tamisier 1972a). Elle permet aussi aux jeunes Anatidés de former les couples et d'exhiber des comportements nuptiaux durant la saison d'hivernage (Houhamdi 2002, Houhamdi et Samraoui 2001, 2003). En Europe et en Amérique ces parades nuptiales sont observées chez les petits groupes (Mac Kinney 1965, Tamisier 1979, Johnson and Rohwer 1998). Dans le lac de Béni-Bélaïd, nous avons notée cette activité (comportement de formation de couples) dès le mois de décembre, confirmant les données de (Mac Kinney et Stolen 1982, Green *et al.* 1994, Pearce 2000). Les conditions climatiques les plus favorables pour l'observation de ces comportements sont les journées ensoleillée et calmes.

L'activité de l'entretien du plumage, de graissage et de toilettage est notée massivement chez les premier individus éclipses occupants du lac de Béni-Bélaïd (Fig.4). Un effondrement brutal est aussitôt noté ramenant le taux de cette activité à 09% et se stabilise pendant toute la saison d'hivernage. Cette activité a été aussi notée dans le marais d'El-Kennar avec des taux faibles avoisinants les 09-20%. Elle est généralement manifestée près des berges dans les zones dégagées de végétation. Les Sarcelles entretiennent leur plumage en se lissant ou en barbotant dans les flaques d'eau. La toilette à lieu le jour sur les remises, pendant l'heure qui suit l'arrivée sur ces lieux et cela pour réarranger les plumes après le vol.. Ces canards de surface viennent d'effectuer leur migration d'automne (migration postnuptiale) et doivent éprouver un besoin de ramener la disposition de leurs plumes, comme elles le font chaque matin après le vol de déplacement entre les gagnages et les remises (Tamisier 1972a). La formation des plumes (la mue) coïncide avec le début de l'hivernage; de fin juin au début septembre pour les males et de la mi-juillet au début d'octobre pour les femelles (Brickel 1988). L'apparition des plumes à la surface de la peau ce n'est que l'étape finale de la mue et la formation des plumes commence bien avant ce qui provoque une certaine irritation qui nécessite une forte activité de toilettage. Ainsi, d'après la littérature scientifique, les valeurs les plus élevées de cette activité sont observées au début de la saison d'hivernage et juste après la migration post-nuptiale, correspondant à des exigences bien définies et deviens donc impérative (Tamisier 1966, Tamisier et Dehorter 1999). D'une manière générale, entretenir son plumage se résume à étaler à la surface de la peau des sécrétions de la glande Uropygienne (glande externe que la plus part des oiseaux possèdent) un produit graisseux que les oiseaux d'eau recueillent avec leur bec et l'enduisent dans leurs plumage en le lissant. Cela les imperméabilise et permet de maintenir en bon état et en place leurs plumages. (Cramps et Simmons 1977).

Le vol est observé avec des taux très faibles, ne dépassant généralement pas les 03% (Fig.3). Il est noté avec des taux avoisinants les 02% à Béni-Bélaïd et 1% à El-Kennar. Il est néant moins important de distinguer trois types de vol chez les Sarcelles d'hiver. Les vols effectués sur les remises pendant la journée et qui correspondent à des changements de places sans cause apparente. Ces déplacements spontanés ne durent jamais plus que 3 minutes par jour (Tamisier, 1970, Dehorter & Tamisier 1997). Les vols engendrés par des dérangements (Humain ou autres) qui représentent essentiellement des vols de sauvegardes occasionnés par le passage des prédateurs, de riverains, de chasseurs et/ou des pêcheurs. Ce type de vol est noté surtout au début de l'hivernage chez les individus éclipses, très farouches et exerçant des vols courts et groupés. Le troisième type est souvent engendré par des exigences particulières et qu'il s'agit de vols systématiques. Noté généralement à l'aube et au crépuscule entre les lieux de remises et les terrains de gagnage (Tamisier, 1970). Cependant, Les Sarcelles d'hiver hivernants au marais d'El-Kennar comptent des effectifs plus élevés et sont plus

habituees à la présence humaine semblent peu affectées par les dérangements et de ce fait ne manifestent pas une grande activité de vol. Cette activité n'est survenue qu'après un vol de Goéland leucophée et/ou de Busard des roseaux ou carrément après une intrusion humaine dans le plan d'eau. Ces oiseaux, une fois se sentent menacés quittent le marais d'El-Kennar et prennent leurs vols vers l'Ouest en direction du marais de Redjla (20 ha) plus sécurisant et à deux minutes en vol d'oiseau (Mayache *et al.* soumise).

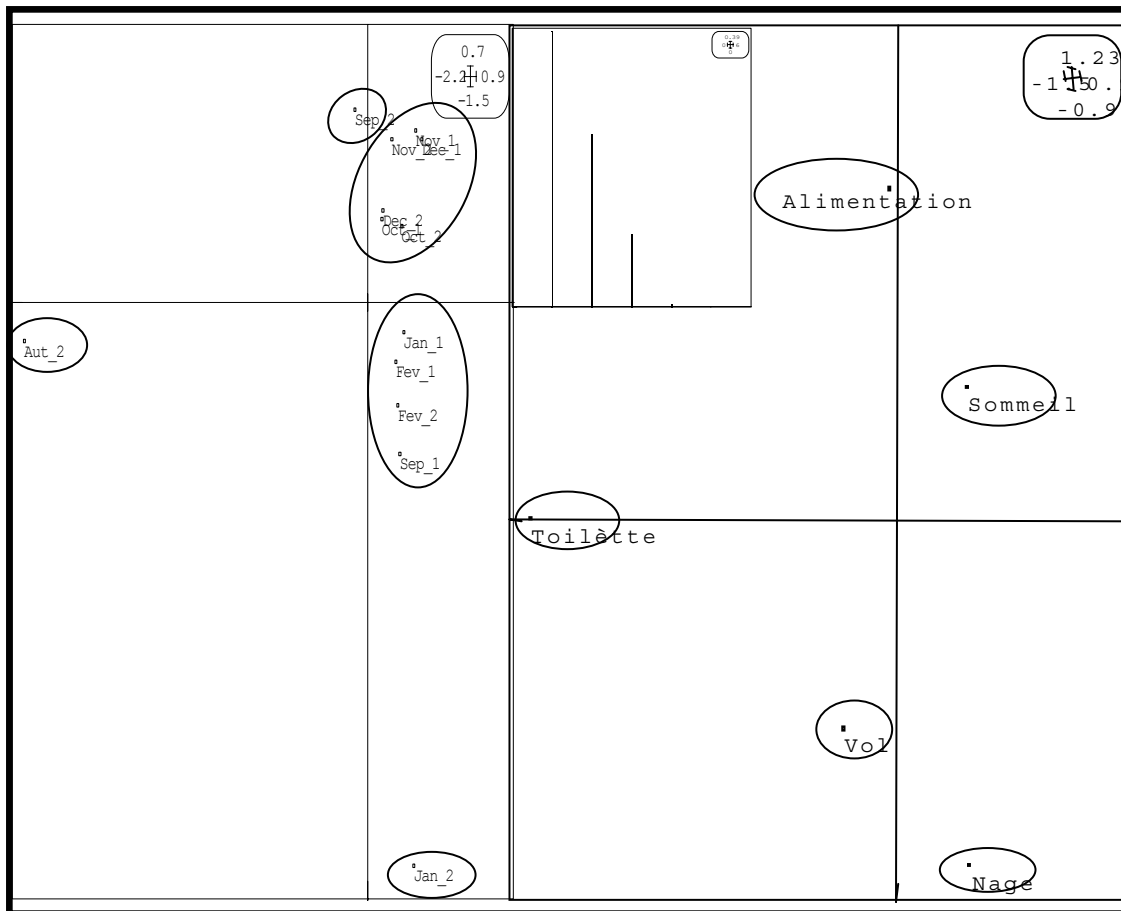
Enfin, l'alimentation ou l'emmagasinement énergétique est une activité quasi nocturne chez les Sarcelles d'hiver hivernantes (Tamisier 1966, 1970, 1972a/b/c, Houhamdi et Samraoui 2001, Guillemain *et al.* 2002). Elle est dès fois observée pendant le jour avec des taux assez conséquents (Felix 1975, Johnson & Rohwer 2000, Rave & Baldassarre 1989, Green *et al.* 1994) où ces Anatidés l'exhibent sur les berges et dans l'eau par différentes manières (par basculement, ou par bec dans l'eau et/ou par plongement de la tête) (Thomas 1982, Nudds & Bowlby 1984, Fox 1986, Duboy 1988, Nummi, 1993). Elle a été observée pendant notre étude diurne avec des valeurs très faibles et tient une part réduite dans les deux écosystèmes étudiés (Fig.3). Dans le lac de Béni-Bélaid, nous l'avons enregistré uniquement chez les premiers occupants du site qui exigent souvent des besoins énergétiques dus à leur migration postnuptiale et dont souvent les apports nocturnes sont insuffisants (Dehorter & Tamisier 1998). Cependant, cette activité était importante pendant les journées des mois de décembre et de février dans le marais d'El-Kennar où elle a été notée avec des taux avoisinants les 25-30% (Fig.4).

### 3. Analyse Statistique

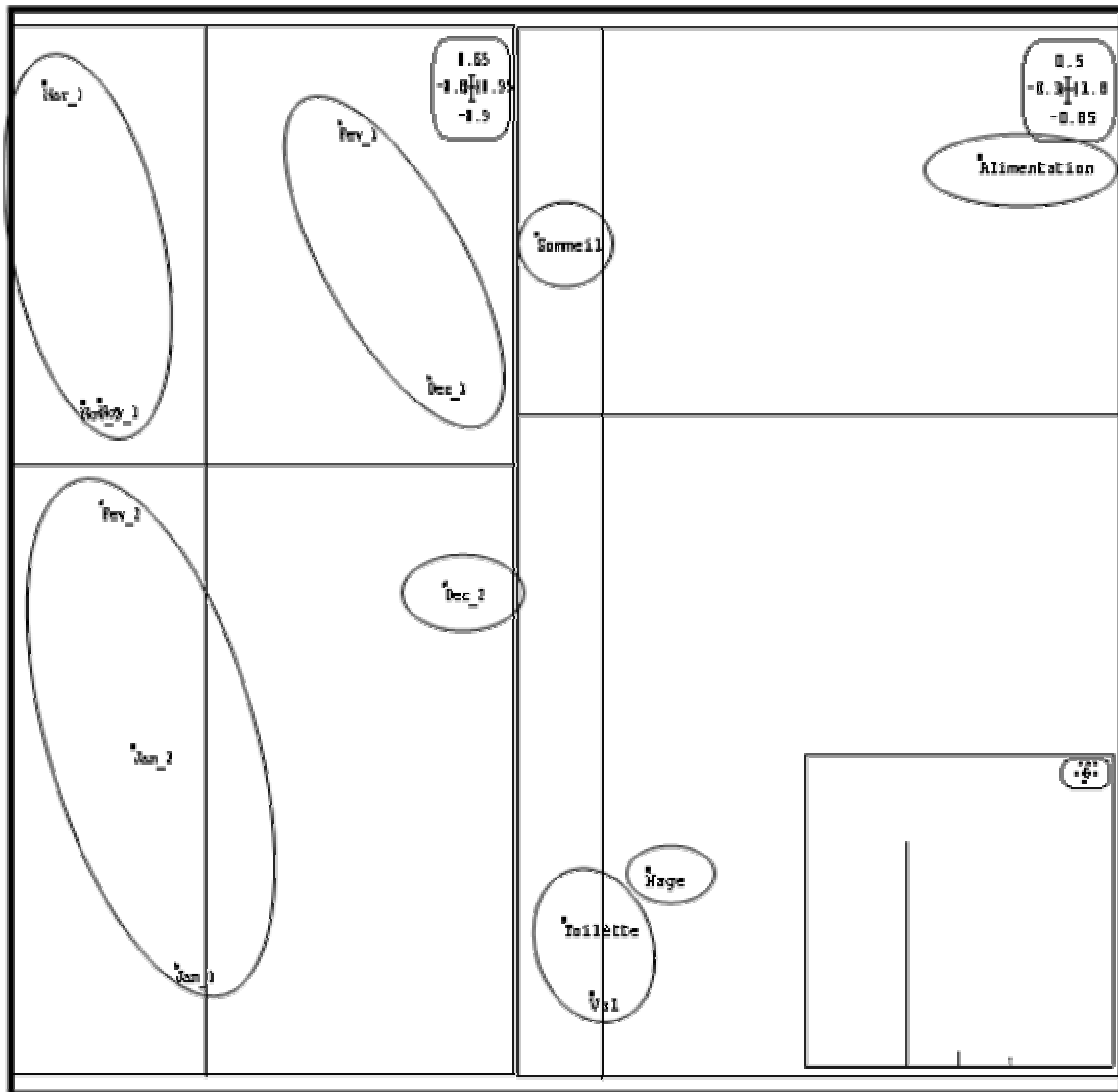
L'étude statistique multivariée des données du budget temps de la Sarcelle d'hiver récoltées durant les deux saisons d'hivernage dans les deux zones humides a été analysée par le logiciel ADE-4 (Chessel et Doledec 1992). Les graphiques des plans factoriels 1x2 de l'AFC (Analyse Factorielle des Correspondances) qui rassemblent respectivement 94% de l'inertie dans le marais d'El-Kennar et 72% dans le lac de Béni-Bélaid nous expose que l'axe des ordonnées (Y) oppose les deux activités principales et vitales des Anatidés: le sommeil et le repos par rapport à l'alimentation et l'emmagasinement de l'énergie (Figs. 5 et 6).



**Figure 5:** Plan factoriel 1x2 de l'AFC des rythmes d'activités des Sarcelles d'hiver *Anas crecca crecca* hivernants dans le lac de Béni-Bélaïd (septembre 2000 - février 2003). [34 heures]. Axes d'inertie: 0.47, 0.25, 0.21 & 0.05



**Figure 6:** Plan factoriel 1x2 de l'AFC des rythmes d'activités des Sarcelles d'hiver *Anas crecca crecca* hivernants dans le marais d'El-Kennar (novembre 2000 - mars 2003). [37 heures]. Axes d'inertie: 0.54, 0.4, 0.2 & 0.01.



Cependant, dans le graphique du lac de Béni-Bélaid, nous pouvons observer une distribution temporelle des activités (Fig.5). Ainsi, pendant le mois d'août, les individus éclipses, farouches et forcément fatigués manifestent beaucoup plus de regroupements et entretiennent leur plumage. Ces activités laissent la place à l'engraissement et une alimentation diurne qui est notée pendant le mois qui suit (septembre). Alors que, plus on s'enfonce dans l'hivernage, le sommeil tient la plus grande part où il domine de loin les mois d'octobre, de novembre et de décembre. Cette activité est souvent associée aux déplacements aquatiques qui dès fois est plus apparente.

Idem que pour le marais d'El-Kennar qui n'a été colonisé que plus tardivement, soit à partir du mois d'octobre nous pouvons dire que l'activité du repos est généralement associée à l'entretien du plumage, au toilettage et au vol qui sont surtout observés pendant la fin de la saison d'hivernage (Fig.6). Elles sont opposées aux autres activités (alimentation et nage) qui caractérisent les mois de décembre et de février.

**Photo 1:** Vue générale du Lac de Béni-Bélaid (Jijel, Nord-Est de l'Algérie). Photo prise le 14 août 2007 par M. Mayache Boualem.



**Photo 2:** Vue générale du marais d'El-Kennar (Jijel, Nord-Est de l'Algérie). Photo prise le 14 août 2007 par M. Mayache Boualem.



## Conclusion

La Sarcelle d'hiver *Anas crecca crecca* a occupée les deux zones humides de l'éco-complexe de Jijel pendant une période de huit mois, allant de la fin du mois d'août jusqu'à la fin du mois de mars et de ce fait présente le statut d'hivernant. Elle commence d'abord par coloniser le lac de Béni-Bélaid vu qu'il est très proche de la Méditerranée. La fréquentation du marais d'El-Kennar dépend essentiellement de la date de sa mise eau. Il reçoit cependant les effectifs les plus élevés pendant toute la saison d'hivernage. D'une manière générale, l'effectif accueilli par tout l'éco-complexe demeure faible par rapport aux zones humides algériennes et méditerranéennes. Le maximum enregistré avoisine les 169 individus. Les Sarcelles d'hiver ont surtout occupés les secteurs peu profonds et loin des dérangements ou elles manifestent un comportement grégaire typique de la majorité des palmipèdes.

Les individus de cette espèce manifestent après une étude de 71 heures un comportement diurne dominé par un repos qui domine de loin le bilan de leurs activités diurnes. Ainsi, les deux zones humides concernées par l'étude n'échappent à la règle et semblent jouer le rôle de remise diurne pour les Sarcelles d'hiver hivernantes. Cette activité de sommeil exhibe des variations temporelles qui sont influencées souvent par les dérangements, principalement humains. Il est néanmoins important de signaler que l'effectif global étudié demeure faible par rapport à l'effectif du Paléarctique occidental et que notre contribution représente une pincée de données nouvelles sur l'écologie et sur l'éco-éthologie de cette espèce d'Anatidés dans les rives sud de la Méditerranée et en Afrique du Nord qui n'a malheureusement pas fait l'objet d'étude scientifique proprement dite mise à part certaines citations dans des articles régionaux.

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## Log-Linear Modeling and Analysis of the Factors, Affecting the Contraceptive Use in Pakistan

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### Abstract

A number of log-linear models were worked out to examine the factors affecting the contraceptive use in Pakistan by using the data from *Pakistan Reproductive Health and Family Planning Survey 2000*. Partial and marginal association tests and standardized values of the model's parameter estimates were shown a highly significant association between women's education, number of living children, sex preference for the next child and working status of women with both the indicators of contraceptive use (currently and ever use of contraception). A highly significant relationship was found between the illiterate respondents who had son preference as sex preference for the next child and non-user of contraceptives. It is concluded that an improvement in women's education level results in greater adoption of contraceptive practices and reduced the cultural factor of sex preference for the next child. The women's education, number of living children, sex preference for the next child and women's working status are strongly associated with (currently and ever) use of contraceptives.

**Keywords:** Contraceptive use, women's education, sex preference for the next child and log-linear modeling.

### Introduction

The increasing population has become a serious challenge to the world. Rapidly increasing population through high fertility is posing serious threats to the peace and prosperity of society. World population is expected to increase to 9.1 billion by the year 2025 (Fortney J.A. 1987). Pakistan, with an estimated population of 145-159 million, is the seventh most populous country in the world with over 40% of its citizens under the age of 15 years. According to United Nations (UN) projections, it will become the fourth most populous country of the world by the year 2050 (World Bank. 2004).

Family planning (FP) is an important issue for developing countries worldwide. In Pakistan, despite a governmental programme supporting family planning and despite the improvements over the last few decades, total fertility rate remains high (4.8 in 2000) and current contraception use, although more important than in the past (11.8% in 1991, 17.8% in 1995, 23.9% in 1997, 28% in 2000), is still relatively low (Hakim A, et. al., 2001). In 2004, birth control was applied less in Pakistan than in most other Muslim countries (N.I.P.S. 2004).



Fertility and contraceptive use in developing countries are associated with various markers of socio-economic status, most prominent of which is women's education (Castro M.T., 1995 and Jejeebhoy S.J., 1995). The well documented link between female education and use of contraception plays an important role in the development of FP policies in lower income countries. Couples in modern society rationally plan their families by calculating costs and benefits of large and small families while in traditional societies they keep producing children as long as they remain fecund. The prevailing traditional and cultural values in the society may have proven to be the barriers to the prevalence of contraceptive use.

For the first time in Pakistan, we used the log-linear model analysis technique to find the appropriate log-linear models for currently and ever contraceptive use by Pakistani married women in relation with socio-economic, socio-demographic and cultural variables. A number of hierarchical log-linear models were worked out with the help of partial and marginal association tests. Standardized values of the selected hierarchical log-linear model's parameter estimates were worked out to examine the pair wise association of different variables at their different levels.

## Material and Methods

### About the Data

In this paper, we used data from the *2000 Pakistan Reproductive Health and Family Planning Survey* (Hakim A, *et. al.*, 2001). A multi-stage sampling method was used to randomly select 7332 households for the data collection (Hakim A, *et. al.*, 2001). In each selected household, 15-49 years old married women were asked to participate in an interview. Interviews were conducted between October 2000 and January 2001 by specially selected and trained female interviewers. Extensive information on household composition and on women's socio-economic, socio-demographic, cultural, reproductive and family characteristics was collected in interview.

We used some basic socio-demographic, socio-economic and cultural characteristics of the women in this study including number of living children, respondents' education attainment, working status of women and sex preference for the next child. The categorization of each variable is shown in tables 3 and 4. Women's education and their working status were taken as the basic measure of their socio-economic status.

## Methods

In this paper, first we analyzed the affect of different factors on currently and ever use of contraception by using the log-linear model analysis technique and then see the difference between the behaviour of respondents in use of (currently and ever) contraception.

### The log-linear model

Log-linear model analysis is an extension of the two-way contingency table where the conditional relationship between two or more discrete, categorical variables is analyzed by taking the natural logarithm of the cell frequencies within a contingency table. The variables investigated by log-linear models are all treated as '*response variables*' that is no distinction is made between independent and dependent variables. Therefore, log-linear models only demonstrate association between variables.

The log-linear model represents the natural logarithm of the expected cell frequencies as a linear combination of main and interaction effects in a manner similar to the usual analysis of variance model. For example, a three variables log-linear model can be written as:

$$\text{Log}(m_{ijk}) = \theta + \lambda_{A_i} + \lambda_{B_j} + \lambda_{C_k} + \lambda_{AB_{ij}} + \lambda_{AC_{ik}} + \lambda_{BC_{jk}} + \lambda_{ABC_{ijk}}$$

Where,

$\text{Log}(m_{ijk})$  is the log of expected cell frequency of the  $(ijk)$ th cell in the three way contingency table,  $\theta$  is the overall mean of the natural log of the expected frequencies,  $\lambda_{A_i}$ ,  $\lambda_{B_j}$  and  $\lambda_{C_k}$  are the main effects for variables A, B, and C respectively and  $\lambda_{AB_{ij}}$ ,  $\lambda_{AC_{ik}}$ ,  $\lambda_{BC_{jk}}$  and  $\lambda_{ABC_{ijk}}$  are the interaction effects for the respective variables.

### Estimation of the Log-Linear Model Parameters and the Expected Cell Frequencies

For the estimation of log-linear model iterative proportional fitting procedure was used (Neil W. 1985). In the iterative proportional fitting procedure, each iteration, involves a proportional adjustment of a row or column of the table of estimated expected cell frequencies. Consider a three-dimensional log-linear model of the form:

$$\text{Log}(m_{ijk}) = \theta + \lambda_{A_i} + \lambda_{B_j} + \lambda_{C_k} + \lambda_{AB_{ij}} + \lambda_{AC_{ik}} + \lambda_{BC_{jk}}$$

The iterative proportional fitting procedure begins by assuming an initial estimate 1 for each expected frequency i.e.  $\hat{m}_{ijk}^{(0)} = 1$  for all  $i, j$  and  $k$  and it proceeds by adjusting these initial estimates proportionally to satisfy the first set of observed marginal totals  $[AB]$ . This is done by calculating,  $\hat{m}_{ijk}^{(1)} = (\hat{m}_{ijk}^{(0)} \times n_{ij+}) / \hat{m}_{ij+}^{(0)}$  and it results in the  $[AB]$  marginal totals of the estimates  $\hat{m}_{ij+}^{(1)}$  being set equal to the observed marginal total  $n_{ij+}$ . These revised estimated expected frequencies are now adjusted to satisfy the second set of observed marginal totals  $[AC]$  by calculating  $\hat{m}_{ijk}^{(2)} = (\hat{m}_{ijk}^{(1)} \times n_{i+k}) / \hat{m}_{i+k}^{(1)}$ . It results in the  $[AC]$  marginal totals of the estimates  $\hat{m}_{i+k}^{(2)}$  being set equal to observed marginal totals  $n_{i+k}$ . Finally, the first cycle is completed by adjusting these revised estimated expected frequencies to satisfy the third set of observed marginal totals  $[BC]$  using

$$\hat{m}_{ijk}^{(3)} = (\hat{m}_{ijk}^{(2)} \times n_{+jk}) / \hat{m}_{+jk}^{(2)}$$

and this results in  $[BC]$  marginal totals of the estimates  $\hat{m}_{+jk}^{(3)}$  being set equal to the observed marginal totals  $n_{+jk}$ . The second cycle now begins using the estimates from the above equations and the process is continued until it converges.  $\hat{m}_{ijk}^{(1)}$ ,  $\hat{m}_{ijk}^{(2)}$  and  $\hat{m}_{ijk}^{(3)}$  represents the expected frequencies for  $(ijk)$ th cell by using the  $[AB]$ ,  $[AC]$  and  $[BC]$  marginal totals respectively. However, once the expected cell frequencies have been estimated, the required parameter estimate can be derived in a straight forward manner for the two-dimensional, three-dimensional, four-dimensional and higher-dimensional cases. For example, in the case of three-dimensional pair wise association model which is just considered, the parameter estimators  $\hat{\theta}$ ,  $\hat{\lambda}_{A_i}$ , ...,  $\hat{\lambda}_{BC_{jk}}$  are given by substituting respective values of the expected cell frequencies  $m_{ijk}$  in the expressions of the form:

$$\hat{\theta} = \frac{1}{IJK} \sum_{i=1}^I \sum_{j=1}^J \sum_{k=1}^K \log m_{ijk}$$

$$\hat{\lambda}_{A_i} = \frac{1}{JK} \sum_{j=1}^J \sum_{k=1}^K \log m_{ijk} - \hat{\theta}$$

$$\hat{\lambda}_{BC_{jk}} = \frac{1}{I} \sum_{i=1}^I \log m_{ijk} - \frac{1}{IK} \sum_{i=1}^I \sum_{k=1}^K \log m_{ijk} - \frac{1}{IJ} \sum_{i=1}^I \sum_{j=1}^J \log m_{ijk} + \hat{\theta}$$

### Partial and Marginal Association Tests

These tests assess each term in two extreme situations: the first is conditional on all other terms of the same order and the second is conditional on only the lower-order relatives of the term in question (Neil W. 1985). In the partial association test, the test of the hypothesis that the partial association of the variables in a contingency table is zero, is a test of a significant discrepancy between the two models. One of these models is a full model and other is full model minus the variable interaction term of interest. For example in a four-dimensional table, to test the partial association of variables A and B, the full second order model would first be fitted i.e.

$$\text{Log}(m_{ijkl}) = \theta + \lambda_{A_i} + \lambda_{B_j} + \lambda_{C_k} + \lambda_{D_l} + \lambda_{AB_{ij}} + \lambda_{AC_{ik}} + \lambda_{AD_{il}} + \lambda_{BC_{jk}} + \lambda_{BD_{jl}} + \lambda_{CD_{kl}}$$

and then the same model without AB interaction term would be fitted i.e.

$$\text{Log}(m_{ijkl}) = \theta + \lambda_{A_i} + \lambda_{B_j} + \lambda_{C_k} + \lambda_{D_l} + \lambda_{AC_{ik}} + \lambda_{AD_{il}} + \lambda_{BC_{jk}} + \lambda_{BD_{jl}} + \lambda_{CD_{kl}}$$

The difference in the  $G^2$  (likelihood ratio chi-square statistic) values of these two models is then the test of partial association. It can be seen that it is a conditional test of the AB interaction term adjusted for all other terms of the same order.

While the test of the hypothesis that the marginal association of the particular variables is zero, is a test that the interaction of said variables is zero in the marginal sub-table formed by the same variables. For example in a four-dimensional table marginal association between variables A and B is tested by forming the two dimensional table indexed by A and B and testing the AB interaction term, that is equivalent to fitting both the models  $\text{Log}(m_{ijkl}) = \theta + \lambda_{A_i} + \lambda_{B_j} + \lambda_{AB_{ij}}$  and  $\text{Log}(m_{ijkl}) = \theta + \lambda_{A_i} + \lambda_{B_j}$  to the full four-dimensional contingency table and compute the difference in their  $G^2$  statistics. A significant result implies that the AB effect makes a difference in the adequacy of fit and should be considered in models to be evaluated further.

The partial and marginal association tests were used simultaneously to screen the various interactions to determine whether they were necessary to include in the model for the data being used. If both partial and marginal association tests are highly significant for an effect ( $p < 0.01$ ), the effect should be retained in further model. If both tests are non-significant ( $p > 0.05$ ), it is probably unnecessary to include the effect in further modeling. If one test is significant and other not then it is doubtful about that effect, it may or may not be consider in the model for the further analysis.

### Standardized Values of the Parameter Estimates

If  $\hat{\lambda}^z$  is any particular parameter estimator and  $\text{Var}(\hat{\lambda}^z)$  its asymptotic variance estimator, then the standardized value of  $\hat{\lambda}^z$  can be calculated as

$$\hat{\lambda}^z / \sqrt{\text{Var}(\hat{\lambda}^z)} \text{ where}$$

$$\text{Var}(\hat{\lambda}^z) = \sum_{i=1}^I \sum_{j=1}^J \sum_{k=1}^K a_{ijk}^2 / n_{ijk}, \text{ } a_{ijk} \text{ is a constant value which depends}$$

upon the particular  $\lambda^z$  under consideration and whose values sum to zero.

Under the null hypothesis that  $\lambda^z$  is zero, is distributed asymptotically as a standard normal distribution with zero mean and unit variance (Neil W. 1985). We compared the computed standardized values with the critical value obtained from standard normal distribution table at a probability level 0.05 and 0.01.

### Likelihood Ratio Chi-Square Statistic

The likelihood ratio chi-square test statistic is defined as

$$G^2 = 2 \sum_{i=1}^I \sum_{j=1}^J \sum_{k=1}^K n_{ijk} \left[ \log \left( \frac{n_{ijk}}{m_{ijk}} \right) \right]$$

where  $n_{ijk}$  is the observed frequency of (ijk)th cell and  $m_{ijk}$  is the corresponding expected frequency. Likelihood ratio statistic is asymptotically distributed as chi-square, with degree of freedom (d.f.) given by the expression

d.f. = number of cells in the table – number of parameters to be estimated in the model.

### Abbreviations

Abbreviations for different variables used in the analysis as below:

<u>Variables</u>	<u>Abbreviations</u>
Education level	E
Number of living children	C
Sex preference	S
Working status	W
Contraceptive use	U

### Results

Valid data of 6579 women's were used for log-linear model analysis to examine the factors affecting the contraceptive use (currently and ever) by the respondents separately. Also see the difference between the behaviour of respondents in currently and ever use of contraception.

Table-1 showed the results of partial and marginal association tests of different variables with both the ever and currently using any type of contraception at all level of interaction terms. It was observed that all 2-factor interaction terms were highly significant in both the currently as well as ever use of contraception. It revealed that the contraceptive use variable, whether it is currently or ever, was strongly associated with women's education, number of living children, sex preference for the next child and working status of women variables. Similar associations were observed from 3-factor and 4-factor interaction terms in both the partial and marginal association tests. All level of factor interactions which are significant in either of partial or marginal association test criterion, included in the model for further process; it may be a nice guide line to choose an appropriate model (Neil W. 1985).

**Table 1:** Partial and Marginal Association Tests

Currently using Contraceptives					Ever using Contraceptives			
Partial Association			Marginal Association		Partial Association		Marginal Association	
Effect	d.f.	G <sup>2</sup>	d.f.	G <sup>2</sup>	d.f.	G <sup>2</sup>	d.f.	G <sup>2</sup>
E	3	6070.65**			3	6070.65**		
C	3	1160.01**			3	1160.01**		
S	2	6198.73**			2	6198.73**		
W	1	209.54**			1	209.54**		
U	1	1470.56**			1	253.40**		
EC	9	653.01**	9	422.00**	9	790.62**	9	422.00**
ES	6	19.17**	6	19.52**	6	17.18**	6	19.52**
EW	3	78.78**	3	137.15**	3	29.96**	3	137.15**
EU	3	356.03**	3	276.58**	3	587.47**	3	397.95**
CS	6	600.52**	6	681.62**	6	578.28**	6	681.63**
CW	3	166.66**	3	271.29**	3	84.57**	3	271.29**
CU	3	533.32**	3	569.28**	3	982.91**	3	964.95**
SW	2	10.52**	2	49.94**	2	8.11*	2	49.93**
SU	2	59.89**	2	178.58**	2	41.25**	2	185.20**
WU	1	289.00**	1	539.44**	1	559.91**	1	930.41**
ECS	25	20.49	27	22.89	27	21.84	27	22.89
ECW	9	6.10	9	18.77*	9	5.54	9	18.77*
ECU	12	23.26*	14	27.68*	9	13.44	9	14.61
ESW	6	12.47	6	17.91**	6	11.57	6	17.91**
ESU	6	3.69	6	10.90	6	18.10**	6	14.69*
EWU	3	5.95	3	0.79	3	5.83	3	0.55
CSW	6	5.58	6	2.74	6	7.75	6	2.74
CSU	6	29.60**	6	28.64**	6	38.84**	6	32.33**
CWU	3	6.91	3	27.66**	3	3.01	3	14.91**
SWU	2	16.32**	2	37.46**	2	10.71**	2	26.37**
ECSW	15	32.19**	19	35.58*	15	43.05**	19	35.58*
ECSU	11	19.45	19	27.04	12	21.16*	22	16.67
ECWU	8	8.21	12	9.23	8	6.44	13	6.43
ESWU	6	8.94	6	6.58	6	10.91	6	5.66
CSWU	5	4.55	12	8.95	5	2.87	12	4.30
ECSWU	9	11.66			9	9.97		

\*p<0.05, \*\*p<0.01

On the bases of partial and marginal association tests, seventeen log-linear models were chosen in hierarchical manner to examine the inclusion of different combination of variables in both currently and ever using any type of contraception, as shown in table-2. Each model is expressed in an abbreviated form, like EC, ES specified the hierarchical model,

$$\text{Log}(m_{ijklm}) = \theta + \lambda_{E_i} + \lambda_{C_j} + \lambda_{S_k} + \lambda_{EC_{ij}} + \lambda_{ES_{ik}}$$

The goodness-of-fit of each hierarchical log-linear model for the given data was examined by the likelihood-ratio chi square test statistic  $G^2$ . The likelihood-ratio chi square test statistic  $G^2$  showed the significant results for first sixteen log-linear models and it was non-significant only for the 17<sup>th</sup> model for the currently contraceptive users. It means that the 17<sup>th</sup> model, which involves two 3-factor and two 4-factor interaction terms (CWU, SWU, ECSW, ECSU), is good fit for the data.

For ever contraceptive users,  $G^2$  showed the significant results for the first fourteen log-linear models while it was non-significant for the next three models. So that, from the goodness-of-fit criteria, the most suitable hierarchical log-linear model for currently and ever use of contraception may be of the form:

$$\text{Log}(m_{ijklm}) = \theta + \lambda_{E_i} + \lambda_{C_j} + \lambda_{S_k} + \lambda_{W_l} + \lambda_{U_m} + \lambda_{EC_{ij}} + \lambda_{ES_{ik}} + \lambda_{EW_{il}} + \lambda_{EU_{im}} + \lambda_{CS_{jk}} + \lambda_{CW_{jl}} + \lambda_{CU_{jm}} + \lambda_{SW_{kl}} + \lambda_{SU_{km}} + \lambda_{WU_{lm}} + \lambda_{CWU_{jlm}} + \lambda_{SWU_{klm}} + \lambda_{ECSW_{ijkl}} + \lambda_{ECSU_{ijkm}}$$

Table-3 showed the results of standardized values of the log-linear model's parameter estimates for currently use of contraception. These values computed from the ratio of the log-linear model's parameter estimate to its standard error. The results revealed that respondent's education attainment played an important role in the prevalence of contraceptive use. It was found that contraceptive prevalence increases

**Table 2:** Specification of Hierarchical Log-Linear Models

S. No	Model Specification	Currently using Contraceptives		Ever using Contraceptives	
		d.f.	G <sup>2</sup>	d.f.	G <sup>2</sup>
1	EC,ES.	168	4538.57**	168	4239.15**
2	EC,ES,EW	164	4191.88**	164	3892.46**
3	EC,ES,EW,EU.	160	2444.74**	160	3241.10**
4	EC,ES,EW,EU,CS.	154	1734.55**	154	2530.91**
5	EC,ES,EW,EU,CS,CW.	151	1407.60**	151	2203.96**
6	EC,ES,EW,EU,CS,CW,CU.	148	630.71**	148	868.89**
7	EC,ES,EW,EU,CS,CW,CU,SW.	146	606.71**	146	844.89**
8	EC,ES,EW,EU,CS,CW,CU,SW,SU.	144	533.41**	144	788.07**
9	EC,ES,EW,EU,CS,CW,CU,SW,SU,WU	143	244.41**	143	228.16**
10	ES,EU,CS,CU,SW,SU,WU,ECW.	134	222.06**	134	210.95**
11	EU,CS,CU,SU,WU,ECW,ESW.	128	208.36**	128	198.50**
12	CS,CU,WU,ECW,ESW,ESU.	122	205.19**	122	185.23**
13	WU,ECW,ESW,ESU,CSU.	116	177.18**	116	149.11*
14	ECW,ESW,ESU,CSU,CWU.	113	163.67**	113	143.89*
15	ECW,ESW,ESU,CSU,CWU,SWU.	111	145.83*	111	130.80
16	ESU,CSU,CWU,SWU,ECSW.	59	84.13*	59	68.73
17	CWU,SWU,ECSW,ECSU.	31	40.23	31	35.49

\*p=<0.05, \*\*p=<0.01

with the increase of education attainment levels of respondent. The standardized values 3.544 and 4.096 showed highly significant positive association between currently use of contraception and respondent's 6-10 and 11+ years of education respectively. It also showed highly significant positive association between non-users and illiterate respondents. There was observed a strongest effect of women's education on number of living children. 11+ years of women's education significantly associated with 1-2 and 3-4 number of living children. Yet, the illiterate and with 1-5 years of education are significantly associated with 5+ number of living children. Women's education levels

**Table 3:** Standardized Values of Log-Linear Model's Parameter Estimates in Case of Currently use of Contraceptive

Variables	Working Status		Sex Preference			Contraceptive Use		Number of Living Children				Responding Education Level in years			
	Yes	No	Boy	Girl	Either	Yes	No	None	1-2	3-4	5+	None	1-5	6-10	10+
<b>Education</b>															
None	-4.613	4.613	2.543	-1.329	-0.832	-8.557	8.557	-9.777	-7.847	-1.185	19.788				
1-5	-0.431	0.431	-0.473	0.676	-0.548	-1.587	1.586	-2.370	-2.328	-0.045	5.540				
6-10	2.159	-2.159	0.410	-1.192	1.526	3.544	-3.544	2.242	0.556	0.570	-3.685				
10+	3.376	-3.376	-1.645	1.406	-0.276	4.096	4.096	6.378	5.983	3.267	-9.805				
<b>Living Children</b>															
None	2.208	-2.208	0.297	0.035	-0.469	-5.108	5.108					-9.777	-2.370	2.242	6.378
1-2	4.641	-4.641	2.373	3.369	-8.261	1.971	-1.971					-7.847	-2.328	0.556	5.983
3-4	3.792	-3.792	-0.082	1.008	-1.452	5.146	-5.146					-1.185	-0.045	0.570	3.267
5+	-1.534	1.534	-2.654	-3.412	9.125	4.524	-4.524					19.788	5.540	-3.685	-9.805
<b>Contraceptive Use</b>															
Yes	6.055	-6.055	-3.002	1.847	1.314			-5.108	1.971	5.146	4.524	-8.557	-1.586	3.544	4.096
No	-6.055	6.055	3.002	-1.847	-1.314			5.108	-1.971	-5.146	-4.524	8.557	1.586	-3.544	-4.096
<b>Sex Preference</b>															
Boy	-2.003	2.003				-3.002	3.002	0.297	2.373	-0.028	-2.654	2.543	-0.473	0.410	-1.645
Girl	-0.032	0.032				1.847	-1.847	0.035	3.369	1.008	-3.412	-1.329	0.676	-1.192	1.406
Either	1.277	-1.277				1.314	-1.314	-0.469	-8.261	-1.452	9.125	-0.832	-0.548	1.526	-0.276
<b>Working Status</b>															
Yes			-2.003	-0.032	1.277	6.055	-6.055	2.208	4.641	3.792	-1.534	-4.613	-0.431	2.159	3.376
No			2.003	0.032	-1.277	-6.055	6.055	-2.208	-4.641	-3.792	1.534	4.613	0.431	-2.159	-3.376

were not mediated a significant association with sex preference for the next child except illiterate women. It showed a strong association between illiterate women and son sex preference for the next child. There was also observed that women's education is also strongly associated with working status of women.

**Table 4:** Standardized Values of Log-Linear Model's Parameter Estimates in Case of Ever Use of Contraceptive

Variables	Working Status		Sex Preference			Contraceptive Use		Number of Living Children				Responding Education Level in years			
	Yes	No	Boy	Girl	Either	Yes	No	None	1-2	3-4	5+	None	1-5	6-10	10+
<b>Education</b>															
None	-3.554	3.554	3.018	-1.696	-0.554	-12.023	12.023	-13.060	-8.075	1.648	21.952				
1-5	-0.274	0.274	-0.531	0.754	-0.653	-1.842	1.842	-3.361	-2.281	0.706	6.258				
6-10	2.840	-2.840	0.662	-1.273	1.458	4.123	-4.123	3.199	0.818	-0.283	-4.517				
10+	3.157	-3.157	-2.020	1.673	-0.407	5.248	-5.248	8.044	5.978	-1.211	-10.901				
<b>Living Children</b>															
None	2.410	-2.410	-0.054	0.038	0.020	-7.180	7.180					-13.060	-3.361	3.199	8.044
1-2	3.827	-3.827	2.769	3.059	-8.405	2.554	-2.554					-8.075	-2.281	0.818	5.978
3-4	2.917	-2.917	0.420	0.971	-2.080	7.543	-7.543					1.648	0.706	-0.283	-1.211
5+	1.104	-1.104	-2.733	-3.339	9.086	6.979	-6.979					21.952	6.258	-4.517	-10.901
<b>Contraceptive Use</b>															
Yes	9.179	-9.179	-2.411	1.178	1.493			-7.180	2.554	7.543	6.979	-12.023	-1.842	4.123	5.248
No	-9.179	9.179	2.411	-1.178	-1.493			7.180	-2.554	-7.543	-6.979	12.023	1.842	-4.123	-5.248
<b>Sex Preference</b>															
Boy	-2.505	2.505				-2.411	2.411	-0.054	2.769	0.420	-2.733	3.018	-0.531	0.662	-2.020
Girl	-0.548	0.548				1.178	-1.178	0.038	3.059	0.971	-3.339	-1.696	0.754	-1.273	1.673
Either	1.327	-1.327				1.493	-1.493	0.020	-8.405	-2.080	9.086	-0.554	-0.653	1.458	-0.407
<b>Working Status</b>															
Yes			-2.505	-0.548	1.327	9.179	-9.179	2.410	3.827	2.917	1.104	-3.554	-0.274	2.840	3.157
No			2.505	0.548	-1.327	-9.179	9.179	-2.410	-3.827	-1.917	-0.104	3.554	0.274	-2.840	-3.157

The results revealed a strong positive association in number of living children and currently use of contraception. The standardized values 5.146 and 4.524 showed highly significant positive association in currently using contraception and number of living children 3-4 and 5+ respectively. A significant association was seen in 1-2 living children and sex preference for the next child. It was also observed a highly significant association between the number of living children and when respondents had working. It was observed that the sex preference for the next child strongly affect the contraceptive use. A standardized value 3.002 showed highly significant positive association between son sex preference for the next child and they were not currently using contraception.

There was also observed highly significant positive association in currently use of contraception and working status of women.

Table-4 shows the results of standardized values of log-linear model's parameter estimates, computed from ratio of the log-linear model parameter estimate to its standard error, in case of ever using any type of contraception. From the results, it was observed that there were not a significant difference in the behaviour of the Pakistani married women either they used ever or currently any type of contraception. The higher standardized values of parameters for current use compare with ever use is probably due to more recent and slightly more precise information on current use.

## Discussion

In exploratory multivariable log-linear model analysis, most of socio-demographic, socio-economic and cultural variables were associated with both indicators of contraceptive use; we found that the most prominent predictors of contraceptive use are the number of living children and women's education level. This association was also found in the literature from South Asia and elsewhere (Castro M.T., 1995, Jejeebhoy S.J., 1995, Fikree, F.F., *et al* 2001 and Al Riyami A., *et al* 2004). The prevalence of use of contraceptive methods increases with the increase in number of living children and education level of women. This was also found in Tanzania where number of children and women's education were the main factors associated with use of contraceptives (Marchant T., *et al* 2004). Pakistan has low

literacy rate, this is even graver in rural areas (Economic Survey of Pakistan 2000). There are only 12.2% women with 6-10 years education and only 5.6% with more than 10 years education (Hakim A, *et al* 2001). Analysis showed 6-10 and 11+ years of education are significantly associated with prevalence of contraceptive use. In Pakistan, contraceptive use is strongly associated with women's education but this relation was not mediated by women's decision autonomy (Shabana S. and Martin B. 2005). It was also noticed that working status of women associated with their education attainments. Education is considered to improve the ability of women to resist subjugation and to acquire greater power in decision-making (Gage A.J. 1995).

Results revealed a significant association between the illiterate, non user of contraception and son sex preference for the next child. Sex preference for the next child emerged a strong barrier to the contraceptive use. This was also found in Nepal where the sex preference was an important barrier to the increase of contraceptive use and decline of fertility in the country (Tiziana Leone, *et al* 2003).

The findings of this study reaffirm the overarching importance of women's education directly and indirectly influence on contraceptive use. Improvement of women's education can also help in deducing the cultural factor of sex preference for the next child, which emerged a strong barrier to the contraceptive use. The results of this study also suggest the need for giving great attention in future studies to the husband-wife relationship, which can remove all the conflicts about their fertility desires.

To achieve a further increase in the contraceptive prevalence rate, it is now worthwhile to create a greater awareness among women of the issues which are found to affect contraceptive prevalence significantly. Thus, awareness programs should encourage women with message saying that they should practice contraception more in their early reproductive lives; they should not be strongly seeking a male child.

Despite highlighting a number of determinants of contraceptive use in Pakistan, this study demonstrates the importance of methodological issues in contraceptive prevalence studies. Because log-linear model analysis technique enhances confidence in the results, it provides a precise measure of associations within all variables under studies in multiway contingency table for a large scale data set.

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## Trade-Growth Linkages in South Asian

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### Abstract

This paper examines the dynamic link between trade and economic growth in four Asian countries including Bangladesh, India, Pakistan and Sri Lanka using annual data over the period 1970-2005. Based on bound testing approach to cointegration we find the existence of cointegration between trade and growth in the case of Pakistan, Sri Lanka and Bangladesh. However, the test fails to produce any evidence of cointegration between trade and growth in the case of India. Two-way causality between trade and growth observed for Pakistan in the long and short-run. For Bangladesh and Sri Lanka the evidence of one-way causality running from growth to trade is identified. We identified the evidence of causality running from trade to growth based on Toda-Yamamoto (1995) multivariate causality test for India. However, this result is very weak and at marginal significance. In the short-run standard Granger causality test fails to identify any causal link between trade and growth for India. Based on these results we can say that Pakistan may continue with the import capital goods and modern technology to expand their productive capacity and pay full attention to expand their exports sector. Bangladesh and Sri Lanka may also import capital goods and modern technology to expand their productive capacity and promote growth. Furthermore, the evidence supports the view that Indian growth is independent of trade.

**Keywords:** Trade, Growth, Cointegration, South Asia

**JEL Classifications Codes:** F10, F43, C209, R19

### Introduction

Economic growth is one of the major macroeconomic policy objectives of every country of the world. There are a number of factors contributing to economic growth and trade is one of them. Trade-led growth hypothesis suggest that trade may produce spillover effects over the rest of the economy through the efficiency, innovations and imitations and promote overall economic development (Dodaro, 1993, Deme, 2002). A wide range of additional growth-inducing benefits have been attributed to trade including capacity utilization, enlarging market size, economies of scale and specialization effects, technological improvements, capital formation, employment creation and efficient management due to greater international competitive pressure (Balassa, 1978, Keesing, 1967, 1979, Krueger, 1988, Bhagwati and Srivasan, 1979, Khalid and Teck-Cheng, 1997 and Dodaro, 1993). These components together induce growth of output. In addition, the presence of domestic market constraints

impedes growth and trade can provide a “vent-for-surplus” type effect (Dodaro, 1993). Trade also opens the possibility for developing countries to earn foreign exchange in order to import capital goods, raw materials and necessary technology required for the expansion of domestic production (Ibid, 1993).

There are a variety channels through which trade is expected to influence economic growth. These include: improved resource allocation in the line with social marginal costs and benefits, free access to better technologies, availability of inputs and material, ability of the economy to take advantage of the economies of scale and scope, favourable environment of growth externalities, transfer of know-how and shakeup of industries that may create a conducive environment for growth. Furthermore, trade may effect growth through the deepening of export sector which generates externalities that increases growth of other sectors of the economy (Dornbusch, 1992 and Lewer and Berg, 2003).

It can be argued that the promotion of trade and development is largely depends on the suitability of trade policy regime. The debate over the suitability of trade policy regime is well documented in the literature (Todaro and Smith, 2003). In the 1950s and 1960s most of the developing countries pursued Import Substitution (IS) policies for the growth and development. The main reason for this policy option was the protection of their infant industries (Chaudhary *et al.*, 2007). However, the economic progress of Japan, South Korea, Hong Kong, Taiwan, and Singapore during 1980s was resulted due to the success of free market and outward orientation policies (World Bank, 2003). This inspired other developing countries to adopt outward orientation policies to promote their economic growth. Hence, many developing countries has been shifted their trade policies towards Export Promotion (EP) strategy by reducing controls and moving towards more liberal trade policies. This U-turn in trade policies are expected to enhance efficiency and growth through better allocation of resource, economies of scale, employment generation, capital formation and technological development. In the perspective of trade-growth linkages, South Asian countries have great potential to expand their productivity and exports because there is no deficiency of domestic natural resources in this region. However, for the exploitation of domestic resources, imports of capital goods and necessary technology is required which play a key role in the expansion of export-oriented industries.

Numerous research work have been conducted in context of South Asia, inter alia, by Rana (1985), Anwar and Sampath (2000), Ahmed *et al.* (2000), Kemal *et al.* (2002), Din (2004), Shirazi and Abdul Manap (2005). Most of these studies tested export-led growth hypothesis and found mixed results. The present study differs from the earlier studies in the following ways: first, unlike previous studies this study uses total volume of trade as independent variable to examine the link between trade and growth. Second, we implement more recent econometric technique — bound testing approach— to determine the long as well as short-run relationship between trade and growth. Third, the study takes into account the causality issue because the determination of the direction of causality between trade and growth has very important policy implications for the formulation of appropriate economic policies.

The main objective of this paper is to examine the dynamic linkages between trade and real GDP for four South Asian countries including Bangladesh, India, Pakistan and Sri Lanka over the period 1970-2005 using bound testing approach to cointegration. If sources of growth are external then these countries should reduce the externality effects of exporting. On the other hand, if the sources of growth are internal then there is no need to undertake trade liberalization measures and may concentrate on the development of internal resources such as, expand and improve the quality of physical capital and human resource development (Walde and Wood, 2004). Thus, the analysis of trade and growth provides important policy implications because trade and growth linkages would allow in formulating trade and domestic policies that raise growth and induce industrialization.

The paper is organized as follows: A brief review of trade policies pursued by the South Asian countries is given in section 2. Theoretical and empirical review of literature is given in section 3. Methodology and data are discussed in section 4. Empirical findings are interpreted in section 5 and concluding remarks are given in the final section.

## 2. Trade Policies in South Asian Countries

Many developing countries have shifted their attention from severe and destructive protection policies to free trade policies (Dornbusch, 1992). Trade literature has well documented the problems of inward-looking trade strategies and the lessons from trade successful strategies which forced the developing countries to adopt outward-oriented policies (Balassa, 1989; Bhagwati, 1978; Krueger, 1978; Michaely *et al.*, 1991). The benefits of outward-orientation policies inspired the South Asian countries to gradually open up their economies. With the adoption of outward-looking trade and investment regime during the 1990s, South Asian countries are now more integrated than prior to 1990s. Globalization and WTO regime enables these economies to reap the benefits from emerging international specialization, obviates the constraints on their development by the expansion of the size of markets and enhance the capacity of absorbing spillovers of knowledge creation in different parts of the world (RIS, 2004). South Asian economies performed well since 1990. The growth has improved steadily and is today's among the highest. The recent growth performance of Bangladesh, India, Pakistan and Sri Lanka can be depicted in table 1.

**Table 1:** Growth Rate of GDP in South Asian Countries (in percentage)

Country/Year	2000	2001	2002	2003	2004	2005	2006	2007	Average
Bangladesh	5.9	5.3	4.4	5.3	6.3	6.0	6.7	6.0	5.74
India	4.4	5.8	3.8	8.5	7.5	8.4	7.8	7.8	6.75
Pakistan	3.9	2.0	3.1	4.7	7.5	8.6	6.6	7.0	5.43
Sri Lanka	6.0	-1.5	4.0	6.0	5.4	6.0	6.1	5.8	4.73
South Asia	4.5	5.1	3.7	7.7	7.4	8.1	7.5	7.5	6.44

Source: ADB (2006)

It may be seen from table 1 that the overall growth performance during 2000 of Bangladesh, India, Pakistan and Sri Lanka was 5.9, 4.4, 3.9 and 6 percent respectively. During 2007 growth in Bangladesh, India and Pakistan reached to 6, 7.8, and 7 percent respectively. This impressive performance could be due to the proactive macroeconomic policies and strong domestic demand. Sri Lanka's growth however remained stable except a sharpe deteriorating to -1.5 percent in 2001. The reasons may be the adverse effects of external factors *inter alia* dampening of manufacturing exports, increase in oil prices and low agriculture productivity.

Most of the South Asian countries adopted inward-oriented trade policy regime for nearly four decades. These policies include high tariffs, various types of non-tariff barriers, exchange rate regulations and other administrative controls. The objective of these highly protectionist trade regime was to promote import substitution industrialization. These policies generated anti-export bias, inefficiencies and promoted rent seeking. Initially Sri Lanka breaks the protectionist circle and launched the trade liberalization Programme in 1977. Following Sri Lanka, the other countries of the region opening up trade and capital flows sponsored by the World Bank and International Monetary Fund (IMF) in the form of Structural Adjustment Programme (SAP) in the late 1980s. The trade reform process includes a series of measures including the reduction of anti-export bias, rationalization of tariff structure and removal of quantitative restrictions. The silent features of trade policy regime of major South Asian countries are summarized in table 2.

**Table 2:** Summary of Trade Regimes in South Asia

Policies	India	Pakistan	Bangladesh	Sri Lanka
Exchange Rate Policies	Unified Free Float	Unified Free Float	Unified Free Float	Unified Free Float
Payment Convertibility				
Current Account	Yes	Yes	Yes	Yes
Capital Account	Yes Limited	No	No	No
Import Restrictions				
General Import Licensing	No	No	No, but some restrictions	No
Some QRs on Imports	Yes	Yes	Yes	Yes, minor
State Import Monopolies	Yes	No	No	No
Tariff Structure on May 2003				
Top normal CD rate	30	25	32.5	25
Average CD rate	26.8	18.2	16.5	9.6
Average CD + other protective taxes	32.7	18.2	21.9	12.5
No. of normal CD slabs	7	4	5	5
Uses anti-dumping	Yes	Yes	No	No
Export Policies				
Some export QRs	Yes	No	Yes	No
Some export taxes	Yes	Yes	Yes	No
Some direct export subsidies	Yes	No	No	Yes
Fright subsidies for new markets and new products.	-	Up to 25%	-	-

Source: Din (2004), World Bank (2003) and RIS (2004)

Almost all the countries in the South Asian region abolished the quantitative restrictions on trade. The maximum custom duty rate is 25 percent in Pakistan, Sri Lanka and Nepal, whereas it is 30 percent in India and 32.7 percent in Bangladesh. The average custom duty is 32.7 percent in India, 18.2 percent in Pakistan, 21.9 percent in Bangladesh, 12.5 percent in Sri Lanka and 16.2 percent in Nepal.

Due to proactive commercial policies, exports growth of 18.6 % was recorded in 2007 in South Asia. Export growth was particularly strong in India at 20%, followed by Bangladesh (18.0%), Pakistan (13.0%) and Sri Lanka (7.5%). In contrast, the import growth which was 40.4% in 2004 decreased to 19.3% in 2007 in South Asia. All South Asian countries showing a declining trend of import growth in 2007 (table 3).

**Table 3:** Exports and Imports of Goods in South Asia (annual % change)

Country	Export/Import	2000	2001	2002	2003	2004	2005	2006	2007
Bangladesh	Exports	7.9	12.6	-7.6	9.5	15.9	14.0	21.6	18.0
	Imports	4.8	11.4	-8.7	13.1	13.0	20.6	12.1	12.0
India	Exports	21.1	-1.6	20.3	23.3	23.9	27.5	20.0	20.0
	Imports	4.6	-2.8	14.5	24.1	48.5	31.6	26.2	20.0
Pakistan	Exports	8.8	9.1	2.3	19.1	13.8	16.8	14.0	13.0
	Imports	-0.1	6.2	-7.5	20.1	20.0	39.6	31.3	15.0
Sri Lanka	Exports	19.8	-12.8	-2.4	9.2	12.2	10.2	8.0	7.5
	Imports	22.4	-18.4	2.2	9.3	19.9	10.8	9.0	6.5
South Asia	Exports	18.0	0.1	12.9	20.4	21.4	24.3	18.8	18.6
	Imports	5.4	-1.7	7.9	21.4	40.4	30.3	25.0	19.3

Source: Asian Development Bank (2006)

This acceleration of exports and deceleration of imports could be due to the positive externalities, proactive commercial and macroeconomic management and liberalization of trade and investment regime. The volume of trade as percentage of GDP also reflected rising trend with the outward-orientation of trade (table 4).

As can be seen from table 4, trade to GDP ratio has increased in all the countries and higher increase take place in Bangladesh followed by India and Pakistan. After 2000 India marks a steady increase in trade to GDP ratio despite of its large domestic consumption requirements.

**Table 4:** Volume of Trade as Percentage of GDP

Year	Countries			
	Bangladesh	India	Pakistan	Sri Lanka
1970	20.82	8.1	17.97	54.05
1975	11.0	13.47	32.39	62.45
1980	23.38	16.63	35.90	87.02
1985	18.78	14.00	33.17	64.8
1990	19.65	15.71	35.12	67.23
1995	28.21	23.21	36.13	81.36
2000	33.21	27.55	28.37	88.64
2001	36.88	26.49	30.72	80.9
2002	33.32	29.86	30.89	78.89
2003	34.25	30.84	32.84	78.05
2004	36.28	38.22	30.30	81.73
2005	39.63	43.61	35.25	76.27
2006	44.22	48.78	38.61	74.78

Source: World Development Indicators (2007)

### 3. Theoretical and Empirical Literature<sup>1</sup>

Trade-led growth hypothesis can be traced back to the classical economists Adam Smith and David Ricardo in the early part of the nineteenth century. They hypothesized that world production would grow when countries undertake the specialization and division of labour based on the principles of absolute and comparative advantage (Deme, 2002). Specialization in the line with comparative advantage helps to optimize the production of a trading country. In the conventional theory, gains from trade come from the export side. However, imports have played indirect role because imports allow the country to buy intermediate goods on more favourable terms than if produced at home. The neo-classical trade theory suggest that trade stimulate growth through the production, consumption and savings linkages. Production for exports is expected to increase the production of other industries through the forward and backward linkages. For example, in the case of consumption linkages, increase in income in the export sector is expected to raise the demand for domestic goods, which in turn, stimulate the domestic production. With respect to savings linkages, it is suggested that an increase in net exports can raise the level of savings needed for capital formation, which in turn, expands the productive capacity of the country. The neoclassical theory is basically supply-oriented (Deme, 2002 and Federici and Marconi, 2002).

The new theories of international trade emphasize the role of economies of scale associated with international trade (Dixit and Norman, 1980). These theories suggested that productivity gains could be attained when countries started their production at larger scale for the international market. Krueger (1988) argued that trade can enhance economic growth through capacity utilization. He further stated that international trade forced the domestic producers to produce at larger scale with the use of idle capacity thereby increasing overall domestic production.

The above theories basically support the export-led growth hypothesis and practically ignored the import-led growth hypothesis. There is no doubt that imports plays crucial role in the process of economic development in developing countries. This is because in many countries a large proportion of imports consist of raw materials, intermediate, and capital goods. A disruption of these resource flows can impose severe adverse impacts on economic growth. Imports can exert favourable impacts on economic growth through various channels. These channels includes: cheaper access to capital and

<sup>1</sup> A comprehensive survey of literature can be found in Lewer and Berg (2003).

intermediate goods, availability of imported intermediate goods and technology, forced domestic producers to allocate domestic resources more efficiently, improve managerial capacity, utilize cheap labour effectively and better capacity utilization etc. Furthermore, liberal import regime helps in bringing greater technological dynamism and creates a business environment that forces inefficient firms to close down, and enables domestic industrial firms to compete more effectively in the world export markets (Goldar and Kumari, 2003 and Din *et al.*, 2003). These factors would allow the domestic firms to reap the benefits of economies of scale generated by trade. Moreover, the intense competition foster by the international market may force domestic producers to improve the domestic technology, production processes and efficiency helps to raise productivity. Therefore, open trade is expected to have a positive impact on economic growth.

Sachs and Warner (1995) argued that countries with more open trade would grow faster than those with restricted trade. In contrast, Levine and Renelt (1992) suggest that trade and growth relations may exist through investment and long-term growth may rise only when openness provides greater access to investment goods. However, domestic investment will be discouraged due to the increased international competition. Grossman and Helpman (1992) argued that protection could raise the long-term growth if government intervention encourages domestic investment in lines with the comparative advantage. Batra and Slottje (1993) and Leamer (1995) suggest that free trade is the primary source of growth. The overall empirical studies do not provide any clear-cut evidence regarding the direction and causality of trade and growth. Therefore, the direction of causality between trade-growth is an empirical question

A large number of empirical studies have been carried out to examine the direction of causality between trade and growth. Greenaway and Sapsford (1994), Sengupta and Espana (1994), Bodman (1996) and Thornton (1996) confirm the trade-led growth hypothesis for some countries, while Boltho (1996) and some others reject it. Moreover, Moschos (1989), Bahmani-Oskooee and Alse (1993), Sprout and Weaver (1993) and Jin and Yu (1995) suggested the positive impact of trade openness on economic growth. Dixit and Norman (1980) supported the growth-led export hypothesis, while Kaldor (1967) argued that causality runs from economic growth to exports. However, many of these studies have focused on the export-led growth hypothesis. Afxentiou *et al.* (2000), Khalid and Cheng (1997), and Marin (1988) investigated the import-led growth hypothesis. The results of Khalid and Cheng (1997), and Marin (1988) supported the import-led hypothesis, while Afxentiou *et al.* (2000) do not support it.

In the context of South Asian countries Rana (1985) find that exports contributed positively to economic growth for 14 Asian countries including Bangladesh, India, Pakistan and Sri Lanka. Anwar and Sampath (2000) tested the export-led growth hypothesis and find unidirectional causality in the case of Pakistan and Sri Lanka and no causality in the case of India. Ahmed *et al.* (2000) find no evidence of feedback effect among export revenue, external debt servicing and economic growth except in the case of Bangladesh. Kemal *et al.* (2002) find positive association between exports and economic growth for India, Pakistan, Bangladesh, and Sri Lanka. In contrast, Din (2004) finds bidirectional causality between exports and output growth for Bangladesh, India and Sri Lanka in the short-run. The study finds long-run relationship between exports, imports and output only for Bangladesh and Pakistan. For India, Nepal and Sri Lanka, the study found no evidence of long-run relationship between the exports, imports and output. Shirazi and Manap (2005) have tested export-led growth hypothesis for India, Pakistan, Sri Lanka, Bangladesh, and Nepal within the framework of Toda and Yamamoto multivariate Granger causality tests. The results of the study strongly supported the existence of long-run relationship between real GDP, exports and imports for all countries except Sri Lanka. They also find the feedback effect between imports and output for Pakistan, Bangladesh, and Nepal, unidirectional causality from imports to output growth for Sri Lanka and no causality for India. The results also showed a feedback effects between exports and output growth for Bangladesh and Nepal, unidirectional causality from exports to output growth for Pakistan, and no causality in the case of Sri Lanka and India. They concluded that export-led growth hypothesis remained valid for Bangladesh, Pakistan and Nepal, but not for India and Sri Lanka.

The results of these studies are mixed, however, these economies has great potential to expand their productivity through the imports of advance technology and the efficient use of domestic natural resources. This study consider the link between real output and total volume of trade, because this link provide important information that whether a country concentrate on domestic resources or foreign resources to enhance its economic growth.

#### 4. Methodology and Data

Trade-led growth hypothesis contends that volume of trade and economic growth is strongly correlated. The hypothesis also maintained that causation runs from trade to growth as the expansion of trade (i.e. exports) would relax the constraint on foreign exchange and thus enables the domestic economy to import more productive capital goods. In this context, the neo-classical theories suggest that exports enhance economic growth through better allocation of international resources and improve productive efficiency.

Another possibility is that due to the advances in technical progress and the accumulation of business skills increases domestic production. The resultant increase in production promotes exports because of the insufficient domestic demand. In this way higher economic growth cause higher exports. In explaining this vicious circle, Bhagwati (1988) argued that increase in trade produces more income, and more income facilitates more trade. Based on these arguments we consider trade-led growth and growth-led trade hypotheses. To access the long-run relationship between real GDP and volume of trade, and vice versa, we implement bound testing approach to cointegration developed by Pasaran *et al.* (2001). The most important advantage of this approach is that it is applicable irrespective of whether the underlying regressors are purely I (0), I (1) or fractionally integrated. Another advantage is that this approach remains more appropriate than the Johansen-Juselius multivariate approach to cointegration when the sample size is small (Pesaran *et al.*, 2001).

The dynamic linkages between real output ( $y_t$ ) and volume of trade ( $z_t$ ) for Bangladesh, India, Pakistan and Sri Lanka can be examined by the specification of following conditional unrestricted error-correction models:

$$\Delta y_t^j = \beta_0 + \beta_1 y_{t-1}^j + \beta_2 z_{t-1}^j + \sum_{i=1}^{\rho-1} \gamma_{1i} \Delta y_{t-i}^j + \sum_{i=1}^{\rho-1} \gamma_{2i} \Delta z_{t-i}^j + \omega \Delta z_t^j + u_t^j \quad (1)$$

$$\Delta z_t^j = \alpha_0 + \alpha_1 z_{t-1}^j + \alpha_2 y_{t-1}^j + \sum_{i=1}^{\rho-1} \phi_{1i} \Delta z_{t-i}^j + \sum_{i=1}^{\rho-1} \phi_{2i} \Delta y_{t-i}^j + \eta \Delta y_t^j + v_t^j \quad (2)$$

Where  $y_t^j$  is the  $j$  th country real gross domestic product (GDP) and  $z_t^j$  is the  $j$  th country volume of trade (i.e. exports plus imports) in real term.  $u_t^j$  and  $v_t^j$  are the error terms. We have used bound testing approach to cointegration to investigate the long-run relationship between  $y_t$  and  $z_t$ . This approach consists of two stages. In the first stage the hypothesis of no cointegration is tested by imposing zero restrictions on the coefficients on the lagged regressors. The null hypothesis  $H_{10}^j : \beta_1 = \beta_2 = 0$  is tested against the alternative of  $H_{11}^j : \beta_1 \neq \beta_2 \neq 0$  and  $H_{20}^j : \alpha_1 = \alpha_2 = 0$  is tested against the alternative of  $H_{21}^j : \alpha_1 \neq \alpha_2 \neq 0$ . The test is based on non-standard F-distribution. Pesaran *et al.* (2001) provides two sets of asymptotic critical values for I (0) and I (1) variables. If the computed F-statistic falls outside the critical bounds, a conclusive inference can be drawn without investigating the order of integration of the variables. However, if F-statistic falls within the critical bounds, inference depends on whether the underlying variables are I (0), I (1) or mutually integrated.

In the second stage the long-run relationship between the cointegrated variables is estimated using autoregressive distributed lag (ARDL) method. The long-run causality is conducted by estimating the following restricted error-correction models:



$$\Delta y_t^j = \alpha + \sum_{i=1}^k \theta_i \Delta y_{t-i}^j + \sum_{i=1}^k \lambda_i \Delta z_{t-i}^j + \kappa(y_{t-1}^j - \beta_0 - \beta_1 z_{t-1}^j) + e_t^j \quad (3)$$

$$\Delta z_t^j = \alpha' + \sum_{i=1}^k \theta_i' \Delta z_{t-i}^j + \sum_{i=1}^k \lambda_i' \Delta y_{t-i}^j + \kappa'(z_{t-1}^j - \beta_0' - \beta_1' y_{t-1}^j) + e_t^{j'} \quad (4)$$

such that  $\kappa \neq 0$  and  $\kappa' \neq 0$

Annual data were retrieved from International Financial Statistics CD-ROM (2006). For India and Sri Lanka the sample consists of 1970-2005, 1972-2005 for Pakistan and 1973-2005 for Bangladesh. Real GDP is used as proxy for economic growth. Real GDP for India, Pakistan and Sri Lanka is calculated as nominal GDP divided by consumer price index (CPI). For Bangladesh real GDP is calculated as the nominal GDP divided by GDP deflator. The volume of trade is calculated by summing the merchandised exports and imports divided by CPI of the respective country.<sup>2</sup>

## 5. Empirical Findings

We estimated equations (1) and (2) for Bangladesh, India, Pakistan and Sri Lanka and tested for the existence of cointegration among and and vice versa. Initially we set 4 lags for VAR and tested down using general-to-specific methodology. The final selection of the estimated equation(s) is being made when it passes all the diagnostic tests including, no serial correlation, homoscedasticity, functional form, normality and CUSUMSQ test of stability. The results of bound test are reported in table 5.

As can be seen from the table 5, the trade and growth has cointegrating relationship in the case of Bangladesh, Pakistan and Sri Lanka. In the case of India the test fails to provide the evidence of cointegration between the variables.<sup>3</sup> This implies that trade-led growth hypothesis is operative only for Pakistan and growth-led trade hypothesis is valid for Bangladesh and Sri Lanka. These findings are consistent with the earlier findings of Dutt and Ghosh (1996) in the case of India and Pakistan.

**Table 5:** Bound Cointegration Test Results

Country	Variable Included	Test Statistic	Optimal Lag <sup>d</sup>
Bangladesh	$F^B(y_t   z_t)$	7.1142**	4
	$F^B(z_t   y_t)^d$	4.3757***	4
India	$F^I(y_t   z_t)$	1.6358	2
	$F^I(z_t   y_t)$	1.3147	2
Pakistan	$F^P(y_t   z_t)$	4.9510**	4
	$F^P(z_t   y_t)$	13.9112**	4
Sri Lanka	$F^S(y_t   z_t)^d$	4.0839***	4
	$F^S(z_t   y_t)$	5.2498**	4

\*\*, \*\*\* indicate significant at the 5% and 10% level of significance. Critical values are taken from Pesaran *et al.* (2001)

Having established a long-run relationship between the real GDP and the volume of trade, we estimated long-run and short-run relationships simultaneously using Autoregressive Distributed Lag (ARDL) method for three countries such as Bangladesh, Pakistan and Sri Lanka. The estimated long-run coefficients for each country are reported in Table 6 and the short-run dynamics are presented in Table 8. As can be seen from the Table 6, the estimated parameters for Bangladesh, Pakistan and Sri

<sup>2</sup> For Bangladesh GDP deflator is used.

<sup>3</sup> Due to non-existence of cointegration in the case of India, we cannot proceed further with ARDL approach. However, to identify the short-run causality between real GDP and volume of trade, we implement Toda-Yamamoto (1995) causality test.

<sup>d</sup> Intercept and trend is included in the test.

Lanka are significant and have a priori sign in the long-run in the case and growth-led trade case. However, the parameters associated to trade-led growth hypothesis are significant only in the case of Pakistan.

**Table 6:** Results of Long-run Estimates Based on ARDL

Country	<u>Trade-Led Growth</u> Dependent Variable: $y_t$	<u>Growth-Led Trade</u> Dependent Variable: $z_t$
Pakistan	$y_t = 4.35 + 0.38 z_t$ (8.79)* (15.57)*	$z_t = -9.26 + 2.51 y_t$ (-14.53)* (39.29)*
Sri Lanka	$y_t = 7.34 + 0.02 z_t + 0.03 trend$ (10.82)* (1.52) (5.56)*	$z_t = -8.31 + 2.65 y_t$ (-3.41)* (9.97)*
Bangladesh	$y_t = 6.11 + 0.16 z_t$ (5.80)* (1.54)	$z_t = -88.15 + 11.56 y_t - 0.38 trend$ (-3.03)* (3.45)* (-2.66)*

Note: t-values are given in parentheses. \* indicate significant at the 1% level of significance.

The long-run results suggest that in Pakistan the volume of trade and real output exerts positive impact on each other significantly. This implies that both exports and imports play a significant role in enhancing domestic production in Pakistan. This evidence supports the validity of trade-led growth and growth-led trade hypotheses in Pakistan. The validity of trade-led growth and growth-led trade hypotheses could be justified on the ground that economic growth enhances efficiency through the improvement of labour skills and knowledge, physical capital and modern technology. This creates comparative advantage for the country which expands trade. Another reason of these results is that in Pakistan exports are import oriented because exports industries using a large amount of imported raw materials. Thus, in Pakistan real output and trade are interdependent.

For the case of Bangladesh and Sri Lanka the volume of trade exerts positive but insignificant impact on output. This could be possible because in these countries domestic demand for exportables may be much higher. Consequently, the weaker relationship between trade and growth is identified. However, for these countries real output exerts positive and significant impact on trade. This implies that in Bangladesh and Sri Lanka there is weak evidence of trade-led growth hypothesis and strong evidence of growth-led trade hypothesis. These results are consistent with Jung-Marshall (1985) internally-generated growth hypothesis. These results could be justified on the grounds that Bangladesh and Sri Lanka are relatively more open to international trade than India.

For India we implemented Toda-Yamamoto (1995) multivariate causality test.<sup>4</sup> The results are reported in Table 7.

**Table 7:** Toda-Yamamoto Multivariate Causality Test for India

Dependent Variable	Sources of Causation	
	$y_t$	$z_t$
$y_t$	-	5.45
$z_t$	1.75	-

Table 7 shows that the null hypothesis of Granger non-causality running from trade to GDP can be rejected at the 10 per cent level of significance. However, the test does not support the reverse case. This implies that there is uni-directional causality running from trade to GDP in India. This result

<sup>4</sup> Since both series are I (1) and lag length is selected of order 2 based on the likelihood ratio adjusted for degrees of freedom. Using this information we jointly estimated equation and equation as Seemingly Unrelated Regression Equations (SURE) and conducted modified Wald (MWALD) test.

confirms trade-led hypothesis for the case of India. However, this evidence is very weak and marginal. There could be due to several possibilities for this result. Dadaro (1993) has noted that the relationship between trade and growth depends on many factors such as country size and importance of external sector. The larger the country size the less important will be the external sector and the weaker will be the relationship between trade and growth. Another possibility is that as economic growth takes place, domestic demand also increases leading to reduce volume of exportable and weakening the relationship between trade and growth. Other factor, such as international characteristics of the economy of each country, markets efficiency, degree of price distortions etc. also responsible in weakening the trade-growth relationship. Michaely (1977) has noted that exports are expected to influence growth only after countries achieved a minimum level of development. This implies that growth-trade relationship can be captured only in a non-linear framework. There may also be possible that in the case of India a rapid growth in domestic demand may create a situation whereby more of output is absorbed domestically leaving less for the export market. Consequently, economic growth and export growth could be moving in opposite directions.<sup>5</sup>

Based on the long-run estimates, we have estimated the short-run dynamics for Pakistan, Sri Lanka and Bangladesh. Table 8 reports the long-run and short-run causality results for each country. Two-way long and short-run causality observed for Pakistan. This result provides very important implications for Pakistan. For example, in the process of growth both exports and imports play very important and significant role through a variety of channels as mentioned in section 3. Import of necessary raw material and modern technology not only increases the value added products but also enhances the productive capacity of the country. Furthermore, cheap access to imports helps in reducing input costs and boost economic growth through technological spillovers. Similarly, exports boosts economic growth through the utilization of excess capacity, access to the wide world market, economies of scale and full capacity utilization of resources. Exports also exerts positive impacts on economic growth through improvements in efficiency due to

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<sup>5</sup> India is highly populated big country consuming a large amount of exportable domestically. Due to this the trade indicators do not represents the trade-growth linkages truly as compared to the other countries of the region.

**Table 8:** Long-Run and Short-Run Causality between  $y_t$  and  $z_t$ 

Bangladesh	$\Delta y_t = -0.25 - 0.57\Delta y_{t-1} + 0.14\Delta y_{t-2} + 0.38\Delta y_{t-3}$ $(-2.58)^* (-4.98)^* (1.33) (-3.78)^*$ $-0.007\Delta z_t + 0.04\varepsilon_{t-1}$ $(-0.89) (1.98)^{**}$ $R^2 adj = 0.66, \quad S.E. of regression = 0.009$ $F-stat = 9.01 \quad DW-stat = 1.89$	Short – run causality $\chi^2(2) = 0.79 [0.375]$ for $\sum \Delta z_t = 0$
	$\Delta z_t = -35.19 + 0.16\Delta z_{t-1} - 0.32\Delta z_{t-2} + 4.14\Delta y_t$ $(-3.10)^* (1.32) (-2.59)^{**} (-3.24)^*$ $-0.15\Delta trend - 0.40v_{t-1}$ $(2.86)^* (-2.77)^*$ $R^2 adj = 0.50, \quad S.E. of regression = 0.15$ $F-stat = 4.68 \quad DW-stat = 1.85$	Short – run causality $\chi^2(2) = 10.49 [0.001]$ for $\sum \Delta y_t = 0$
India	$\Delta y_t = 0.08 + 0.05\Delta y_{t-1} - 0.31\Delta y_{t-2} - 0.03\Delta y_{t-3} - 0.19\Delta y_{t-4}$ $(4.10)^* (0.31) (-2.10)^{**} (-0.21) (-1.27)$ $+0.08\Delta z_{t-1} - 0.07\Delta z_{t-2} + 0.02\Delta z_{t-3} - 0.01\Delta z_{t-4}$ $(2.07)^{**} (-1.72)^{***} (0.38) (-0.26)$	Short – run causality $\chi^2(4) = 6.05 [0.196]$ for $\sum \Delta z_t = 0$
	$\Delta z_t = 0.10 + 0.13\Delta y_{t-1} - 0.65\Delta y_{t-2} + 0.32\Delta y_{t-3} + 0.71\Delta y_{t-4}$ $(1.02)(0.16) (-0.81) (0.38) (0.85)$ $+0.29\Delta z_{t-1} + 0.08\Delta z_{t-2} + 0.09\Delta z_{t-3} - 0.17\Delta z_{t-4}$ $(1.37) (0.34) (0.40) (-0.75)$	Short – run causality $\chi^2(4) = 1.91 [0.753]$ for $\sum \Delta y_t = 0$
Pakistan	$\Delta y_t = 0.75 + 0.07\Delta z_t - 0.08\Delta z_{t-1} - 0.17\varepsilon_{t-1}$ $(2.51)^* (2.31)^{**} (2.76)^* (-2.08)^{**}$ $R^2 adj = 0.18, \quad S.E. of regression = 0.02$ $F-stat = 3.66 \quad DW-stat = 2.22$	Short – run causality $\chi^2(2) = 8.82 [0.012]$ for $\sum \Delta z_t = 0$
	$\Delta z_t = -6.69 + 0.55\Delta z_{t-1} + 1.82\Delta y_t - 0.72v_{t-1}$ $(-5.04)^* (3.77)^* (5.13)^* (-5.01)^*$ $R^2 adj = 0.45, \quad S.E. of regression = 0.12$ $F-stat = 9.41 \quad DW-stat = 2.13$	Short – run causality $\chi^2(2) = 26.27 [0.000]$ for $\sum \Delta y_t = 0$
Sri Lanka	$\Delta y_t = 2.19 + 0.02\Delta z_t - 0.009\Delta trend - 0.20\varepsilon_{t-1}$ $(3.08)^* (1.19) (3.09)^* (-3.35)^*$ $R^2 adj = 0.42, \quad S.E. of regression = 0.03$ $F-stat = 8.39 \quad DW-stat = 2.22$	Short – run causality $\chi^2(2) = 1.41 [0.235]$ for $\sum \Delta z_t = 0$
	$\Delta z_t = -3.57 + 0.38\Delta z_{t-1} + 1.14\Delta y_t - 0.43v_{t-1}$ $(-2.09)^{**} (2.44)^{**} (3.10)^* (-3.78)^*$ $R^2 adj = 0.46, \quad S.E. of regression = 0.22$ $F-stat = 7.84 \quad DW-stat = 1.94$	Short – run causality $\chi^2(2) = 9.63 [0.002]$ for $\sum \Delta y_t = 0$

\*, \*\* and \*\*\* indicate significant at the 1%, 5% and 10% level of significance respectively

the world competitive pressure, welfare gain through innovations and imitations, and accumulate foreign exchange which would facilitates more imports. Trade also allows efficient allocation of resources through the principles of comparative advantage. The result implies that in Pakistan trade-led growth and growth-led trade hypotheses hold in the long and short-run. This implies that Pakistan may incorporate both domestic and foreign resources in his development strategy<sup>6</sup> and may continue to focus on the expansion of trade through the import of necessary raw material and needed technology.

The evidence of one way causality running from growth to trade is identified for Sri Lanka and Bangladesh in the long as well as short-run. This suggest that for Bangladesh and Sri Lanka growth enhances trade in the long and short-run

Finally, in the case of India, the results of the long-run multivariate causality provide much weaker evidence of causality running from trade to growth. However, there is no evidence of short-run causality in either case. Only trade lagged by one and two period exerts positive and negative effects on growth respectively but the joint effect of trade on growth is insignificant. This implies that Indian growth is influenced by the foreign trade only in the long-run. However, the impact is very weak and negligible. This could be possible that Indian economy is not much open as much as in the case of other economies of the region, the domestic consumption is relatively large and perhaps India is still pursuing import substitution development strategy. Hence, India may concentrate more on domestic resources and less on foreign resources in order to accelerate the pace of its economic development.

## 6. Conclusions

The purpose of this study is to examine the dynamic linkages of trade-led growth hypothesis for four South Asian countries including Bangladesh, India, Pakistan and Sri Lanka within the framework of bound testing approach to cointegration. We find the evidence of cointegration in the case of Pakistan, Sri Lanka and Bangladesh. For India no evidence of cointegration is found. The evidence supports the validity of trade-led growth and growth-led trade hypotheses in Pakistan in the long -run. Based on the Granger-Causality test two-way causality exists in the case of Pakistan. In Bangladesh and Sri Lanka the evidence supports the hypothesis of growth-led trade in the long-run. Furthermore, there is evidence of one-way causality running from growth to trade is observed in the short-run for Bangladesh and Sri Lanka. For the case of India weak evidence of causality running from the trade to growth is found based on Toda-Yamamoto multivariate causality test in the long-run. However, in short-run the traditional Granger causality test fails to confirm any possibility of trade-growth linkages in either direction.

The important policy implications can be drawn on the basis of empirical evidence are:

- (i) Pakistan should continue with the import of necessary raw material and advanced technology to expand their productive capacity and pay full attention to boost their exports sectors. Bangladesh and Sri Lanka should concentrate on the expansion of domestic productive capacity of their economies.
- (ii) Indian growth is independent of trade and in order to obtain a meaningful gain from international trade India should further accelerate the pace of trade and economic liberalization.

This study provides very important implications regarding the dynamic linkages between trade and growth. However, the only limitation of the analysis is that the study simply focused on the link between growth and trade, but there are some other important factors that can influence the trade and growth process. Wacziarg (2001) hypothesized that trade effects growth through six potential channels:

- (i) macroeconomic policy quality,
- (ii) government size,
- (iii) price distortions/black market premium,
- (iv) investment share to GDP,

<sup>6</sup> Although, we focused only on the external side. However, domestic resources play decisive role in the development strategy of these countries.

- (v) technology, and
- (vi) foreign direct investment.

Hence, simultaneous equations model is needed that capture all these factors and determine how these channels influence economic growth. Future research in this area is expected to provide much useful information regarding the trade-growth linkages.

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## **Dioxin Contaminations of Synthetic Industrial Essential Oils (*Turare*) Utilized in Northern Nigeria**

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### **Abstract**

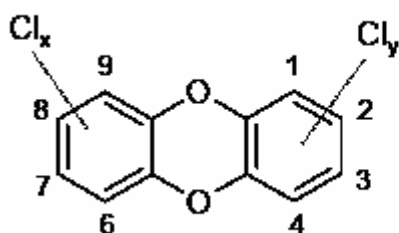
Synthetic Industrial Essential Oils (SIEOs) commonly referred to as *Turare* (in Hausa) is a highly utilized form of fragrance material in Northern Nigeria and was investigated for dioxin contaminations. The study area and sampling points consisted of the three major points of distribution of SIEOs in Northern Nigeria: Sokoto, Kano and Maiduguri. Three major categories of applications were also identified: socio-cultural, fashion and industrial formulations. Fifteen (15) typical SIEO samples were statistically pooled for this study. The EPA-17 targeted dioxins were determined by the EPA Method 1613. The results revealed the presence of the EPA-17 targeted dioxins at varying concentrations. These variations were statistically (ANOVA) significant at  $p < 0.05$  for the categories of samples analysed. The TEQ for dioxins in the samples ranges from 1.310-3.040ng/kg. These values were above the LOAEL reported by WHO. QC sample run for all samples gave a value within  $\pm 17\%$  and percentage recoveries were in the range of 73-115%. The uncertainty of measurement is within the acceptance criteria based on a confidence level of 95%. The implications of this result are the higher likelihood of exposure enrichments of dioxins with potential hazards to human health and the environment from the continuous utilization of SIEOs in Northern Nigeria.

**Keywords:** Dioxin, synthetic industrial essential oils, contamination, human health and environment

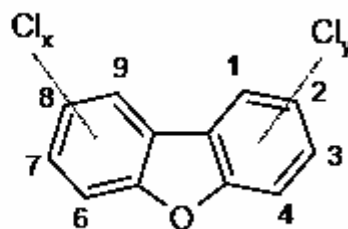
## Introduction

Synthetic Industrial Essential Oils (SIEOs) are essential oils containing synthetic fragrant compounds (Burfield, 2003; Calkin and Jellinek, 1994). The developments of synthetic organic chemistry within the last two decades have promoted the use of synthetic fragrant compounds in our lives (Turin, 2004), which have become highly acceptable due to the relatively low cost of production and steady available alternatives to the costly natural essential oils. Also, due to the drive to meet with the growing demands of the diverse application of fragrant compounds in manufacturing industries (Fortineau, 2004; Turin and Yushi, 2003). SIEOs commonly referred to as Turare (in Hausa) is a highly utilized form of fragrance material and its direct application is a widespread practice in Northern Nigeria which has grown steadily in recent years (Hati, 2005). The level of risks associated with the exposure to possible toxicants in this product, to human and the environment through the various forms of direct applications of SIEOs in Northern Nigeria remain unknown. Studies (Turin, 2004; Burfield, 2003; FDA, 1995) have reported certain components of synthetic fragrant compounds to be bio-persistent such as the long used nitromusks and polycyclic musks, polyaromatic hydrocarbons, pesticides and especially *dioxins* that are associated with industrial processes.

Dioxin is a shorthand term for a class of chemicals called polychlorinated dibenzo-p-dioxins and polychlorinated dibenzo-p-furans (structures of general formulae I and II) (WHO, 1998), in this paper, the terms 'dioxin' and 'dioxins' are used to include both. These chemicals have never been intentionally produced on an industrial scale, but are generated as wastes and by-products from combustion sources and certain chemical and industrial processes (Nordin, 2006; UNEP, 2002; ATSDR, 1998).



I. *polychlorinated dibenzo-p-dioxins*



II. *polychlorinated dibenzo-p-furans*

The most potent form of dioxin is 2, 3, 7, 8- tetrachlorodibenzo-p-dioxin (TCDD), and serves as the standard against which the toxicity of other dioxin congeners and other dioxin-like substances are measured. This measure is commonly referred to as the toxic equivalent factor (TEF) given by World Health Organization (WHO) (EPA, 2007). Dioxins cause a broad spectrum of different effects in several organs and tissues (EC, 1999; WHO, 1998). They have also being reported to be resistant to degradations, with long half-lives in air, water and soil, bioaccumulate and can be transported over long international boundaries (WHO, 2003; UNEP 2002).

Therefore, this work attempts to present information, which is lacking, on the level of contaminations of dioxins in SIEOs utilized in Northern Nigeria.

## Materials and Methods

### Study Area, Samples and Sampling

The study area comprises the three major points of distributions of SIEO products within Northern Nigeria: Sokoto, Kano and Maiduguri (Figure 1). A total of 75 SIEO samples were collected for this study over a two year (2005 and 2006) period. This followed the detailed survey of the forms of applications of SIEOs in Northern Nigeria as described by Hati (2005). Three major categories of SIEOs applications were identified. These are socio-cultural, fashion and industrial formulations (Table 1).

Due to the wide range of these products, samples collected for this work was obtained from narrowed statistical data of volumes of annual output distribution of the products. This was obtained from manufacturers' distributors in the study area. Thus, only SIEO products  $\geq 4500$  tons/yr were collected for analysis. Only 15 typical SIEO products qualified. For each of these, a composite (100ml) of five different batches of 20ml each was collected directly from product manufacturers distributors by decanting into well labeled sterile glass bottles.

**Figure 1:** Map of Nigeria Indicating the Three Major points of Distribution of Synthetic Industrial essential Oils (SIEOs) in Northern Nigeria



**Table 1:** Three Major Categories of Application of SIEOs in Northern Nigeria

Category	Description
Socio-cultural	1. Burning SIEOs with woods, resinous and other fragrance substances. 2. Multiple mixtures of SIEOs applied on body.
Fashion	Applications of SIEOs as perfume/fragrance on body, clothe and home/office
Industrial formulations	Industrial use for production of eau de cologne, soap, pomade, perfume, etc.

### Determination of Dioxins

The EPA 17-targeted chlorinated dioxins were determined by In-House Method based upon EPA Method 1613 (EPA, 1994). This method is for the determination of tetra- through octa-chlorinated dibenzo-*p*-dioxins (CDDs) and chlorinated dibenzofurans (CDFs) by isotope dilution, high-resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS). The analysis was conducted in Hall Analytical Laboratories Ltd. Millbrook, Manchester (UK). The determination also received slight modifications due to the nature of samples based on Schrock, *et al* (1996) for the simultaneous and efficient screening of the dioxin compounds.

### **Preparations of Dioxins Internal Standard and Spiking Solution**

Each labeled CDDs/CDFs internal standard solution was prepared from their standard stock solutions. 2 mg of 2,3,7,8-TCDD weighed to three significant figures in a 10mL ground-glass-stoppered volumetric flask and filled to the mark with nonane. A sufficient volume of the labeled  $^{13}\text{C}_{12}$ -1,2,3,4-12TCDD to  $^{13}\text{C}_{12}$ -1,2,3,7,8,9-HxCDD in nonane were further diluted by a factor of 50 with acetone to prepare a diluted spiking solution. Each sample analyte used 1.0mL of this solution as described in EPA Method 1613 (EPA, 1994).

### **SIEO Sample Preparation for HRGC/HRMS**

One (1g) each of the SIEO sample was dissolved in 10ml of toluene and spiked with PCDD/PCDF internal standard solutions. They were swirled well to mix, covered with foil, and allowed to stand for approximately 5 minutes. Further samples were spiked with 2,3,7,8-TCDD- $^{37}\text{C}_{14}$  and cleanups standards procedure carried out with activated Florisil 60-100 mesh as described in EPA Method 1613 (EPA, 1994).

### **HRGC/HRMS Analysis**

Waters AutoSpec® HRGC/HRMS with a resolving power of 10,000 and a 60m DB5-MS J&W GC column was used for this analysis. Simultaneous analysis of the seventeen 2,3,7,8-substituted PCDD/PCDF was performed on injection volumes of 0.5 $\mu\text{L}$  at the following GC temperature and time program: 200-220°C, at 5°C/minute, 220°C for 16 minutes, 220-235°C, at 5°C/minute; 235°C for seven minutes, 235-330°C, at 5°C/minute. Selected ion current profiles for analyte and method blank were recorded.

### **Data Analysis**

Data obtained were subjected to simple percentage calculations and statistical data analyses using and Analysis of Variance (ANOVA) and considered significant when  $p < 0.05$ . Data analysis was performed using coupled Microsoft Excel+Analyse-it® version 1.73 (2006).

### **Results**

Figure 2 shows the percentage distributions of samples analysed in this work, according to the three categories of applications of SIEOs in Northern Nigeria. It showed that 61%, 21% and 13%, of the total samples analysed were for applications in socio-cultural, fashion and industrial formulations respectively. It also showed the percentages of more than a single form of applications of the SIEO samples within two categories. Such as, up to 90% of samples in the industrial formulation category have been noted to be utilized for socio-cultural purposes. Similarly, only about 15% of samples in the industrial formulation category are used of fashion. While up to 75% of samples in fashion category have been noted to be applicable for socio-cultural use. These percentage distributions are relevant for assessing both socio-cultural and fashion forms of application as they are the two pertinent forms of direct applications.

**Figure 2:** Percentages of SIEO samples application coverage based on volume of utilization in Northern Nigeria

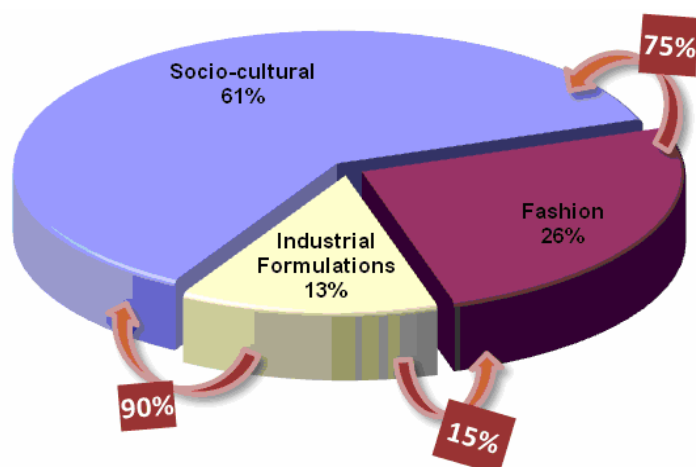


Figure 3 shows the mean WHO I-TEQ of dioxins in all samples analyzed, irrespective of category of application of SIEOs. The error bars are standard deviations ( $\pm$ SD). The result revealed that 1,2,3,7,8-penta chlorinated dibenzo-p-dioxin (1,2,3,7,8-PeCDD) and 1,2,3,7,8,9-hexa chlorinated dibenzo-p-furan (1,2,3,7,8,9-HxCDF) were the highest in concentrations and variation for the polychlorinated dibenzodioxins and the polychlorinated dibenzo-p-furans respectively. The least concentrations and variations were observed for the highly substituted octa and hepta congeners (OCDD/F and HpCDD/Fs). ANOVA, with Scheffe Test for Post Hoc comparison showed that the variations between some of the samples were significant ( $p < 0.05$ ) only in terms 1,2,3,7,8-PeCDD and the HxCDDs.

The results for quality control (QC) sample run for all samples gave a value within  $\pm 17\%$  of the mean value from 20 individual analyses. This means the uncertainty of measurement is within the acceptance criteria based on a confidence level of 95%. The percentage recoveries were in the range of 73- 115%.

**Figure 3:** Mean concentrations of dioxins in SIEOs utilized in Northern Nigeria

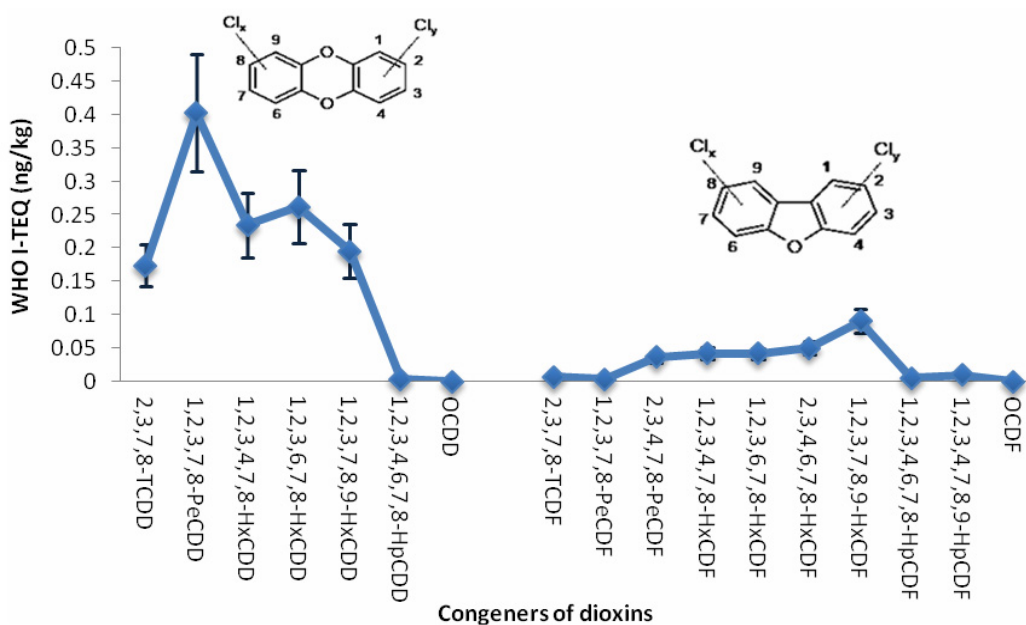
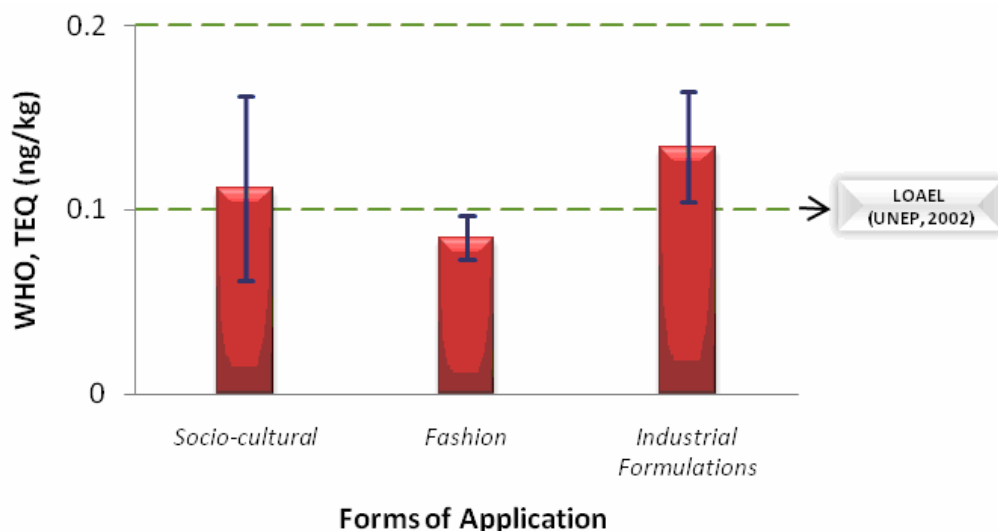


Figure 4 shows the mean  $\pm$  SD (error bars) WHO's TEQ of SIEO samples analyzed according to the three categories of applications in Northern Nigeria. Excepting the fashion category of SIEOs application, both socio-cultural and industrial formulations showed mean TEQ at levels beyond the Lowest Observable Adverse Effect Level (LOAEL) of 0.1ng/kg reported by UNEP (2002). SIEO samples categorized in the application group of industrial formulations present the highest mean TEQ. This difference was observed to be statistically significant ( $p < 0.05$ ) by ANOVA, with Scheffe Test for Post Hoc comparison.

**Figure 4:** TEQ for the categories of SIEO samples analysed for dioxin contaminations



## Discussion

Results showed that socio-cultural application of SIEOs is the basis for the large distribution in Northern Nigeria and perhaps a vital factor for their importations in Nigeria. The results also showed that SIEOs are contaminated by dioxin at a TEQ level of concern as regards the direct forms of applications.

Three types of chemical manufacturing processes have been suggested to be possible causes of dioxins contamination. These are bleaching of wood pulp in paper manufacturing, chlorine and chlorine-derivative manufacturing, and halogenated organic chemical manufacturing (Clement *et al.*, 1989; Swanson *et al.*, 1988). For SIEOs, the complex chemical reactions involved in their production requiring chlorinated reagents at one stage on another, coupled with petroleum products as raw materials already containing dioxins are very likely to be the sources of dioxins contaminations (Burfield, 2003; RUK, 2004). However, the general variations in the levels of dioxins may be as a result differences in batch production (Byrne and O'Grady, 1990) and type of essential oil formulations (RUK, 2004). Other factors may include the economic considerations in the proliferations of lower SIEO versions; physical and chemical changes through production, transportation and storage conditions.

Product label of SIEOs indicate certain common fragrant compounds as contents, e.g. terpenes, cyclopenta benzopyran and Galaxolide®, these are likely to be responsible for the prevailing higher TEQ concentration values of the polychlorinated dibenzo-p-dioxins (especially the 1,2,3,7,8-PeCDD) in the SIEO samples analysed. It is also anticipated that this variations may broaden considerably if the entire range of SIEOs are considered. Thus the justification of the sampling criterion to  $\geq 4500$  tons/yr was to obtain a pilot idea on exposure frequency.

Though the TEQ of dioxins is higher in samples within the category of industrial formulations, but would not have been so much cause for concern if SIEOs in this category are specifically used for the purpose of industrial admixes. Because only about 5-15% of total volume of finished product is SIEO or fragrance in most industrial products (Api, 2000). However, as presented in Table 1 and Figure 4, the socio-cultural form of application are likely to poses a greater danger of possible exposures of dioxins contaminations to both human health and the environment. A number of studies (ATSDR, 1998; Wunderli et al., 2000; Gullett et al., 2001) have shown that combustion is one major source of dioxin. Therefore burning SIEOs could lead to higher exposure enrichment as it acts both as a source and providing aromatic precursor compounds, and in the presence of a chlorine donor promoted by a transition metal catalyst, high dioxin emissions are achieved (Liberti and Brocco, 1982; Dickson and Karasek, 1987). Further possibilities of dioxin formation during combustion process have been well established with the *De novo* synthesis pathways (Luijk et al., 1994; Addink et al., 1995). Combustion or burning temperatures between 200° and 450° Celsius (C) are most conducive to forming dioxins, with maximum formation occurring at around 350°C (Addink et al., 1995; UNEP, 2002), which is within the temperature range for burning SIEOs in most Northern Nigerian homes. Therefore inhalation of dioxins as well as air pollution from this form of continuous applications is promoted. Application of SIEOs on the body leads to dermal exposure of these contaminants, which though not as hazardous as inhalation (Duffus and Worth, 1996) but are encouraged thereby.

The toxicological effects of dioxins reported by UNEP (2002) refer to their agonist for the Aryl hydrocarbon Receptor (AhR). All the 2,3,7,8-substituted PCDDs and PCDFs show the same type of biological and toxic response (WHO, 1998; WHO, 2003).

Apart from the possible human health hazards that this product might pose upon direct application, environmental hazards via incidental combustion such as the fire incidence of Wednesday 26 July 2006 (Bego and Idris, 2006), in the Maiduguri Monday Market which affected mainly the fragrance section of the market, certainly exposed the entire Maiduguri biota to toxic emissions of combustion (especially the dioxins) at that moment.

Though, the current regulatory system allows synthetic chemicals into our lives unless proven beyond doubt to be dangerous. Usually, it takes dramatic episodes of workplace injuries or wildlife poisonings, combined with rigorous scientific proof of harm and public outcry, before the government will act to restrict or ban any chemical (EC, 2003). Natural materials are not necessarily safer than synthetics. However, they have a much longer history of use so the adverse effects are better known. Natural materials are mixtures of sometimes hundreds of compounds. There are both synergistic and modifying effects of combinations of chemicals. The actions of these combinations are often very different than isolates or synthetics (Schueller and Romanowski, 1996).

Safety and precautionary information on the product labels of most of SIEOs product packages, including pictograms of health and environmental hazards for each product. Indicates that products are essential oils for industrial use or industrial admix, personal protective equipments (PPE) e.g. gloves are to be worn when handling, and that products contain chemicals that can pose long term toxic effects on aquatic organism, and may cause irritation or damage to eyes, skin and lungs upon contact. "Avoid release to the environment" and the UN class for transportation of dangerous, flammable and toxic materials are also indicated. Some of the products labels indicate presence of compounds such benzoic acid, 2- (phenylmethylene-1-trans 3)-ester, as substances of various allergic potentials. These safety and precautionary background information are not observed.

## Conclusion

The levels of dioxin contaminations determined in this work are significantly high. The results revealed a higher likelihood of exposure enrichments through the pertinent forms of applications of SIEOs in Northern Nigeria, with potentials for human health and environmental hazards. Further studies on the exposure levels of dioxins to users of SIEOs will be helpful in ascertaining the interaction profile of this contaminant in humans.

## Acknowledgement

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## **Mineralogical and Chemical Characters of the Aféma Shear Zone Gold Mineralization, South-East of Ivory Coast: Exemple of the Hermann Mine**

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### **Abstract**

The Hermann deposit which is in the Afema district (area of Aboisso, South-East of Ivory Coast) is located in the large Afema-Bibiani shear zone. The study of the mineralized zones showed that gold mineralisation was associated to a strong hydrothermal alteration. The mineralized bodies are made of quartz veins of N30°E direction, enclosed in an acidic volcanic rock (rhyolite type). The metalliferous paragenesis is mainly made of pyrite which is often associated to arsenopyrite and rarely to sphalerite, gold, and chalcopyrite. The gold grains are observed either as fine inclusions in the pyrite, or as veinlets filling microcracks of the pyrite crystals (the most widespread texture). In fact, the setting up of the mineralization seems to have been carried out in the circulation of two fluids: the first is marked by the cristallization of quartz ( $\pm$  calcite), pyrite, arsenopyrite, sphalerite, gold and chalcopyrite; the second fluid is marked by the cristallization of quartz and gold in fractures of pyrite. The gold minerals are never pure, but always contain small amounts of silver (8.5 to 10.13 wt %).

**Keywords:** Aféma; Birimian; Metarhyolite; Hydrothermal alteration; Sulfides; Gold.

## 1. Introduction

Le Protérozoïque inférieur de l'Afrique de l'Ouest est une période marquée par d'importantes minéralisations aurifères (Milesi *et al.*, 1989; Sylla *et al.*, 1993). La région de l'Aféma, dans le Sud-Est de la Côte d'Ivoire (Fig. 1) constitue une de ces provinces aurifères. Plus d'une quinzaine de lentilles aurifères y ont été identifiées. Parmi celles-ci, cinq ont été exploitées entre 1990 et 1998 par la Société des Mines d'Aféma (SOMIAF), produisant ainsi 125 000 onces d'or. La région revêt encore un grand intérêt et est actuellement l'objet de plusieurs campagnes de prospection (Bradford, 2005).

Le présent travail se voudrait être une contribution à une meilleure connaissance des types de minéralisations aurifères du couloir de cisaillement de l'Aféma et plus précisément du secteur de la mine "Hermann".

## 2. Cadre Géologique Régional

La mine Hermann est localisée dans l'Aféma (région d'Aboisso) au Sud-Est de la Côte d'Ivoire. Elle se situe dans le domaine paléoprotérozoïque du bouclier ouest-africain, plus précisément de la dorsale de Man dont l'épisode majeur est le Birimien. Le Birimien est un épisode de création crustale entre 2,2 et 2,1 Ga (Abouchami *et al.*, 1990; Boher, 1991).

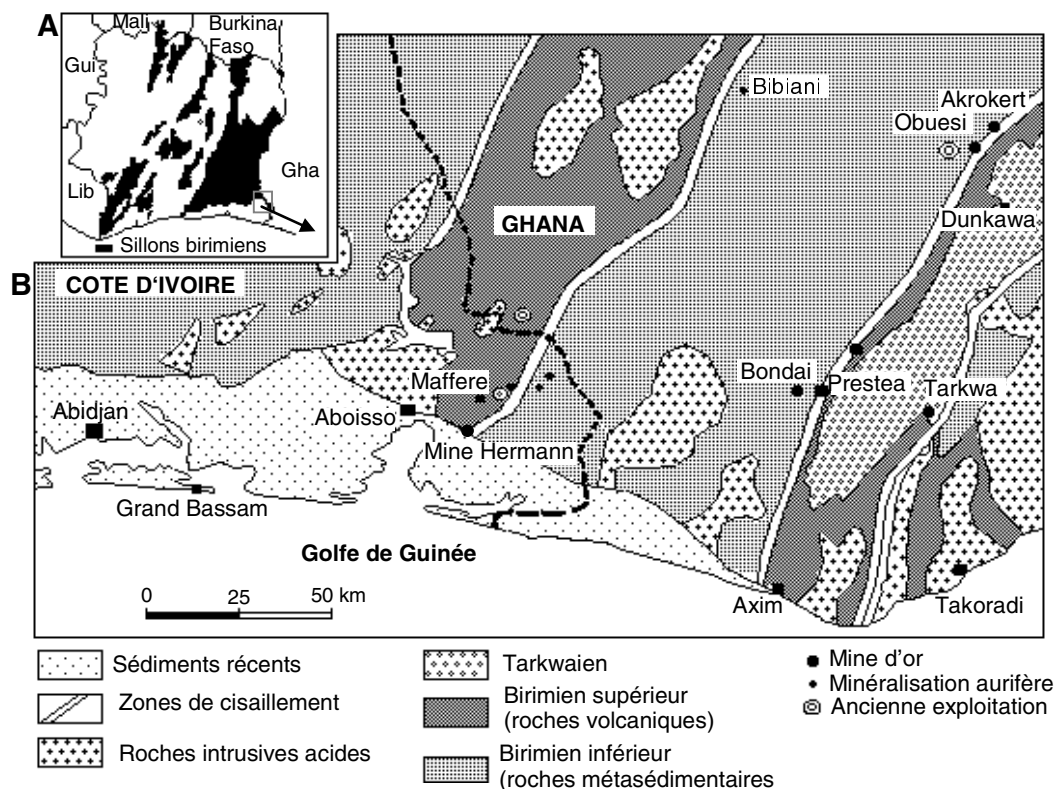
Le Sud-Est de la Côte d'Ivoire, auquel appartient la zone d'étude est localisé dans l'unité birimienne de la Comoé (Vidal, 1987, Fig. 1). En allant du Nord-Ouest vers le Sud-Est, les formations birimiennes de cette région sont constituées par une série de roches volcano-sédimentaires et méta-sédimentaires. Les roches volcano-sédimentaires et méta-sédimentaires sont séparées par une zone de contact de 3 km de largeur appelée couloir de cisaillement de l'Aféma (Fig. 2) ou zone tectonique d'Aféma (Tourigny, 1998). Cette zone constitue l'élément structural majeur à l'échelle régionale. Elle s'étend au delà de la frontière ivoirienne, et est connue au Ghana sous le nom de "Sefwi belt". Les formations birimiennes de ce couloir sont marquées par un plissement isoclinal sub-vertical ( $70^{\circ}$  à  $80^{\circ}$  SE) de direction N  $30^{\circ}$  E.

La minéralisation aurifère qu'on y trouve est de type filonien. Elle comprend des filons et des filonnets de quartz à sulfures aurifères ayant pour encaissant soit des formations méta-sédimentaires: schistes graphiteux et schistes quartzeux à séricite (Sonnendrücker, 1967; Adou, 1995; Husson, 1998), soit des tufs rhyolitiques; c'est le cas des gisements des mines de Jonction et d'Aniuri (Allou, 1998; Pothin *et al.*, 2002 et 2003). Ces filons et filonnets de quartz forment les méga-lentilles des mines de Jonction, d'Aniuri, de Brahima et d'Asupiri-Adiopon.

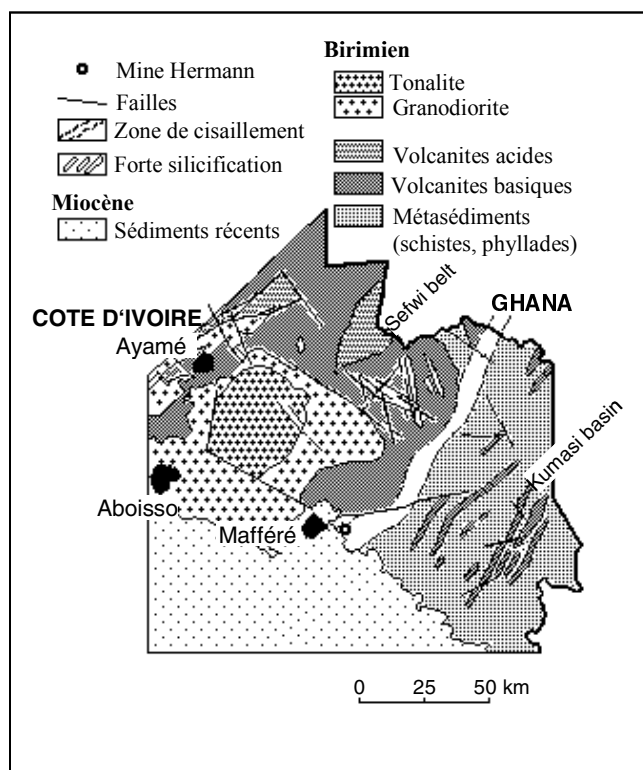
## 3. Méthodes

Cette étude du gisement Hermann a été faite à partir de travaux de terrain et l'observation des carottes de sondages. Les échantillons représentatifs de chaque faciès pétrographique et des zones minéralisées, ont été prélevés pour la réalisation de lames minces et sections polies.

**Figure 1:** A: Carte de la Côte d'Ivoire avec la localisation des principaux sillons birimiens (Gui: Guinée, Lib: Libéria, Gha: Ghana)  
B: Carte géologique de la région et localisation de la mine Hermann (document SOMIAF repris par Watts et al., 1995, modifié)



**Figure 2:** Carte géologique du permis d'Aféma



Une étude pétrographique et physique des phases minérales a été faite grâce à l'utilisation de la loupe binoculaire, du microscope optique au laboratoire de Géologie du Socle et de Métallogénie de l'UFR STRM à l'Université de Cocody. L'étude a été complétée par des observations au microscope électronique à balayage ainsi que des analyses ponctuelles de la composition chimique des phases métallifères à la microsonde électronique (Camebax SX50) à l'Université Henri Poincaré de Nancy I sur les lames minces et sections polies.

## **4. Résultats**

### **4.1. Géologie du secteur de la mine Hermann**

Les formations birimiennes du secteur de la mine Hermann sont constituées de roches d'origine volcanique (Kramo, 2001). Ce sont des méta-rhyolites, des méta-basaltes et des méta-dolérites. Ces formations ont été affectées par un métamorphisme régional épizonal de type faciès schiste vert. Des filons et des filonnets hydrothermaux de quartz et sulfures aurifères sont encaissés dans la formation rhyolitique, à proximité de la zone de contact avec le metabasalte. En bordure des veines de quartz, la roche présente une couleur blanchâtre liée à l'altération hydrothermale. Les phénomènes hydrothermaux à quartz dominant sont largement développés tout au long du couloir de cisaillement de l'Aféma. Ce phénomène d'ampleur régional serait à l'origine de nombreux filons de quartz localement minéralisés en or (Sylla *et al.*, 1993).

### **4.2. Minéralisation**

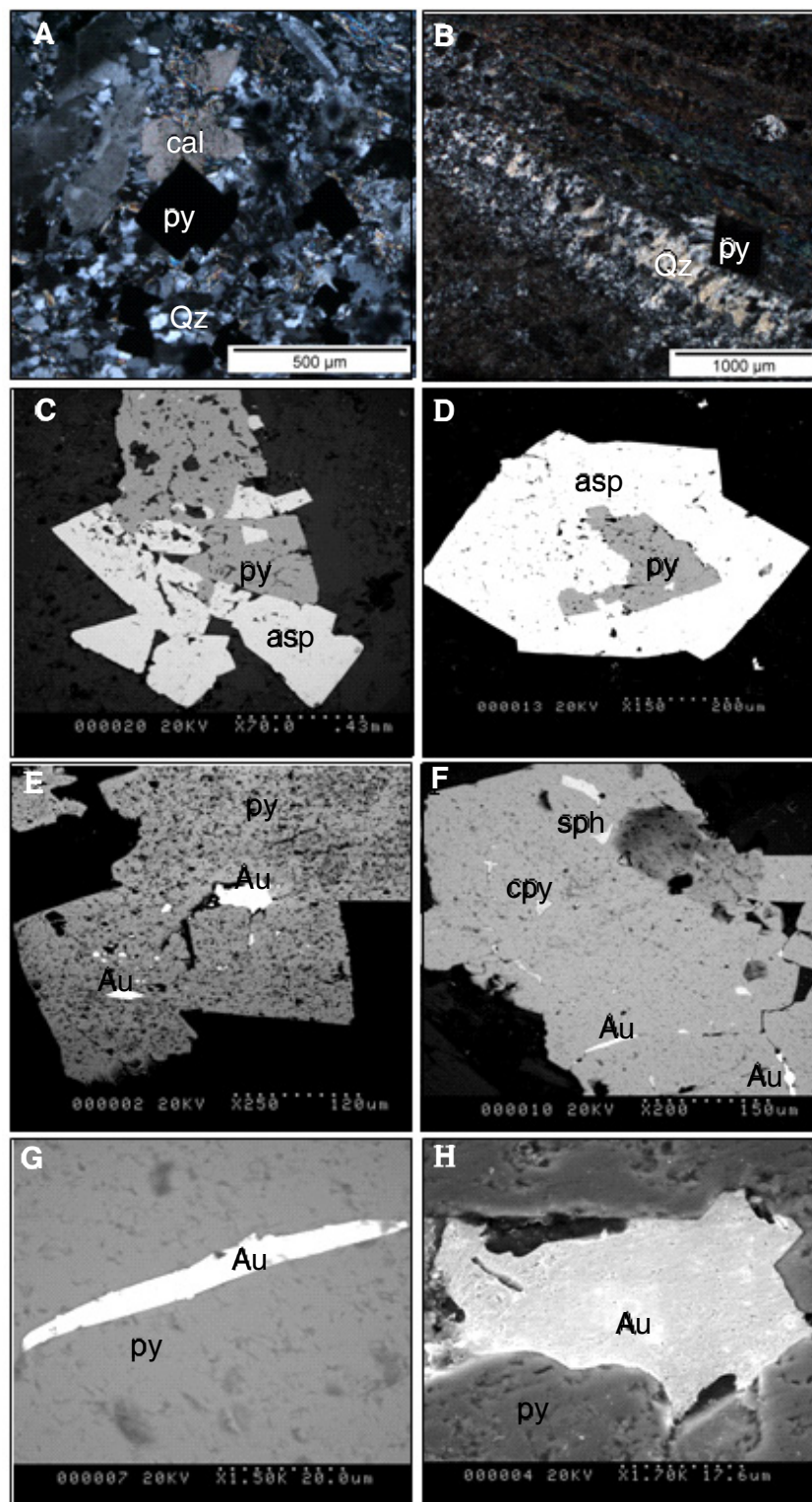
#### **4.2.1. Pétrographie de la zone minéralisée**

Les observations macroscopiques et microscopiques faites sur les carottes de sondage et sur le terrain permettent d'affirmer que la zone minéralisée de la mine Hermann est caractérisée par une forte altération hydrothermale marquée par des filons et des filonnets de quartz dont la puissance varie de 0.5 cm à 150 cm. Ces filons et filonnets de quartz sont localisés dans des fractures ouvertes orientées N30°E (direction du couloir de cisaillement de l'Aféma) observées dans des roches volcaniques acides de type rhyolite.

Le quartz a une structure massive et compacte, mais présente des micro-fractures disposées de façons irrégulière dans les zones de fortes teneurs en or. Au microscope, ces veines de quartz sont constituées par une association de petits cristaux polygonaux à extinction roulante associés à des plages de sulfures, calcite, et quelques rares cristaux d'épidote (Fig. 3 A et B). Le quartz peut également se présenter en ruban dans les ombres de pression des gros minéraux de pyrite. Les filons de quartz de la zone minéralisée sont parallèles à la schistosité de flux  $S_1$  et par endroit réorientés par les différentes phases de déformation postérieures à leur mise en place.

Ces filons hydrothermaux sont enveloppés par une zone d'altération pervasive de l'encaissant, visible à l'œil nu sur les carottes de sondages. Au microscope, cette zone est caractérisée par une abondance de carbonates (calcite essentiellement), de sulfures et une forte silicification de l'encaissant. Selon Kramo (2001), les veines et filons de quartz présentant une abondance de sulfures ont les teneurs les plus élevées en or.

**Figure 3:** Photomicrographies aux microscopes optique (A, B) et électronique à balayage (C, D, E, F, G, H) de la minéralisation de la mine Hermann A, B: Filonnets de quartz hydrothermal; C,D: Association pyrite (py)-arsénopyrite (asp); E: inclusions d'or dans la pyrite, F: filonnets d'or dans la pyrite fissurée; G, H: détails des grains d'or



#### 4.2.2. Caractères minéralogiques et chimiques de la paragenèse métallifère

Dans la mine Hermann, la pyrite constitue plus de 80 % du volume de la paragenèse métallifère; le reste étant constitué par ordre décroissant d'arsénopyrite, de sphalérite, d'or et de chalcopryrite.

### **La pyrite**

Elle se présente sous diverses formes et de taille variable dans la zone minéralisée. Les cristaux grossiers et trapus montrent de nombreuses inclusions de quartz, d'autres sulfures et d'or natif. Les grains de pyrite sont dépourvus de toute texture de déformation ductile et présentent des zones abritées où on note des cristaux allongés de quartz. Ces cristaux de pyrite portent par contre des craquelures qui témoignent de l'intensité des phénomènes tectoniques qu'a subit la zone minéralisée (Fig. 3 C, D, E et F). Ces micro-fractures peuvent renfermer de l'or natif (Fig. 3 E et F).

L'analyse ponctuelle effectuée sur les pyrites donne les proportions pondérales suivantes: 44.78 de Fe, 54.28 de S et 0.91 de As (Tableau I). La présence de l'arsenic dans la pyrite s'explique par une substitution du soufre par l'arsenic dans le réseau cristallin de la pyrite. Fleet *et al.* (1989), en se basant sur des données obtenues par microscopie électronique à transmission et micro-diffraction aux rayons X, concluent que l'arsenic est incorporé dans la pyrite sous forme d'une solution solide métastable du type  $\text{Fe}(\text{S}, \text{As})_2$  avec une structure de type marcassite.

### **L'arsénopyrite**

L'arsénopyrite est le second sulfure le plus abondant dans la zone minéralisée. Elle se présente sous diverses formes: aiguille, losangique, bâtonnet allongés et xénomorphe. Certains cristaux renferment des inclusions de la gangue. Ces inclusions sont toutefois moins fréquentes que celles observées dans la pyrite. Les cristaux d'arsénopyrite sont par endroit associés à la pyrite (Fig. 3 C). Des gros cristaux généralement sub-automorphes se substituent à la pyrite (Fig. 3 D). Lorsque ces deux sulfures sont associés, ils présentent les mêmes textures: de nombreuses microfractures avec des pores de dissolution. On observe un remplissage des microfractures par la gangue constituée essentiellement de quartz (Fig. 3 C). Ceci peut s'interpréter par la circulation d'une seconde génération de quartz postérieure à la mise en place de l'arsénopyrite et de la pyrite.

Ces deux textures, dissolution et fracturation démontrent que ces métaux ont été soumis à des conditions oxydantes éphémères et de déformation cassante (Michel, 1993).

L'analyse de l'arsénopyrite nous donne les proportions pondérales suivantes 34.58 de Fe, 41.08 de As et 24.33 de S (Tableau II). En comparant ces résultats à la composition standard de l'arsénopyrite donnée par Aubert *et al.* (1978), on remarque un enrichissement important des arsénopyrites de la mine Hermann en soufre.

### **La sphalérite ou blende**

Ce sulfure n'a été observé que grâce au microscope électronique à balayage. Il se présente en cristaux microscopiques en inclusion dans la pyrite (Fig. 3 F).

Les proportions pondérales sont 4.22 de Fe, 36.71 de S et 59.07 de Zn (Tableau III).

### **La chalcoppyrite**

Elle est rare, car un seul grain a été observé au microscope électronique en inclusion dans un cristal de pyrite (Fig. 3 F). La faible teneur de chalcoppyrite pourrait s'expliquer par la faible présence de Cu dans le fluide minéralisateur originel. Elle est constituée de 29.58 pds% de Fe, 38.63 pds% de S, 31.79 pds% de Cu

**Table I:** Composition chimique de la pyrite (% du poids total)

Echantillon	Eléments en % pds		
	Fe	S	As
H1SP-1	44,19	54,63	1,18
H1SP-5	44,42	55,03	0,54
H1SP-6	44,72	55,28	
H1SP-8	44,49	55,10	0,41
H2SP-3	44,57	53,33	2,10
H2SP-4	44,66	54,38	2,98
H2SP-7	44,86	54,44	0,70
H2SP-9	44,89	54,18	1,01
H4SP-4	47,06	52,62	0,18
H4SP-3	44,10	55,90	

**Table II:** Composition chimique de l'arsénopyrite (% du poids total)

Echantillon	Eléments en du pds %		
	Fe	S	As
H2SP-1	34,46	24,26	41,27
H2SP-2	34,83	24,67	40,50
H2SP-5	34,82	24,58	40,60
H2SP-6	34,27	24,27	41,46
H2SP-8	34,54	23,90	41,55

**Table III:** Composition chimique de la sphalérite (% du poids total)

Echantillon	Eléments en pds%			
	Fe	S	Zn	Autres
H1SP-9	8,04	38,98	52,98	
H1SP-11	2,05	38,18	59,77	
H4SP-1	5,81	38,08	56,11	
H4SP-3	0,97	31,62	67,42	Si=0,14

### L'or natif

Les cristaux d'or ont été observés soit en fines inclusions dans la pyrite, soit en remplissage des micro-fractures des cristaux de pyrites (texture la plus répandue). La taille et la forme des grains d'or sont variables (Fig. 3 E et F): allant des formes allongées sous forme d'aiguille d'or natif (Fig. 3 G) à des grains xénomorphes (Fig. 3 G). Une observation de la surface des grains d'or au fort grossissement, montre une irrégularité de celles-ci, qui serait due à des niveaux de recristallisation des grains d'or.

L'analyse ponctuelle des grains d'or révèle que l'or n'est jamais pur, mais toujours associé à une faible proportion d'argent (8.5 à 10.13 pds%). Quelques grains d'or renferment des traces de fer estimée à 3.88 pds% (Tableau IV). D'autres indiquent des traces de fer (1.3 pds%) et d'aluminium (0.43 pds%). Selon Lawrance (1991), la présence d'éléments tels que Al, Fe et Si dans la composition chimique de l'or est probablement due à l'inclusion de la gangue dans le grain d'or natif au cours de sa croissance, parce qu'il n'y a pas de substitution naturelle de ces éléments dans la structure de l'or.

**Table IV:** Composition chimique de quelques grains d'or (% du poids total)

Echantillon	Eléments en pds %			
	Au	Ag	Fe	Al
H1SP-2	90,43	9,57		
H1SP-3	91,48	8,52		
H1SP-4	86,29	9,83	3,88	
H1SP-7	88,14	10,13	1,30	0,43



## 5. Discussion

### 5.1. Origine de la minéralisation

La minéralisation aurifère de la mine Hermann est à distribution préférentielle car cantonnée à des roches volcaniques acides de type rhyolite, à proximité de la zone de contact avec le basalte. L'ensemble des formations de la zone a été affecté par un métamorphisme général dans le faciès des schistes verts. C'est une minéralisation hydrothermale qui apparaît syntectonique, donc épigénétique. En effet, d'une part, la paragenèse métallifère est incluse dans des filons hydrothermaux parallèlement à la schistosité et d'autre part, les sulfures sont dépourvus de toute texture de déformation ductile.

Les zones minéralisées sont essentiellement les filons et les filonnets de quartz localisés dans les fractures ouvertes orientées N30°E (direction du couloir de cisaillement de l'Aféma).

### 5.2. Paragenèse métallifère

La paragenèse métallifère rencontrées dans la minéralisation de la mine Hermann est constituée par ordre d'abondance décroissante de pyrite, arsénopyrite, or, sphalérite, et chalcoppyrite. A l'exception de l'arsénopyrite qui présente une teneur élevée en soufre, les sulfures de la zone minéralisée ont tous une composition chimique qui est proche de celle des sulfures théoriques.

La sphalérite et la chalcoppyrite ont toujours été observés en inclusion dans les cristaux de pyrite en compagnie d'une partie de l'or natif. Les gros cristaux de pyrite et d'arsénopyrite présentent de nombreuses fractures et microfractures dont certaines (cas de la pyrite) sont remplies de cristaux d'or natif. Cet or apparaît ainsi postérieur à la fracturation et donc à la mise en place de la pyrite et de l'arsénopyrite.

Vue tout ce qui précède et en se basant sur la définition de la paragenèse comme étant une association minéralogique résultant d'un même événement géologique (Park et MacDiarmid, 1975), nous pouvons distinguer deux stades paragenétiques liés à la circulation de deux fluides hydrothermaux essentiellement siliceux:

- stade 1: mise en place du quartz 1 et d'une association métallifère essentiellement constituée de pyrite souvent associée à l'arsénopyrite et quelques rares cristaux d'or, sphalérite et chalcoppyrite sous forme d'inclusions dans la pyrite,
- stade 2: remplissage des micro-fractures des sulfures du stade 1 par l'association quartz 2 et or.

L'or a été observé uniquement dans la pyrite soit en remplissage des micro-fractures soit en fines inclusions. En revanche, aucun grain d'or n'a été observé dans l'arsénopyrite, qui est pourtant souvent associé à la pyrite aurifère. Il n'est toutefois pas exclu que ce minéral contiennent de l'or sous forme d'inclusions sub-microscopiques. L'or n'est pas totalement pur et est toujours associé à une faible fraction d'argent (8.5 à 10.13 pds%). Des travaux réalisés dans d'autres régions minéralisées en or du Protérozoïque inférieur ont également révélés des teneurs en argent des particules d'or comprises entre 6% et 9% (Minko *et al.*, 1992; Sylla *et al.*, 1993; Freyssinet, 1993).

## 6. Conclusion

La minéralisation aurifère de la mine Hermann est cantonnée à des roches volcaniques acides de type rhyolite, à proximité de la zone de contact avec un basalte. C'est une minéralisation hydrothermale qui apparaît syntectonique, donc épigénétique. La paragenèse métallifère est constituée par ordre d'abondance décroissante de pyrite, arsénopyrite, or, sphalérite, et chalcoppyrite. Les grains d'or s'observent soit en fines inclusions dans la pyrite, soit en remplissage des micro-fractures des cristaux de pyrites. Ainsi, la mise en place de la minéralisation semble s'être effectuée à la faveur de la circulation de deux fluides: le premier est marqué par la mise en place de quartz ( $\pm$  calcite), pyrite, arsénopyrite, sphalérite, or et chalcoppyrite. le second par la mise en place de quartz et or dans les

fractures affectant la pyrite du stade 1. L'or n'est jamais pur, mais toujours associé à une faible proportion d'argent.

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# **Caractérisation de la Répartition Spatio-Temporelle des Bactéries à L'interface Eau-Sédiment D'une Lagune Tropicale: Cas de la Baie du Banco, Abidjan, Côte D'ivoire**

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## **Abstract**

A study was conducted on a tropical lagoon in Abidjan, Côte d'Ivoire, to assess the sanitary level of water and sediment interface. A total of 90 water samples were collected from three sampling stations (A, B and C) with 30 samples for each station. The results obtained reveal that the water-sediment interface was highly contaminated. Mean count ( $\log_{10}$  CFU/g) of fecal coliform, fecal *streptococcus* and *Clostridium perfringens* were  $3.77 \pm 3.5$ ,  $2.9 \pm 2.6$ ,  $3.5 \pm 3$  respectively. *Salmonella* was not found in all the samples. Twenty

two non-coli form enterobacteria strains were found in 49% of the water samples examined. *Proteus* was the most important genus with a prevalence of 41% followed by *Edwardsiella* 27.3%, *Hafnia* 13.6% and *Providencia* 18.1%. The statistical analysis using the Levene test showed a significant difference ( $\alpha=0.05$ ) in the distribution of fecal coliform and fecal *streptococcus* from the 3 stations. However there was significant difference in the distribution of *Clostridium perfringens*. Some physico-chemical parameters were also measured. Salinity (17,18<sup>0</sup>/100), pH (7,63), conductivity (21,45  $\mu\text{S}/\text{cm}$ ) and temperature (26°C) seemed determining in the distribution of the microorganisms from the 3 stations according to seasons.

**Keywords:** Interface, lagoon, bacteria, station, season

## 1. Introduction

La lagune Ebrié (5° N; 4° O) d' Abidjan, Côte d'Ivoire, s'étend sur une longueur de 130 Km et une largeur de 4 à 5 Km avec une superficie de 523 Km<sup>2</sup>. Elle présente de nombreuses baies et des chenaux peu profonds (Carmouze et Caumette, 1985). La lagune Ebrié est l'endroit de déversement des eaux usées de la ville d'Abidjan et également un lieu de défécation pour les populations riveraines (Nononsi, 1999); 70 à 80% des effluents (déchets domestiques, industriels etc.) sont directement déversés dans la lagune sans aucun traitement (BNEPT, 1996).

De toutes les activités polluant le milieu lagunaire, la contamination microbienne constitue une des agressions anthropiques les plus préoccupantes compte tenu des risques sanitaires qui lui sont associés (Carmouze et Caumette, 1985). Ainsi, l'eau en tant que réservoir de germes pathogènes devient le vecteur de nombreuses infections d'origine intestinales telles que les fièvres typhoïdes et le cholera...(Lanusse et Guiral, 1988).

Les principaux indicateurs de pollution sont les coliformes thermotolérants, les streptocoques fécaux et les anaérobies sulfite réducteurs (Marsalek et Rochfort 2004; Marino and Gannon, 1991; OMS, 1994). En raison de leur facilité de détection, les coliformes fécaux servent à évaluer le degré de traitement à appliquer à des eaux de différentes qualités et pour définir des objectifs de performance en ce qui concerne l'élimination des bactéries d'origine fécale de l'eau (CCME, 1999; OMS, 1994). Les streptocoques fécaux se multiplient rarement dans l'eau polluée et leur persistance n'est pas supérieure à celle des *E. coli* et des coliformes (Davies et al., 1995; Rodier, 1984). Les streptocoques fécaux sont de plus en plus recherchés en association avec les coliformes fécaux et peuvent servir à différencier l'origine humaine ou animale d'une contamination selon que le rapport coliformes fécaux et streptocoques fécaux est  $>1$  (origine humaine) ou  $< 0.7$  (origine animale) (Leclerc, 1996; Rodier, 1984).

En raison de leur longévité, les *Clostridium perfringens* sont surtout capables d'indiquer une contamination intermittente ou à distance. Afin de réduire les difficultés et les dépenses impliquées dans la recherche de pathogène spécifique, les indicateurs entériques sont utilisés pour estimer la présence éventuelle et la persistance des pathogènes dans l'environnement (Crane et al., 1981).

L'Interface eau-sédiment, objet de cette étude revêt une importance capitale compte tenu de sa richesse en ressources halieutiques (poissons, crustacés...). C'est une zone riche en matière organique et elle constitue de ce fait un réservoir de nutriments pour les microorganismes (Ling et al., 2002; Manizan, 2003; Berard, 1993). Or les poissons et crustacés sont beaucoup pêchés dans la lagune et vendus sur les différents marchés d'Abidjan (Koffi et al., 2006) et surtout aux populations riveraines. La consommation de ces poissons peut constituer un risque pour la santé publique s'ils sont contaminés par les microorganismes pathogènes qui pillulent dans la lagune.

A notre connaissance, l'interface eau-sédiment de la lagune Ebrié n'a fait l'objet d'aucune étude bactériologique. Aussi, paraît-il important de connaître l'écologie microbienne de cette interface,

objet de ce travail à travers la recherche de bactéries témoin de contamination fécale notamment les coliformes fécaux, les streptocoques fécaux, *Clostridium perfringens*, *Salmonella* et de caractériser leur habitat naturel ou modifié en mesurant certains paramètres physiques et chimiques tels que le pH, la température, la salinité et la conductivité.

## **2. Matériel et méthodes**

### **2.1. Matériel**

Le matériel d'étude est l'eau prélevée à l'interface eau sédiment de la baie du banco de la lagune Ebrié.

#### **Milieu d'étude**

La baie du banco de la lagune Ebrié, située en zone urbaine d'Abidjan est limitée au Nord-Ouest par la forêt du banco, à l'Est par la commune d'Adjamé et au Sud-Ouest par la commune de Yopougon.

Trois stations de prélèvement soumises aux plus forts rejets d'eaux usées et celles dont les vocations socio économiques sont les plus courantes sont retenues pour l'échantillonnage. La première station (A) située à l'entrée de la baie du Banco est soumise aux rejets d'eaux usées. Le tourisme et la pêche y sont pratiqués. La 2<sup>ème</sup> station (B) est située au milieu de la baie, au point de stationnement des navires. La principale activité pratiquée est la pêche. La 3<sup>ème</sup> station (C) est située dans le fond de la baie du Banco à une dizaine de mètres du lieu d'embarquement des barques. La baignade et la pêche sont les activités pratiquées dans cette station. Ces trois stations sont distantes l'une de l'autre d'environ 250 mètres.

### **2.2. Méthode**

#### **Echantillonnage**

Les prélèvements sont effectués à l'aide de flacons stériles de 1500 mL, à une profondeur de 0.7 m du fond. Les prélèvements sont effectués à l'aide d'un échantillonneur d'eau à une profondeur de 0,7 m du fond au moyen d'un échantillonneur. Ce dernier comporte une bouteille stérile de prélèvement (water sampler) d'eau, fermée hermétiquement et plongé jusqu'au niveau de la colonne d'eau choisie (0,7 m du fond) au moyen d'une vedette Neptune servant de moyen de transport. Une fois la bouteille de prélèvement remplie, elle est remontée à la surface et l'eau prélevée est transvasée dans un flacon stérile de 1000 mL; ce qui représente un échantillon d'eau. Au total, 90 échantillons ont été prélevés pendant 7 mois, de mars à septembre 2004, à raison de 30 prélèvements par station.

Les échantillons identifiés sont aussitôt mis dans une glacière contenant de la carboglace et transportés au laboratoire pour analyse.

#### **Analyses physico-chimiques**

La température, la salinité, la conductivité (WTW conductivity Meter LF25) et le pH (Hanna Instrument 9024 micro compteur) ont été mesurés *in situ* au niveau de l'interface. Après la mise sous tension des différents appareils (pH-mètre et conductimètre), les sondes sont plongées dans l'eau jusqu'à 0,7 m de profondeur. Ainsi, la sélection de la fonction désirée permet l'affichage automatique de la valeur de cette fonction.

#### **Etude bactériologique**

Les méthodes bactériologiques utilisées étaient celles référencées dans la norme AFNOR (1996) pour le dénombrement des coliformes thermo tolérants, *Salmonella*, Streptocoques fécaux et *Clostridium perfringens*. Toutefois, la recherche des germes s'est faite par concentration sur membrane filtrante à l'exception de *Clostridium perfringens* qui a été recherché en tube dans la gélose TSN (tryptone sulfite néomycine).

Le nombre de colonies est exprimé sous forme de UFC/100 mL d'eau analysée puis transformé en  $\log_{10}$ . La répartition des germes au niveau des 3 stations s'est faite en utilisant le test de Levene.

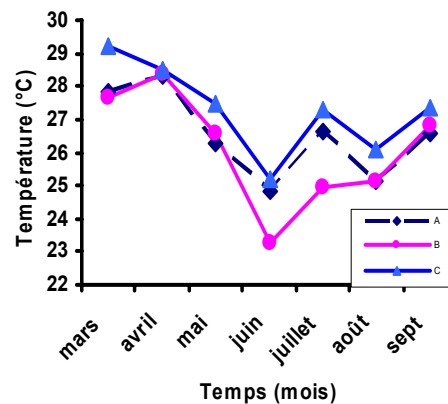
### 3. Résultats

#### Variation des paramètres physico chimiques

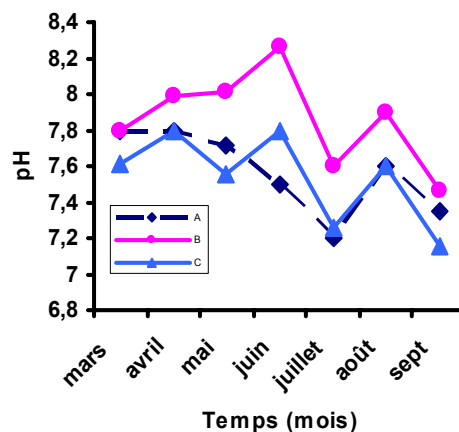
Les figures 1 à 4 illustrent les variations des paramètres physico- chimiques selon les stations d'étude et les mois de prélèvement. Les courbes de température, de pH, de salinité et de conductivité présentent des fluctuations saisonnières différentes sur l'ensemble de l'échantillonnage. La moyenne des températures varie très peu pendant la période d'étude de 26 à 27°C au niveau des 3 stations. Les courbes de température présentent la même allure: la température baisse de mars à juin de 28-29°C à 23-25°C, puis augmente à environ 26°C en septembre pour les stations A et B et 27°C pour la station C (figure 1). Le pH de l'eau au niveau des 3 stations est proche de la neutralité, variant en moyenne de 7,51 à 7,84.

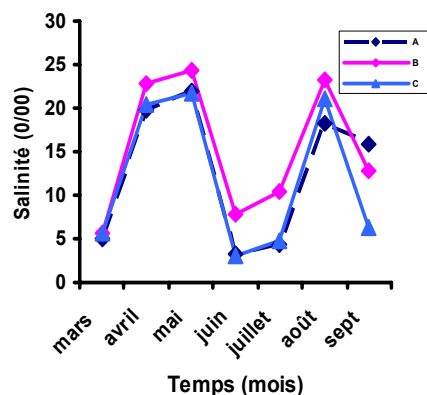
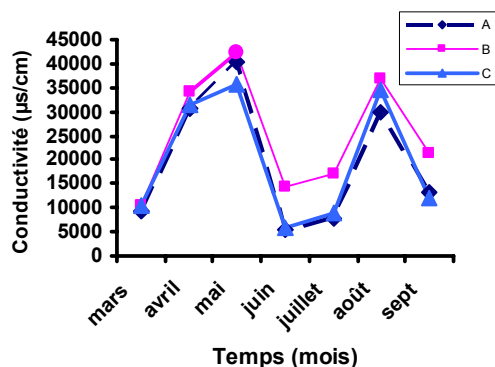
Le pH diminue au mois de juillet, augmente légèrement en Août puis diminue de nouveau au mois de septembre (figure 2).

**Figure 1:** Courbe des Variations de la température en fonction des stations et des mois



**Figure 2:** Courbe des variations du pH en fonction des stations et des mois



**Figure 3:** Courbe des variations de la salinité en fonction des stations et des mois**Figure 4:** Courbe des variations de la conductivité en fonction des stations et des mois

Les courbes de salinité et de conductivité présentent les mêmes allures se traduisant par des variations identiques aux 3 stations (*figures 3 et 4*). La salinité et la conductivité de l'eau de la baie du banco augmentent de mars à mai où on observe un pic, puis diminuent au mois de juin pour atteindre un nouveau pic au mois d'Août, suivi d'une baisse en septembre.

### Variation des germes fécaux

Les *tableaux 1 et 2* donnent le nombre moyen de germes enregistré aux niveaux des 3 stations selon les mois. Les germes fécaux présentent des variations différentes tout au long de l'échantillonnage quelque soit la station ou le mois. Ainsi, pour les coliformes fécaux, le nombre diminue de mars à mai avec des valeurs variant de 3,9 à 3,38  $\log_{10}$  ufc/100 ml. A partir de juin jusqu'en septembre, le nombre de coliformes fécaux augmente avec des valeurs allant de 3,38 à 4,04  $\log_{10}$  ufc/100 ml (*tableaux 1 et 2*). La moyenne des coliformes fécaux obtenue à la station C est plus élevée (3,92  $\log_{10}$  ufc/100 ml), suivie de celle de la station B (3,78  $\log_{10}$  ufc/100 ml) puis enfin de celle de la station A (3,62  $\log_{10}$  ufc/100 ml).

**Tableau 1:** Nombre moyen de bactéries recherchées selon les stations de prélèvement

Stations d'étude	Germes fécaux ( $\log_{10}$ ufc/100ml)		
	Coliformes fécaux	Streptocoques fécaux	<i>Clostridium perfringens</i>
A	3,62 ± 3,4	2,8 ± 2,68	3,17 ± 2,94
B	3,78 ± 3,5	2,8 ± 2,5	3,08 ± 2,99
C	3,92 ± 3,74	3,08 ± 2,8	3,2 ± 3,1
Moyenne	3,77 ± 3,5	2,9 ± 2,6	3,15 ± 3



Les streptocoques fécaux évoluent dans des proportions différentes pendant tout l'échantillonnage. Ainsi, de mars à mai, le nombre ( $\log_{10}$  ufc/100ml) des streptocoques fécaux augmentent rapidement de 2,3 à 3,2 puis à 2,7 pour légèrement remonter de juin à septembre à 3,08  $\log_{10}$  ufc/100 ml (*tableau 2*).

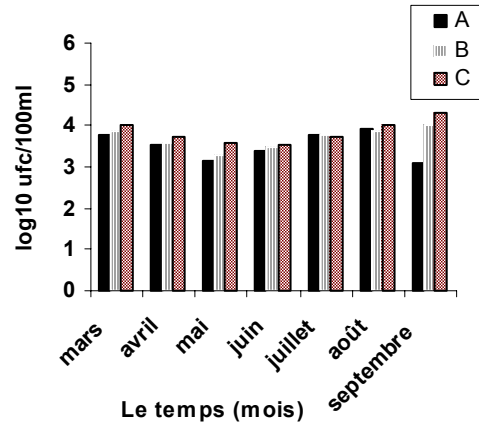
**Tableau 2:** Nombre moyen de germes fécaux selon les mois d'étude

Mois	Germes fécaux ( $\log_{10}$ ufc/100ml)		
	Coliformes fécaux	Streptocoques fécaux	<i>Clostridium perfringens</i>
Mars	$3,9 \pm 3,08$	$2,3 \pm 1,85$	$2,54 \pm 2,04$
Avril	$3,61 \pm 2,98$	$2,8 \pm 2,1$	$2,65 \pm 1,3$
Mai	$3,38 \pm 2,95$	$3,2 \pm 2,5$	$3,08 \pm 2,82$
Juin	$3,48 \pm 2,8$	$2,71 \pm 2,68$	$3,04 \pm 2,70$
Juillet	$3,76 \pm 2,95$	$2,84 \pm 2,36$	$3,17 \pm 2,63$
Août	$3,96 \pm 2,08$	$2,95 \pm 2,72$	$3,36 \pm 2,63$
Septembre	$4,04 \pm 3,89$	$3,08 \pm 2,72$	$3,5 \pm 2,75$

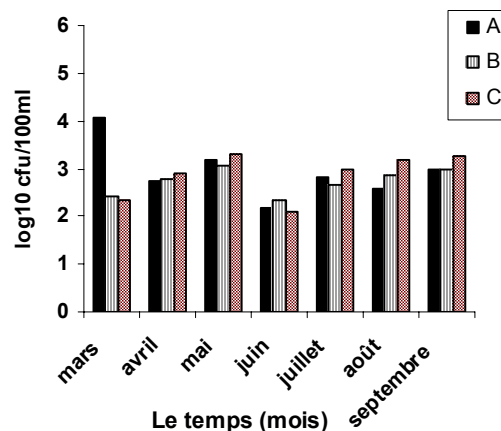
Le nombre moyen de streptocoques fécaux est identique aux stations A et B (2,8 ufc/100ml) mais inférieur à celui de la station C (3,08 ufc/100ml).

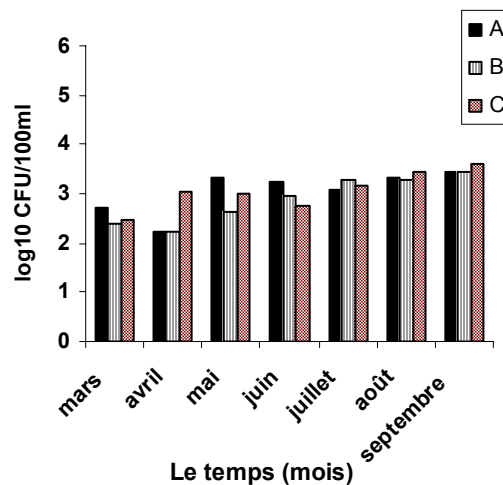
Le nombre moyen mensuel de *Clostridium perfringens* croît de mars à septembre, de 2,54 à 3,5  $\log_{10}$  ufc/100 ml (*tableau 2*). La station B est moins polluée en *C. perfringens* (3,08 ufc/100ml) que les stations A et B (environ 3,2 ufc/100ml) (*figure 5a, 5b et 5c*).

**Figure 5a:** Charge de la baie en coliformes fécaux



**Figure 5b:** Charge de la baie en streptocoques fécaux



**Figure 5c:** Charge de la baie en *Clostridium perfringens*

La répartition des coliformes et des streptocoques fécaux au niveau des 3 stations est significative ( $\alpha < 0,05$ ). Cependant celle des *Clostridium perfringens* n'est pas significative ( $\alpha > 0,05$ ).

### Les salmonelles

La recherche de *salmonella* s'est avérée négative sur l'ensemble des échantillons d'eau analysés. Des souches d'entérobactéries non coliformes ont été isolées. Ce sont entre autres, 9 souches de *Proteus* (41%), 6 de *Edwardsiella* (27,3%), 4 de *Providencia* (18,1%) et 3 de *Hafnia* (13,6%) (Tableau 3).

**Tableau 3:** Fréquence d'isolement des souches d'entérobactéries non coliformes recensées dans la baie du banco

Répartition des souches par station de prélèvement					
	Station A	Station B	Station C	Total des souches recensées	Fréquence d'isolement (%)
<i>Proteus</i>	3	2	4	9	41
<i>Edwardsiella</i>	1	2	3	6	27,3
<i>Hafnia</i>	1	1	1	3	13,6
<i>Providencia</i>	2	1	1	4	18,1
Nombre de souches isolées	7	6	9	22	100

## 4. Discussion

### Variation des paramètres physico chimiques

Les résultats de la variation de température au niveau de la baie du banco se rapprochent de ceux obtenus par Hunter (2003) et Anonymous (1998). Daniel et Alain (1987) ont enregistré aux stations A et C des données comparables aux résultats de cette étude. La forte valeur de pH (8,26) obtenue à la station B qui est le point de stationnement des navires serait certainement due à un apport important en solution basique qui proviendrait d'un navire coulé à cet endroit à la mi-mai de l'année 2004 (année d'étude).

Pour les stations A et C, les variations de pH de 7,6-7,8 en mars à 7,3 en juillet résulteraient de la saison des pluies (effet de dilution) commencée à partir de fin mai et qui s'est étendue jusqu'en juillet. Ces valeurs de pH sont similaires à celles obtenues par Mauro et al. (2003) dans la lagune d'Orbetello (Tuscany, Italie) (pH 7,2 et 8,8).

Les valeurs de conductivité et de salinité obtenus dans cette étude sont très différentes de celles rapportées par Anonymous (1998) lors de travaux similaires sur la baie du banco. Certains auteurs ont montré que la salinité et la conductivité diminuent de mars à septembre avec des valeurs variant autour de 28 à 11‰ pour la salinité et de 41000 à 15000  $\mu\text{S}/\text{cm}$  pour la conductivité. Cette discordance au niveau des résultats serait probablement imputable aux conditions temporelles rencontrées au niveau de l'interface.

Les valeurs de salinité observées dans cette étude seraient dues à l'absence de pluie (saison sèche) de Mars à Septembre. Cette observation a été faite également par Daniel et Alain (1987) qui soutiennent que les salinités et les conductivités présentent leurs valeurs maximales durant la saison sèche; cela pourrait aussi être due à une sédimentation des matières organiques à l'interface eau/sédiment pendant cette période et l'augmentation de la salinité proviendrait-elle de l'intrusion de la mer dans la lagune en saison sèche (Kouassi et Dosso, 1990).

### **Variation des germes fécaux**

Le nombre de coliformes et de streptocoques fécaux est relativement élevé au niveau de la baie du banco. Ce qui rend la baie impropre pour les activités humaines (baignade, pêche etc.). Les valeurs obtenues pour les coliformes fécaux (3,38 à 4,04 ufc/100ml) concordent avec celles de Marsalek et Rochfort (2004) qui après avoir travaillé sur la contamination fécale des eaux de surface, en Ontario au Canada, ont estimé que le nombre de coliformes fécaux variait entre 3 et 4 ufc/100ml. La baisse de la concentration en coliformes fécaux de mars à mai traduit une diminution du degré de contamination qui résulterait de la saison sèche caractérisée par les grandes valeurs de salinités.

Ces résultats confirment ceux obtenus par les études de Kouassi et Dosso (1990) qui ont indiqué que pendant la saison sèche, l'intrusion de la mer dans les eaux lagunaires entraînent une inaptitude des coliformes fécaux à se développer dans un milieu à salinité élevée. Cette observation est expliquée par le fait que les coliformes fécaux et les streptocoques fécaux ne sont pas des germes halophiles.

La diminution du nombre de coliformes fécaux serait également imputable à la variation de température du milieu (26,53 à 27,31°C). En effet, les travaux de Carmouze et Caumette (1985) ont montré lors d'une étude que pour des températures d'eau variant entre 25 et 27°C, le temps de multiplication des coliformes est long (5 à 7 heures) tandis que pour des températures supérieures ou égales à 30°C, le temps de division de ces bactéries est réduit (1 à 2 heures).

L'abondance de coliformes fécaux et streptocoques fécaux pendant la saison des pluies est due aux valeurs de pH favorables à la croissance de ces bactéries et à une majoration des apports anthropiques par lessivage des sols souillés et par vidange des égouts. Les pluies enrichissent le milieu lagunaire en sels nutritifs (Manizan, 2003), les eaux deviennent plus douces et plus eutrophes; ce qui prolonge la vitalité de ces germes.

Par ailleurs, les densités importantes de coliformes fécaux observées en saison des pluies (juin) traduirait une élévation du degré de contamination microbienne amplifiée par les pluies locales enregistrées. Des observations similaires ont été faites en lagune Ebrié (Abidjan) par Lanusse et Guiral (1988), dans les rivières et les eaux marines au Canada par Hunter (2003) et par de nombreux autres auteurs (Ogawa, 1974; Jannasch, 1968; Monzer *et al.*, 2005). Ces derniers ont montré que la survie des bactéries entériques et plus précisément celle des coliformes fécaux est considérée comme proportionnelle à la concentration des substances organiques utilisables résultant des apports liés aux eaux de ruissellement et aux intenses activités humaines dans la lagune. Marsalek et Rochfort (2005) ont montré que la qualité microbiologique de l'eau devenait mauvaise pendant la saison des pluies.

Les coliformes fécaux sont généralement plus abondants dans les matières fécales de l'homme que les streptocoques fécaux. Ces derniers seraient plus importants en nombre que les coliformes fécaux chez l'animal. D'où la notion de rapport de coliformes fécaux sur streptocoques fécaux utilisée pour déterminer l'origine fécale des eaux (Leclerc, 1996). Dans cette étude, ce rapport de l'ordre de 1

permet d'attribuer l'origine fécale de la contamination de la baie aux déversements des eaux usagées non traitées, aux diverses installations situées en bordure de la lagune mais également aux déjections humaines et animales (bœufs).

Quelque soit la saison, les densités des *Clostridium perfringens* à l'interface eau-sédiment sont systématiquement supérieures à celles estimées pour les eaux de surface (Guirald et *al.*, 1993). L'augmentation du nombre de *Clostridium perfringens* traduit une élévation du degré de contamination qui résulterait des apports liés aux eaux de ruissellement, à la vidange des égouts notamment pendant la saison des pluies. La particulière forme de résistance (spore) des *Clostridium perfringens* leur permet de survivre dans tous les milieux (Anonyme 1, 1994).

L'absence de *salmonella* pourrait s'expliquer par la lutte pour la survie. En effet, les eaux lagunaires abritent des bactéries et des virus qui par leurs activités bactéricides et prédatrices sont susceptibles d'entraîner la disparition d'autres bactéries (Caumette et Carmouze, 1994). L'absence de *Salmonella* serait aussi liée à leur faible résistance aux contraintes telles que la salinité, l'action des savons et détergents des lavandiers et populations riveraines. Les salmonelles sont de mauvais compétiteurs (Guiraud, 1998).

La présence des entérobactéries non coliformes indique bien que l'état sanitaire de l'interface est préoccupant. Par ailleurs, les entérobactéries non coliformes isolées peuvent se comporter comme des pathogènes opportunistes et causer des maladies (Grabow et *al.*, 1991). Ce qui constitue un risque pour la santé de la population (surtout immunodéprimée) qui peut se contaminer au cours des activités récréatives (baignade, pêche...).

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## **In-Service Teachers' Attitude to Computers and their Perception of Obstacles to their Use in Primary and Secondary Schools in Nigeria**

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### **Abstract**

This paper reports on an investigation into in-service teachers' attitude to computers and their perception of the obstacles and key challenges to their use in primary and secondary schools in Nigeria. The participants were primary and secondary school teachers enrolled in the Bachelor of Education part-time programme of the Faculty of Education, University of Benin, Benin City, Nigeria, during the 2007 contact period. The study also investigated differences between the perception of the primary and secondary school teachers on the obstacles to computer use in their schools. Participants were 89 secondary school teachers and 128 primary school teachers who are full time teachers from schools all over Southern Nigeria. Data was obtained from the participants with the aid of 44-item structured questionnaire. The results showed that the two groups of teachers have positive perception toward computers. Results also indicated that lack of budget to purchase computer facilities, lack of computer laboratory, inadequate fund from government, high cost of hardware and software, lack of training and poor leadership were the major obstacles to computer use in primary and secondary schools in Nigeria.

Recommendations were made on how to rectify the situation so that computers and their use become pervasive in primary and secondary schools in Nigeria.

**Keywords:** Primary schools, Secondary schools, Computer education, Technology barriers, In-service teachers, Technology integration.

### **Introduction**

In every aspect of the global economy in the twenty-first century, information and communication technologies have played very significant role to improve productivity. Many sectors of the global economy have benefited from computers. Transportation, businesses, the military, government and telecommunication have had the most beneficial applications of information and communication technology (ICT). Even though schools have also incorporated computers into the classroom, nobody is quite sure that the same productivity results have been attained in the education sector. This is particularly true of most developing nations such as Nigeria. Ndukwe (2004) ascertained that one of the most beneficial applications of ICT is in the education sector. Ndukwe who is the current vice-executive chairman and chief executive officer of Nigerian Communication Commission (NCC) also indicated that students and teachers in secondary and post secondary institutions in Nigeria can be afforded the benefits of constant and easy access to updated information through ICT.

The introduction of computer education into secondary schools in Nigeria started in the 1980s with a pilot scheme in the Federal Government Colleges and the armed forces secondary schools in 1988 (Olalere, 2005). However, empirical studies (Ayoola, 1994, Jegede and Owolabi 2003) have shown that the provision of computers in these schools merely consisted of purchasing few computer sets and software, whereas the full potential of computers is yet to be exploited within the Nigerian school system (Olalere, 2005). When the Federal Government Colleges which were less than 100 were provided with computers, the more than 6000 public secondary schools in the country were left in the lurch to fend for themselves. Because of the shortage of fund for the purchase of the necessary ICT facilities, majority of the public secondary schools in Nigeria could not purchase computer facilities. Besides, teachers in few Nigerian secondary schools with computer facilities could not “effectively tally their ICT instructional materials such as computers, audio visual aids, slides, video clip, electronic whiteboard... to the goals of their instructional objectives...” (Ololube, 2006:102).

There is no doubt that in recent years, Nigeria aimed to excel in information and communication technology considering the level of progress made in the last eight years. Since the coming of a democratic dispensation in 1999, Nigeria has made remarkable stride in the development of ICT facilities and their deployment to major sectors of the economy. Nigeria may not be a giant yet in ICT, the country has had a fair share of an electronic boom, though belatedly (Ibom, 2007). The liberalization of the IT sector in 2001 led to the recent steady growth. Four digital mobile licenses were auctioned to private investors. With only 400,000 connected telephone lines and less than 1 million internet users in 1999, the country stable democracy provided the enabling environment that has led to massive growth resulting in over 36 million lines in 2007. With the recent launch of Nigeria's telecommunication satellite **Nigcomsat-1**, the country is now rated as one of the top three in terms of connected lines in Africa (Ibom, 2007).

Today, ICT is playing key role in the educational sector, especially in higher education in Nigeria. Many universities now conduct registration for examinations online, admit and register students through the internet. Meanwhile primary and secondary schools in developing countries are under pressure to incorporate emerging technologies into their curriculum. Many different types of technology can be used to support and enhance teaching of subjects in Nigerian secondary schools. However, there is dearth of literature on how primary and secondary school teachers are utilizing ICT in their classroom practices. Few studies by Olalere (2005), Ololube (2006) and Tella et al (2007) showed that, though teachers in secondary schools in Nigeria fairly use technological products in instructional delivery, majority do not have access to the internet and e-mail. The main purpose of this study, therefore, is to ascertain the main obstacles and key challenges to the use of ICT by primary and secondary school teachers in Nigeria. While there are few studies on secondary school teachers' use of ICT, there is acute scarcity of literature on the use of computers by primary school teachers in Nigeria. This study is partly designed to fill the gap.

## **The Problem**

Insight to this study emanated from a seemingly innocuous question which the researcher asked in-service teachers enrolled in the Bachelor of Education (B.ed) part-time programme of the University of Benin, Benin City, Nigeria, during the 2007 contact session. At the first meeting designed as an overview of the course, EDU223 – Instructional Technology, the researcher asked members of the class numbering 227 to list verbally those technological gadgets they use frequently in their lessons. Not surprisingly, the in-service teachers mentioned instructional materials such as charts, graphs, maps, photographs, real objects, radio cassette recorders/audio tapes, and television sets. However, due to the absence of computer facilities among the list of instructional materials they gave, the researcher fired another question thus, “how many of you use computers in the classroom?” Surprisingly, there were five hands raised. Four of the five people who signified that they use computers said they only use it for word processing while one said he could use it both for word processing and internet browsing.



The situation above gave rise to this research study which is designed to investigate the major obstacles and key challenges to ICT usage in elementary (primary) and secondary schools in Nigeria. If over 200 teachers who are mostly teachers from primary and secondary schools in Southwest, South-South and South East geopolitical zones in the country are not utilizing ICT facilities in their teaching, majority of Nigerian children in schools are placed at a great disadvantage in the information age where most developing countries are working hard to close the digital divide between them and the developed countries.

Quoting the latest World Economic Forum Global Information Technology report, Bakare (2007) asserted that Nigeria is rated 10<sup>th</sup> in the development of information and communication technologies (ICT) in Africa and 88<sup>th</sup> in ranking which featured 122 countries of the world. Nigeria is rated behind Tunisia (First), South Africa (Second), Mauritius (third), Botswana (Fourth), Morocco (fifth), Egypt (sixth), Algeria (seventh), and Namibia (eight) in African ranking (Bakare, 2007). Though Nigeria was ranked as the only country with improved score in sub-Saharan Africa, it would appear that the rapid growth of ICT in the country has not rubbed off on the lower rung of the educational sector. The pertinent questions to ask at this juncture are; what are the major obstacles to the utilization of ICT in elementary and secondary schools in Nigeria? What is the overall attitude of the in-service teachers towards computers? Attitudes towards computer often influence future use of computers (Sanders and Morrison-Shetlar, 2001). The purpose of this study therefore, is to investigate in-service teachers' attitudes to computers and their perception of obstacles and key challenges to their use. The following research questions are relevant to the study:

1. What is the attitude of in-service teachers to computers and their use in education?
2. What would the in-service teachers perceive as key challenges or obstacles to technology use in primary and secondary education in Nigeria?
3. Do the elementary school teachers perceive obstacles that are different from those perceived by secondary school teachers?

## **Review of Literature**

There is scarcity of literature on ICT integrated in primary and secondary schools in Nigeria. Olubube (2006) and Tella et al (2007) agree with this assertion. The reason for this is not far fetch. First, the field is an emerging one in the country and educational technology as a course is not as popular among Nigerian students as courses such as accounting, law, medicine, engineering, dentistry, business administration, pharmacy and others. Second, very few universities in the country have educational technology department where courses in the field are offered. These are the main reasons why there are few graduates in the field in Nigeria.

However, there are little literature dealing with technology integration in tertiary institutions in the country and few others dealing with secondary education. Browsing the internet for literature dealing with ICT integration in elementary schools in Nigeria revealed one report on one lap top per child programme initiated at L.E.A primary school in Galadima, a suburb of Abuja, in March 2007. (Vota 2007). The programme which supplied one laptop for each Nigerian child in primary 4, 5 and 6 and each member of staff is a pilot project that is too early to assess.

In a study by Oni (2007), it was asserted that vocational technical institutions in Nigeria do not train engineers, technicians and technologists to use computer while Jegede and Owolabi (2005) found that vocational technical education teachers held the least positive attitudes about ICT. The study lamented that these teachers who are saddled with the task of training the junior secondary school teachers will have negative implications for teacher education and curriculum implementation in Nigeria. Olakulehin (2007) ascertained that teacher training in Nigeria has failed to adhere to provisions of the National Policy on Education that teacher education shall continue to partake of changes and innovations in the curriculum. This may be due to lack of training of Nigeria teachers in ICTs and their integration in the curriculum. Again, Tella et al (2007) and Olakulehin (2007) asserted that there is a deluge of challenges confronting the application of ICTs in teacher training in Nigeria.

They identified infrastructure, lack of information and information illiteracy in teachers, inadequate learning resources, attitudes of teachers as some of the key challenges facing ICT integration in education in Nigeria. Olulube (2007) maintained that Nigeria adopted ICT late and has progressed slowly in applying technology in education as a result of economic disadvantages and government policies. Again, Ololube (2006) asserted that limited attention has been given to professional development of teachers in ICT in Nigeria.

On ICT usage among teachers in Nigeria, Olalere (2005) and Ureigbo et al. (2007) indicated that most teachers in Nigeria do not have requisite experience and competence in computer usage and that the present state and level of utilization of internet in tertiary education is still very low. Kalu and Ekweme (2007) ascertained that the traditional mode of teaching is still being adopted by science teachers in Nigeria and that only few science teachers are literate in computer usage. They also mentioned that science teachers' awareness and knowledge ability of educational application of ICT are low and that their attitude to ICT integration in the curriculum is only marginally positive. Most of the studies cited were done on tertiary education in Nigeria.

Most of the studies conducted on the obstacles and key challenges to technology integration were carried out in developed countries such the United States of America, Canada, United Kingdom, Australia, Netherlands and others. Chief among researchers' findings on barriers or key challenges to technology integration is poor administrative support and lack of computers (Barison 2003, Feist 2003; Murray 2004 and Mayya 2007). These researchers believe that administrative leadership is not supportive towards efforts to improve staff computer literacy. Leadership is the single most important factor affecting successful technology integration. Administrators are reluctant to introduce changes in the school system that will disrupt the stability. Lack of quality resources is a major factor in determining teachers' engagement with ICT. Studies by Murray (2004), Kurt (2005) Lim and Khine, (2006) and Jamieson-Proctor et al (2006) identified lack of time, lack of infrastructure, (access to quality hardware and software), lack of training (professional development) resistance to change, lack of technical/support and cost of technology as barriers and key challenges to technology integration in schools.

There is no doubt that most of the developed countries may have overcome the access barrier and many others, and that new technologies are providing teachers in these countries with opportunities to transform the way they work and develop innovative approaches to facilitate students learning. The same cannot be said of most developing countries of which Nigeria is one. This study, therefore, is designed to examine the barriers and key challenges to technology integration in primary and secondary schools in Nigeria. As the integration of ICT in curriculum gain momentum around the world, there is urgent need to identify barriers and formulate necessary strategies to tackle them. Also, since attitudes with which teachers approach ICT enhanced learning are important factors in the integration of technology in the classroom, the study will also determine attitudes of the teachers to ICT use. It may be easy for many people to assume that once the necessary ICT facilities are put in place in the classroom, their integration will be automatic. Without the positive attitude of teachers towards technology and their acceptance of technology, teachers as gatekeepers in the classroom will not use ICT (Lim and Khine, 2006).

## **Participants**

Participants in this study were purposively identified as they were in-service teachers enrolled in the Bachelor of Education, part-time programme of the University of Benin, Benin City, Nigeria. All the participants are holders of the National Certificate of Education, (NCE) or its equivalents. These are middle cadre professional teachers who are employed to teach in primary and junior secondary schools in Nigeria. At the part-time B.ed programme in the University, in-service teachers spend five contact academic sessions to qualify for the award of the Bachelor of Education (B.Ed) degree. Classes are

held during the long vacation period between July and September each year. The in-service teachers are self-sponsored in the programme and majority has 5 to 15 years teaching experience.

This is an intact class and they are cohorts of some sort. Though this is an intact class, participants are from diverse ethnic groups, schools, and states in Nigeria. They are mainly from the Southwest, Southeast and South-south geopolitical zones of the country. Nigeria is divided into six geopolitical zones. The participants are true representatives of the middle cadre of teachers in Southern Nigeria. There were 128 primary school teachers and 89 secondary school teachers thus making a total of 217 participants. Among the participants were 62 male and 155 female teachers respectively.

### **Research Instrument**

A 44-item questionnaire designed to examine teachers' attitude to ICTs and their perception of obstacles to their Integration in primary and secondary education was used to collect data for the study. Section A of the questionnaire deals with demographic information requiring the in-service teachers to indicate sex, where they teach (primary or secondary schools), type of school (public or private) teaching experience and qualification. Items in section B of the instrument deals with the attitudes of the teachers towards computers and their use in education on a four point likert-type scale of Strongly Agree (4), Agree (3), Disagree (2), Strongly Disagree (1) for positive statements and reverse for negative statement. The response scale was designed in such a way that the highest number '4' indicates a strong agreement and the least number '1' indicates a strong disagreement. Section C of the instrument was created to consist primarily of Likert-type items dealing with perceived obstacles or key challenges to ICT use on a four-point scale of major obstacles (4), Moderate obstacles (3), Minor obstacles (2), and not an obstacle (1). As a requirement, the questionnaire was evaluated by 3 experts for content validity and usability. The Chronbach alpha was used to test the reliability of the instrument and this yielded alpha of 0.87. The instrument was actually constructed based on review of literature and many of the items were adapted from some instruments used by researchers in the field of interest. The original questionnaires were modified to suit this study. The questionnaire was administered by the researcher to the participants during one of the lecture periods. A total of 227 copies of the questionnaire were administered to the participants. Out of this number, 10 copies were discarded because they were not properly filled. A total of 217 copies of the questionnaire were eventually used for data analysis.

### **Data Analysis**

The data from the study was collated and analyzed using mean, standard deviation and t-test. For the t-test, the .05 level of statistical significance was selected.

### **Findings**

The data analyzed was used to answer the three research questions postulated for the study.

**Research Question 1:** What is the attitude of in-service teachers to computers and their use in education?

Table 1 showed the mean and standard deviation of in-service teachers' attitude towards computers.

**Table 1:** Mean and Standard Deviation of In-service Teacher's Attitude to Computers

S/No.	Statements	X	SD	Remark
1.	I think that working with computers would be enjoyable and stimulating	3.60	0.77	Agree
2.	I want to learn more about computers	3.74	0.69	Agree
3.	Use of computers in education almost always reduces teacher personal interaction with students	2.17	1.07	Disagree
4.	Learning about how to use computers is boring to me	2.17	1.07	Disagree
5.	It is important for me to learn how to use a computer	3.25	0.95	Agree
6.	Figuring out computer problems does not appeal to me	1.91	1.01	Disagree
7.	I would work harder if I could use computers more often	3.03	0.85	Agree
8.	I get scared each time I think of learning about computers	1.98	1.42	Disagree
9.	I can learn more from books than from a computer	2.26	1.06	Disagree
10.	I enjoy learning how computers are used in our daily lives	3.22	0.87	Agree
11.	Computers can be useful instructional aids on almost all subject areas	3.17	0.83	Agree
12.	Knowing how to use computers is a worthwhile skill	3.09	0.98	Agree
13.	I get sinking feeling when I think of trying to use a computer	2.15	1.06	Disagree
14.	Computers would significantly improve the overall quality of students' education	3.14	0.77	Agree
15.	Teacher training should include instructional applications of computers	3.74	0.69	Agree
16.	Working with computers would make me nervous	1.68	1.27	Disagree
17.	The use of e-mail make a course more interesting	3.01	0.85	Agree

Generally, the in-service teachers seemed to have positive attitudes toward computers and their use in education. Individual items means for the positive statements recorded means above 3.0 which indicate that the in-service teachers view computers as desirable technology in education. Respondents agree with all the positive statements while they disagree with all the negative statements.

**Research Question 2:** What would the in-service teachers perceive as the key challenges/obstacles to technology use in primary and secondary education in Nigeria?

The data in Table 2 shows what the in-service teachers perceived as the key challenges or obstacles to the use of computers in primary and secondary schools in Nigeria. Any item with mean of 3.10 to 4.0 will be regarded as a major obstacle or key challenge, items with means of 2.5 to 3.0 will be regarded as moderate obstacles or moderate challenge while items with means of 2.0 to 2.4 are regarded as minor obstacles or minor challenges. Item with means between 1.0 and 1.9 will be regarded as no obstacle or not a challenge.

**Table 2:** Mean, Standard Deviation and Rank Order of Perceived Obstacles to Computer Use

Item No.	Perceived obstacles	N	X	SD	Rank
2	My school has no budget to purchase computer facilities	217	3.4793	1.0004	1 <sup>st</sup>
8.	The school lacked computer laboratory	217	3.4792	.9722	2 <sup>nd</sup>
23.	Adequate fund is not made available by government and school to purchase computer	217	3.4654	.9813	3 <sup>rd</sup>
1.	High cost of computer hardware and software	217	3.4608	.8275	4 <sup>th</sup>
9.	Government has not encouraged the schools to use computers	217	3.3733	1.0110	5 <sup>th</sup>
16.	Lack of workshops/seminars and in-service training in computer usage	217	3.2350	1.1160	6 <sup>th</sup>
22.	My school is not connected to the internet	217	3.1935	1.1301	7 <sup>th</sup>
20	School administrators have not encouraged teachers to use computers in classroom	217	3.1290	1.1064	8 <sup>th</sup>
10	Lack of adequate computers policy by government	217	3.0829	1.0596	9 <sup>th</sup>
3	There is no electricity in my school	217	2.9954	1.2152	10 <sup>th</sup>
7	I am not trained to use computer	217	2.9585	1.2558	11 <sup>th</sup>
26	There are few computer literate teachers in schools	217	2.9539	1.1457	12 <sup>th</sup>
4	Electricity supply to my school is very unstable	217	2.9493	1.1475	13 <sup>th</sup>
24	The fee for internet connectivity is too high	217	2.8894	1.1290	14 <sup>th</sup>
15.	Dearth of qualified computer software designers	217	2.7972	1.2078	15 <sup>th</sup>
5.	Inadequate telephone facilities	217	2.7834	1.2450	16 <sup>th</sup>
21.	There is no well articulated compelling reason to use computes in the classroom	217	2.7419	1.1376	17 <sup>th</sup>
13.	Lack of locally trained workers to install, maintain and support computer use	217	2.6820	1.1806	18 <sup>th</sup>
14.	Lack of relevant software	217	2.6810	1.1727	19 <sup>th</sup>
6	After teaching there is no time to learn to use computers	217	2.6037	1.2321	20 <sup>th</sup>
18	My school is not secured enough to house computers	217	2.5714	1.2382	21 <sup>st</sup>
19	Most teaching staff are reluctant to learn how to use technology	217	2.4424	1.1046	22 <sup>nd</sup>
25.	Teachers are satisfied using traditional teaching methods	217	2.4055	1.1712	23 <sup>rd</sup>
11.	Teachers fear technology may displace them in the classroom	217	2.1889	1.1123	24 <sup>th</sup>
27.	Teachers may lose direct control of teaching/learning process	217	2.0645	1.0344	25 <sup>th</sup>
12.	Development in computer technology is too fast	217	1.8986	1.0269	26 <sup>th</sup>
17	I do not feel comfortable teaching with technology	217	1.8295	1.0199	27 <sup>th</sup>

Table 2 suggests that items ranked between 1<sup>st</sup> and 8<sup>th</sup> are major obstacles facing teachers in the utilization of ICT in classroom. All the items ranked between 9<sup>th</sup> and 21<sup>st</sup> are regarded as moderate obstacles or moderate challenges while those items ranked 22<sup>nd</sup> to 25<sup>th</sup> are minor obstacles or challenges. Only two items ranked 26<sup>th</sup> and 27<sup>th</sup> are not regarded as obstacles or challenges.

**Research Question 3:** Do the elementary school teachers perceive obstacles that are different from those of the secondary school teachers?

The data in Table 2 indicated the difference between the elementary school teachers in their perception of the obstacles or challenges they face in ICT utilization.

**Table 3:** Calculated t-values on the Differences in the perception of the Secondary and Primary School teachers on obstacles to ICT use.

S/N		Teacher s	N	X	SD	df	t	Sig.
1.	High cost of computers	Sec. Prim.	89 128	3.44 3.46	.812 .842	215	-.169	.866
2.	No budget to purchase computer facilities	Sec. Prim.	89 128	3.48 3.47	.966 1.02	215	.48	.962
3.	No electricity supply	Sec. Prim.	89 128	3.04 2.96	1.11 1.28	215	.500	.618
4.	Electricity supply unstable	Sec. Prim.	89 128	2.94 2.95	1.03 1.22	215	-.059	.953
5.	Inadequate telephone facilities	Sec. Prim.	89 128	2.91 2.69	1.23 1.25	215	1.25	.212
6.	After teaching no time to learn to use computer	Sec. Prim.	89 128	2.67 2.55	1.13 1.29	215	.702	.484
7.	Not trained to use computer facilities	Sec. Prim.	89 128	3.37 2.67	1.08 1.29	215	4.18	.000*
8.	The school lacked computer laboratory	Sec. Prim.	89 128	3.43 3.50	.952 .988	215	-.518	-.605
9.	No government encouragement	Sec. Prim.	89 128	3.23 3.46	1.00 1.01	215	-.518	.605
10.	Lack of adequate computer policy by government	Sec. Prim.	89 128	2.96 3.16	.970 1.11	215	-1.35	-.177
11.	Teachers fear technology may displace them in class	Sec. Prim.	89 128	2.28 2.12	1.07 1.13	215	1.01	.311
12.	Development in computer is too fast	Sec. Prim.	89 128	1.98 1.83	.994 1.04	215	1.07	.282
13.	Lack of locally trained workers to install and maintain computers	Sec. Prim.	89 128	2.76 2.62	1.12 1.12	215	.853	.395
14.	Lack of relevant software	Sec. Prim.	89 128	2.89 2.53	1.04 1.23	215	2.29	.023*
15.	Dearth of qualified computer software designers	Sec. Prim.	89 128	3.03 2.63	1.16 1.21	215	2.43	.016*
16.	Lack of seminars/workshops for teachers	Sec. Prim.	89 128	3.33 3.16	1.05 1.15	215	1.12	.262
17.	Uncomfortable teaching with technology	Sec. Prim.	89 128	1.98 1.71	.982 1.03	215	1.93	.055
18.	My school is not secured to house computers	Sec. Prim.	89 128	2.44 2.65	1.09 1.32	215	-1.21	.227
19.	Most teaching staff are reluctant to learn how to use technology	Sec. Prim.	89 128	2.42 2.45	1.07 1.12	215	-.171	.864
20.	School administrators have not encourage computer use	Sec. Prim.	89 128	3.17 3.09	1.06 1.13	215	.562	.574
21.	No well articulated reason to use computers in class	Sec. Prim.	89 128	2.85 2.66	1.05 1.19	215	1.21	.227
22.	My school is not connected to internet	Sec. Prim.	89 128	3.16 3.21	1.12 1.14	215	-.271	.786
23.	Inadequate fund provided by government and school for computers	Sec. Prim.	89 128	3.40 3.50	1.06 .922	215	-.762	.447
24.	High cost of internet connectivity	Sec. Prim.	89 128	2.87 2.89	1.06 1.17	215	-.141	.888
25.	Teachers are satisfied using traditional methods	Sec. Prim.	89 128	2.35 2.43	1.08 1.22	215	-.481	.631
26.	Few computer literate teachers in schools	Sec. Prim.	89 128	3.02 2.90	1.07 1.19	215	.734	.0464
27.	Teachers may lose control of teaching/learning process	Sec. Prim.	89 128	2.07 2.05	1.01 1.05	215	.167	.867

\* Significant at .05

As shown in Table 3, comparison of the overall perception scores of the secondary and primary school teachers using the t-test statistical analysis showed a significant difference in only three items

out of the twenty seven items. The difference in the perception of the secondary and primary school teachers occurred in items 7, 14 and 15. What this means is that there is no unanimous agreement between the secondary and primary school teachers that lack of training to use computers, lack of relevant software and dearth of qualified computer software designers were major obstacles or key challenges in the use of technology in school in Nigeria.

## **Discussion**

The results of this study have shown that most secondary and primary school teachers have positive perception towards computers and their usage in schools. The data analyzed revealed that there are 8 major obstacles or key challenges to technology integration in primary and secondary schools in Nigeria. These key challenges are (1) lack of budget to purchase computer facilities; (2) lack of computer laboratories; (3) inadequate fund from government to purchase computer facilities; (4) high cost of computer software; (5) lack of encouragement from government; (6) lack of workshops/seminars and in-service training for teachers to learn to use computers; (7) schools are not connected to the internet; and (8) lack of encouragement from school administrators.

The obstacles observed above can be classified into four key challenges facing computer integration in primary and secondary schools in Nigeria. These are infrastructure related challenges; challenges with respect to capacity building, leadership related challenges, and challenges related to cost. These obstacles are barriers and barriers here can be defined as conditions that make it difficult to make progress or to achieve an objective. The objective here is the integration of computers into classroom. The findings here corroborated those of Tella et al (2007), Jegede and Owolabi (2003), Olakulehin (2007) and Olubube (2006). Bariso (2003), Feist (2003). Murray (2004) Lim and Khine (2006) and Mayya (2007) have also indicated that lack of infrastructure, cost, lack of capacity building and leadership were the bane of technology integration in some other parts of the world. The fact is that, these barriers are some of the most cited in literature. Kurt (2005) suggests that these barriers persist and even reappear with new technologies and that even the barriers found in 1999 still exist.

The obstacles or key challenges that were found in this study that are of moderate degree include, lack of adequate computer policy by government, inadequate electricity supply, lack of training, few computer literate teachers in schools, high internet connectivity fees, dearth of qualified software designers, inadequate telephone facilities, lack of relevant software, time and security. These are moderate challenges which the primary and secondary school teachers face in integrating technology into their classroom practice. Murray (2004), Kurt (2005) Lim and Khine (2006), Adeyinka (2007) and Mayya (2006) have also found these barriers to be limiting factors in the integration of technology in the classroom. Though these obstacles have been termed moderate in this study, they are not to be taken lightly as they are challenges that need to be addressed with the same vigor as those that are regarded as major obstacles. The word moderate may not exactly denote the magnitude they constitute barriers to technology use in primary and secondary schools in Nigeria, they however, constitute formidable problems in Nigerian schools. The importance of adequate computer policy, infrastructure, and skill acquisition, availability of relevant software, time and security can not be overemphasized in effective integration of technology into education. Effective integration of technology in the teaching and learning processes calls for a new vision of professional development, effective management of time and resources, teaching skills, modern telecommunications, technical support personnel, and clear computer policy for schools.

## **Conclusion and Recommendation**

There is no gain saying that computers will become integrated into primary and secondary education in Nigeria. Parents, teachers, school administrators, local communities and the nation must make this happen, otherwise, the nation's educational system may be left behind in a tech-served world. As computer technology becomes standard and requisite equipment in sophisticated school districts in

countries of the world, and as industries target school graduates and the homes as their key focus, classroom teachers will increasingly be required and expected to be familiar with more sophisticated level of computer literacy and proficiency. Teachers and students will be expected to acquire information skills such as the ability to locate information, to select appropriate applications and software, to organize materials in ordered fashion, to assess the relevance of information sourced and to present the information appropriately. For teachers to be able to do these the following recommendations are made:

- There is need to revise and reinvigorate current computer policy to make it workable and applicable in primary and secondary schools in Nigeria. The government needs to develop and update a comprehensive plan starting with a new vision, mission and goals that would support school implementation of technology. There is need for a plan that reflects the ideas and ideals of the entire school community and the country.
- There is need for professional development of teachers as this is one of the key strategies that are often employed to overcome barriers to technology integration. Such professional development programme must be carefully designed and implemented to provide continuity between what teachers learn and their classroom practices. Continuing education and training in form of short course, in-service training, regular workshops and seminars are some of the professional development exercises where teachers acquire technology skills and update their knowledge. Primary and secondary school teachers need skills in basic operations of technological equipment, evaluation of software, pedagogical issues, such as classroom management/learning theories/learning styles-values and ethics of using technology.
- It will be a waste of time to provide technology training for teachers when they don't have access to relevant resources they need to implement technology policies enacted by government. It is therefore recommended here that adequate computer facilities be provided in primary and secondary schools in Nigeria. Computer laboratories, with internet connectivity, should be provided in schools and they must be accessible to teachers and students. A ratio of 1 computer to 5 pupils is suggested and teachers should be provided with laptops to make their work flexible and exciting. It will be a Herculean task to integrate technology to support learning if schools cannot overcome basic technological and key facility issues.
- At the school administration level, school administrators should work out detail plan of action and develop goals necessary for reforming primary and secondary education in Nigeria. School administrators should encourage technology use in the classroom by providing effective leadership inform of encouraging teachers to use technology and providing necessary incentive for computer integration into the school curriculum. School administrators should plan for not only the acquisition of relevant equipment and materials but must also plan for continuous upgrade of hardware and software.
- Support facilities and personnel should be provided for the integration of technology into primary and secondary education in Nigeria. Some of the support facilities urgently needed in schools include, telephones, functional and constant supply of electricity and adequate classroom. There should be comprehensive support plan that help peer support, personnel/with relevant skills for installation and maintenance of basic equipment, and internet connectivity.



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## Appendix

### Faculty of Education, University of Benin Benin City, Nigeria

#### Questionnaire on Obstacles to Computer usage in Schools

The purpose of this questionnaire is to determine your perception of the major obstacles to the use of computer facilities in elementary and secondary schools in Nigeria. Please, complete all items as your response will be treated with utmost confidentiality.

#### Section A (Tick (✓) the Appropriate box)

Gender: Male ( ) Female ( )  
 Where do you teach: Secondary School ( )  
 Primary School ( )  
 Type of school: Public ( ) Private ( )  
 Location of your school: Urban ( ) Rural ( )  
 Teaching Experiences: 1-5 years ( ) 6-10 years ( ) 11-15 years ( ) 16 years and above ( )  
 Qualification: (TC II, NCE etc) .....  
 How many computers do you have in your school? None ( ) 1-5 ( ) 6-10 ( ) 11 – 20 ( ) Above 20 ( )

#### Section B

Please, indicate by marking (x) in the appropriate column the degree to which you agree or disagree with statements.

**KEY:** Strongly Agree (SA), Agree (A), Disagree (D), Strongly Disagree (SD)

S/No	Statements	SA	A	D	SD
1.	I think that working with computers would be enjoyable and stimulating				
2.	I want to learn more about computers				
3.	Use of computers in education almost always reduces teacher personal interaction with students				
4.	Learning about how to use computers is boring to me				
5.	It is important for me to learn how to use a computer				
6.	Figuring out computer problems does not appeal to me				
7.	I would work harder if I could use computers more often				
8.	I get scared each time I think of learning about computers				
9.	I can learn more from books than from a computer				
10.	I enjoy learning how computers are used in our daily lives				
11.	Computers can be useful instructional aids on almost all subject areas				
12.	Knowing how to use computers is a worthwhile skill				
13.	I get sinking feeling when I think of trying to use a computer				
14.	Computers would significantly improve the overall quality of students' education				
15.	Teacher training should include instructional applications of computers				
16.	Working with computers would make me nervous				
17.	The use of e-mail make a course more interesting				

### Section C

Please, indicate by marking (x) in the appropriate column the degree to which the following factors serve as obstacles to technology integration in your school.

S/No.	Perceived Obstacles	Major Obstacles	Moderate Obstacles	Minor Obstacles	Not an Obstacle
1.	High cost of computers hardware and software				
2.	My school has no budget to purchase computer facilities				
3.	There is no electricity in my school				
4.	Electricity supply to my school is very unstable				
5.	Inadequate telephone facilities				
6.	After teaching, there is no time to learn how to use the computer				
7.	I am not trained to use computer facilities				
8.	The school lacked computer laboratory				
9.	Government has not encouraged the schools to use computers				
10.	Lack of adequate policy by government				
11.	Teachers fear technology may displace them in the classroom				
12.	Development in computer technology is too fast				
13.	Lack of locally trained workers to install, maintain and support computer use in schools				
14.	Lack of relevant software				
15.	Dearth of qualified computer software designers				
16.	Lack of workshops / seminars and in service training in computer usage for teachers				
17.	I do not feel comfortable teaching with technological gadgets				
18.	My school is not secured well enough to house computer facilities				
19.	Most teaching staff are reluctant to learn how to use technology				
20.	School administrators have not encouraged teachers to use computers in the classroom				
21.	There is no well articulated compelling reason to use computers in classroom				
22.	My school is not connected to the internet				
23.	Adequate fund is not made available by government and school to provide computer facilities				
24.	The fee for internet connectivity is too high				
25.	Teachers are satisfied using traditional teaching method				
26.	There are few computer literate teachers in secondary schools				
27.	Teachers may lose direct control of the teaching learning processes.				

## Testing for Long Memory in Daily Fisheries and Aquaculture Prices: New Evidence

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### Abstract

In this paper we test for the presence of fractional integration in the Greek fisheries and aquaculture prices. Using Autoregressive Fractionally Integrated Moving Average (ARFIMA) models, we investigate the long memory property in the daily prices of the main species landed into Piraeus. The results show strong evidence of long memory for six species, namely Anchovy, Hake, Picarel, Seabass, Sardine, and Seabream. Only Bogue shows a weak evidence of long memory. It is concluded that most series are long-term dependent, indicating market inefficiency and a high degree of predictability.

**Keywords:** Long memory, fisheries, aquaculture, Piraeus (Greece), ARFIMA.

**JEL Classification Codes:** C32, C53, Q22.

### I. Introduction

If prices display long memory, they exhibit significant autocorrelation between observations widely separated in time (Gil-Alana, 2006). According to Assaf (2007), the autocorrelation functions of various measures decay at a very slow mean-reverting hyperbolic rate. This feature is labelled a long memory or long range dependence [1]. Evidence of long memory indicates that shocks to the prices persist over a long period of time, see Floros and Failler (2007). In addition, the presence of long memory has potentially important implications for predictability and market efficiency. If the series are

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<sup>1</sup> Assaf (2007, p. 709) argues that "The long memory property describes the high-order structure of a series. If a series exhibits long memory, there is persistent dependence even between distant observations....The presence of long memory dynamics causes nonlinear dependence in the moments of the distribution and hence a potentially predictable component in the series dynamics".

long-range dependent, then distant observations are positively autocorrelated (for more details see Christodoulou-Volos and Siokis, 2006).

A number of studies have tested the long memory hypothesis for stock market returns using prices from financial markets (e.g. Cheung and Lai, 1995; Ding and Granger, 1996; Gil-Alana, 2006; Lo, 1991; Barkoulas *et al.*, 2000; Floros *et al.*, 2007; and Floros, 2008). According to Christodoulou-Volos and Siokis (2006), the results depend on the testing method, sample period and frequency of the data. Despite the extant literature that analyses the long memory properties of stock markets prices (and returns), there is little research done on the time series properties of fisheries and aquaculture markets. In this paper, we test for the presence of long memory in fisheries and aquaculture prices, or fractional dynamics, using the method of Autoregressive Fractionally Integrated Moving Average (ARFIMA). We test for the presence of long memory in the log-prices of fisheries and aquaculture data from Greece. The existing work on long memory in fisheries prices derives largely from the pioneering work of Floros and Failler (2007) and Floros and Avdelas (2006). They both investigate long memory in the fisheries markets of UK and Greece using weekly and monthly prices. In particular, Floros and Failler (2007) test for the presence of long memory in the monthly fisheries prices of Cornwall (UK) using ARFIMA models. The data covers the period 1992-2006. Their results show strong evidence of long memory for 7 species (Anglerfish, Cod, Crabs, Dogfish, Hake, Lemon Sole and Sole), while three species (Haddock, Mackerel and Plaice) show a weak evidence of long memory. Furthermore, Floros and Avdelas (2006) test for long memory in the weekly fisheries prices of Greece. The data covers the period 2000 to 2003. The results show that 19 series (out of 20) support the long memory hypothesis. Only Shrimps show a weak evidence of long memory. Hence, Floros and Avdelas (2006) conclude that weekly fisheries prices in Greece persist over a long period of time.

The main objective of this paper is to re-examine and justify the presence of long memory (via fractional integration) in the prices of the top seven species landing into Piraeus (Greece). The paper follows, and extends, the previous works of Floros and Failler (2007), Floros and Avdelas (2006) and Avdelas (2004). We aim to address long-memory estimations by applying ARFIMA techniques to daily Greek data. It is important to test if ARFIMA models support the long memory hypothesis when daily data series is applied. To the best of our knowledge, this is the first empirical investigation of long memory hypothesis to daily fisheries and aquaculture data.

This paper is organized as follows. Section II presents the long memory methodology through ARFIMA models. Section III provides data information. Section IV presents the empirical results. Finally, Section V concludes the paper and summarises our findings.

## II. Methodology

Mandelbrot (1972) used the “range over standard deviation” (or rescaled range statistic R/S) to detect long-range dependence. Here, we estimate ARFIMA( $p, d, q$ ) via conditional maximum likelihood. For the returns series  $r_t$ , where  $t = 1, \dots, T$ , the ARFIMA model is given by:

$$\phi(L)(1-L)^d(r_t - \mu) = \theta(L)\varepsilon_t \quad (1)$$

$L$  is the lag operator ( $L^j r_t = r_{t-j}$ ),  $\phi(L)(1-L)^d(r_t - \mu) = \theta(L)\varepsilon_t$  is the autoregressive polynomial, and  $\theta(L) = 1 + \theta_1 L + \dots + \theta_q L^q$  is the moving average polynomial. The differencing parameter  $d$  is not necessarily an integer, but integer values of  $d$  lead to the traditional ARIMA model. Therefore the fractional differencing parameter  $(1-L)^d$  can be defined for non-integer values by the following binomial expansion:

$$(1-L)^d = \sum_{j=0}^{\infty} \binom{d}{j} (-L)^j \quad (2)$$

We also make the assumptions that (i) the residuals  $\varepsilon_t \sim NID(0, \sigma_\varepsilon^2)$  and (ii) the roots of the AR and MA parameters fall outside the unit circle and do not have common roots. Significance of

$d$  parameter is evidence of long memory. When  $d$  parameter has values greater or equal to 0.5, the series does not have stationary covariance, and consequently it has infinite covariance as shown by Baillie *et al.* (1996). When  $d$  is between 0 and 0.5, the lag length increases the autocorrelations decay hyperbolically to zero, while when  $d = 0$ , decays exponentially to zero. If  $d$  is between -0.5 and 0, then it is usually identified as having intermediate memory, since autocorrelations are always negative (see Floros *et al.*, 2007).

Further, we select a parsimonious ARFIMA( $p, d, q$ ) model using two information criteria: the Akaike (AIC) and Schwarz (SBC). The best (selected) model has the smallest AIC or SBC value. It is known that AIC always selects a generously parameterized model, while SBC selects a less generously parameterized model (Floros and Failler, 2007).

### III. Data Description

The data employed in this paper comprise daily observations on the top five species produced in Greece [2] as well as the two most important finfish produced by the Greek aquaculture. Data is covering the period from January 2000 to August 2005 and was derived from Piraeus (Keratsini) which is the biggest fish landing site and fishery market in Greece, serving mainly the Metropolitan area of Athens. Approximately 136 species are landed yearly at Piraeus. The production of the top five species represents in terms of volume 36% – 40% of the Greek capture fishery production.

Daily average prices (euro/tonne) for the seven species were obtained from ETANAL S.A. We consider daily data of the following species: Anchovy, Bogue, Hake, Picarel, Sardine, Seabass and Seabream.

**Table 1:** Greek Fisheries and Aquaculture production

	2000	2001	2002	2003	2004	2005
<b>Capture Fisheries Production</b>						
Sardine	16026	14395	16331	8667	9217	11258
Anchovy	9863	10770	9976	13780	13404	11324
Bogue	4096	3674	3793	4025	3906	4185
Hake	2960	2753	3279	3164	3748	3871
Picarel	3036	2927	2934	2883	3584	3216
<b>Total</b>	<b>35980</b>	<b>34519</b>	<b>36312</b>	<b>32518</b>	<b>33859</b>	<b>33854</b>
Total Capture Fisheries Production	93980	89231	91891	89632	91139	90446

Source: National Statistics Service of Greece ([www.statistics.gr](http://www.statistics.gr))

<b>Aquaculture Production</b>	2000	2001	2002	2003	2004	2005
Seabass	26653	25342	23860	27324	25766	30959
Seabream	38587	40694	37944	44118	37394	43829

Source: FAO - Fisheries and Aquaculture Information and Statistics Service (<http://www.fao.org/fi>)

Table 2 presents the descriptive statistics for the log-prices of the top species landed into Piraeus. Most series show positive skewness (the distribution is skewed to the right), while the distribution is peaked (or leptokurtic) for bogue and flat (or platykurtic) relative to normal for all other series. We also reject the hypothesis of normal distribution at the 5% level for all series. In addition, the ADF tests show evidence of non-stationarity,  $I(1)$ , for all series (the results are not reported here).

**Table 2:** Descriptive Statistics for log-prices

Fish	Mean	S.d.	Skewness	Kurtosis	Normality
Anchovy	0.5419	0.3493	0.4397	0.3251	54.32 (0.00)
Bogue	0.5139	0.2654	-0.4122	6.0701	831.7 (0.00)
Hake	1.8165	0.2646	0.4320	-0.0092	71.86 (0.00)
Picarel	0.7635	0.3633	0.4085	0.1879	49.58 (0.00)
Sardine	0.1847	0.3193	0.5313	0.9841	74.39 (0.00)
Seabass	1.5151	0.1855	-0.008	0.6653	28.23 (0.00)
Seabream	1.4015	0.1551	0.3723	1.1788	71.39 (0.00)

**Notes:**

- Skewness is a measure of asymmetry of the distribution of the series around its mean.
- Kurtosis measures the peakedness or flatness of the distribution of the series.
- Normality (under Jarque-Bera test) is a test statistic for testing whether the series is normally distributed (probability value in parentheses).

## IV. Empirical Results

A number of ARFIMA(p,d,q) models are estimated (we estimate different specifications with  $p+q \leq 3$ ) using the Maximum Likelihood method. There is evidence of unit roots, and the selected ARFIMA model for all species is ARFIMA(1,d,1). The results, reported in Table 3, show that  $d$  parameter varies from 0.07 to 0.49 and it is statistically significant (at 5% level) in six cases. In other words, six species (Anchovy, Hake, Picarel, Seabass, Sardine, and Seabream) show strong evidence of long memory. Only Bogue shows a weak evidence of long memory.

Our findings show that the long memory evidence for Picarel is stronger, with  $d$  suggesting that there is a high degree of predictability in that series. As far as the Bogue series, the evidence is consistent with the weak form of market efficiency, which implies unpredictability of future prices based on historical prices.

It is concluded that daily fisheries and aquaculture prices in Piraeus persist over a long period. Therefore, simple ARFIMA models support the evidence of long memory in Greek prices. Hence, our findings show that shocks to the prices persist over a long period of time, while prices don't reflect available information (market efficiency hypothesis is not supported). We conclude that the fishing and aquaculture markets of Piraeus (Greece) are not informationally efficient. Furthermore, the evidence of long memory component presented in this study may indicate that prices are not immune to persistent informational asymmetries, especially over longer time spans (see Kilic, 2004). Our results are similar to those of Floros and Failer (2007) for the UK and Floros and Avdelas (2006) for Greece.

**Table 3:** Long memory results

### A. Anchovy

Maximum likelihood estimation of ARFIMA(1,d,1) model				
The estimation sample is: 0 (1) - 0 (1606)				
The dependent variable is: Lp (anchovy)				
	Coefficient	Std.Error	t-value	t-prob
d parameter	0.356278	0.02794	12.8	0.000*
AR-1	-0.328448	0.4012	-0.819	0.413
MA-1	0.388586	0.3805	1.02	0.307
Constant	0.542655	0.1171	4.63	0.000*
log-likelihood	-173.614787			
no. of observations	1606	no. of parameters		5
AR-1	-0.328448	0.4012	-0.819	0.413
MA-1	0.388586	0.3805	1.02	0.307
Constant	0.542655	0.1171	4.63	0.000*
log-likelihood	-173.614787			
no. of observations	1606	no. of parameters		5
AIC.T	357.229575	AIC		0.222434356



(Table 3 contd.)

**B. Bogue**

<b>Maximum likelihood estimation of ARFIMA(1,d,1) model</b>				
<b>The estimation sample is: 0 (1) - 0 (1635)</b>				
<b>The dependent variable is: Lp (bogue)</b>				
	<b>Coefficient</b>	<b>Std.Error</b>	<b>t-value</b>	<b>t-prob</b>
d parameter	0.0706773	0.09165	0.771	0.441
AR-1	0.873817	0.02879	30.3	0.000*
MA-1	-0.6875620.08313	-8.27	0.000*	
Constant	0.523949	0.02189	23.9	0.000*
log-likelihood	175.608406			
no. of observations	1635	no. of parameters	5	
AIC.T	-341.216813	AIC	-0.208695298	

**C. Hake**

<b>Maximum likelihood estimation of ARFIMA(1,d,1) model</b>				
<b>The estimation sample is: 0 (1) - 0 (1628)</b>				
<b>The dependent variable is: Lp (hake)</b>				
	<b>Coefficient</b>	<b>Std.Error</b>	<b>t-value</b>	<b>t-prob</b>
d parameter	0.496004	0.005544	89.5	0.000*
AR-1	-0.0750136	0.1645	-0.456	0.648
MA-1	-0.0261395	0.1644	-0.159	0.874
Constant	1.80346	0.8949	2.02	0.044*
log-likelihood	663.273328			
no. of observations	1628	no. of parameters	5	
AIC.T	-1316.54666	AIC	-0.808689592	

**D. Picarel**

<b>Maximum likelihood estimation of ARFIMA(1,d,1) model</b>				
<b>The estimation sample is: 0 (1) - 0 (1589)</b>				
<b>The dependent variable is: Lp (picarel)</b>				
	<b>Coefficient</b>	<b>Std.Error</b>	<b>t-value</b>	<b>t-prob</b>
d parameter	0.497630	0.003301	151	0.000*
AR-1	-0.494097	0.1861	-2.65	0.008*
MA-1	0.428190	0.1930	2.22	0.027*
Constant	0.763149	1.467	0.520	0.603
log-likelihood	378.614125			
no. of observations	1589	no. of parameters	5	
AIC.T	-747.22825	AIC	-0.470250629	

**E. Sardine**

<b>Maximum likelihood estimation of ARFIMA(1,d,1) model</b>				
<b>The estimation sample is: 0 (1) - 0 (1634)</b>				
<b>The dependent variable is: Lp (sardine)</b>				
	<b>Coefficient</b>	<b>Std.Error</b>	<b>t-value</b>	<b>t-prob</b>
d parameter	0.484996	0.01978	24.5	0.000*
AR-1	0.490851	0.09493	5.17	0.000*
MA-1	-0.618115	0.08728	-7.08	0.000*
Constant	0.181171	0.4520	0.401	0.689
log-likelihood	274.150919			
no. of observations	1634	no. of parameters	5	
AIC.T	-538.301838	AIC	-0.32943809	

(Table 3 contd.)

**F. Seabass**

Maximum likelihood estimation of ARFIMA(1,d,1) model				
The estimation sample is: 0 (1) - 0 (1638)				
The dependent variable is: Lp (seabass)				
	Coefficient	Std.Error	t-value	t-prob
d parameter	0.477809	0.02638	18.1	0.000*
AR-1	0.243278	0.07242	3.36	0.001*
MA-1	-0.547852	0.07233	-7.57	0.000*
Constant	1.52605	0.1933	7.89	0.000*
log-likelihood	896.509747			
no. of observations	1638	no. of parameters	5	
AIC.T	-1783.01949	AIC	-1.08853449	

**G. Seabream**

Maximum likelihood estimation of ARFIMA(1,d,1) model				
The estimation sample is: 0 (1) - 0 (1650)				
The dependent variable is: Lp (seabream)				
	Coefficient	Std.Error	t-value	t-prob
d parameter	0.495986	0.005596	88.6	0.000*
AR-1	0.138108	0.08326	1.66	0.097
MA-1	-0.400457	0.07747	-5.17	0.000*
Constant	1.42307	0.3688	3.86	0.000*
log-likelihood	1695.15196			
no. of observations	1650	no. of parameters	5	
AIC.T	3380.30392	AIC	-2.04866904	

Notes: \* Significant at 5% level. We report the results from ARFIMA(1,d,1) models.

**V. Conclusion**

There is a large body of existing empirical evidence to suggest that long horizon data (mainly stock market prices) are forecastable. Such forecastability may arise from the possibility of long memory in the data (Henry, 2002). In this paper, we examine the evidence of long memory in the daily fisheries and aquaculture prices using data from Greece. We consider prices from the top five species produced in Greece, as well as the two most important finfish produced by the Greek aquaculture. The top species landed into Piraeus (Keratsini) covering the period from January 2000 to August 2005. Conditional maximum likelihood is employed to estimate ARFIMA(p,d,q) models.

The results from the selected ARFIMA(1,d,1) models show evidence of long memory in six species (Anchovy, Hake, Picarel, Seabass, Sardine, and Seabream). For these species, the fractional integration parameter,  $d$ , is positive and significant at 5% level. Hence, the evidence is consistent with the long memory property, that is, there is evidence that these series are autocorrelated which could give rise to improved predictability. According to Kilic (2004), the evidence of long memory component may indicate that prices are not immune to persistent informational asymmetries, especially over longer time spans. We conclude that the fishing and aquaculture industries in Greece are not efficient enough. According to Floros and Failler (2007), a strong long-range dependence may be a source of long-horizon predictability. In addition, a possible long-horizon strategy may represent an unexploited profit opportunity (for the above six species). Furthermore, we find weaker evidence in favour of long memory for bogue. For this specie, the fractional integration parameter is statistically insignificant (at 5% level). Hence, we find evidence of market efficiency in the form that the bogue market fully and correctly reflects all available information in determining its price.

These findings are helpful to fisheries and aquaculture managers and researchers dealing with long dated price series. Our results should also be useful to Greek economists, whose success depends on the ability to predict price movements over long horizons. Further research should examine the visibility of long-memory component at both short and long horizons. We should include the estimation of several ARFIMA-GARCH and FIGARCH models for estimating volatility and

examining how the above models can be used for predicting daily, weekly and monthly fish and aquaculture prices.

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## **Fracture Networks Analysis in Crystalline Basement: Case of Bondoukou Area (Northeast Cote D'Ivoire)**

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### **Abstract**

The present study is about a region located in the Northeast of Cote d'Ivoire (Bondoukou) where fracturing is developed and has been measured. The aim of this study is the analysis of the structural organization of fracture networks in hard crystalline and metamorphic rocks of Bondoukou area with a view of the modelling of groundwater flow. Fracture networks are obtained from Landsat 7 satellites image captor ETM+ treatment. These fracture networks have been analyzed according to statistical and geostatistical approaches.

Statistical analysis results show that fractures lengths are distributed according to a power law. Fracture networks are spatially organised and multi structured because its behaves as a regionalized variable. Variogram analysis of family fractures show that the behaviours of these fractures in space are not identical.

These results allow to conclude that fracture networks of Bondoukou area have reached an advanced stage of development.

This study contributes to a better knowledge of fracture networks of the Bondoukou area with a view to develop a representative numerical model.

**Keywords:** Fracture, Cote d'Ivoire, geometric parameters, statistical, geostatistical.

### **1. Introduction**

Durant ces trois dernières décennies, de nombreux travaux ont montré le rôle important joué par la géométrie des réseaux de fractures sur les propriétés d'écoulement et de transport dans les milieux

souterrains discontinus (Renshaw, 1996; Bodin et Razack, 1999; de Dreuzy, 2000; Lasm, 2000; Bodin, 2001; Darcel, 2002; Kouamé *et al.*, 2005). Les approches quantitatives et qualitatives ont été abordées au cours de ces études. Les principaux résultats ont contribué à une meilleure connaissance des paramètres géométriques de la fracturation et une meilleure compréhension des phénomènes d'écoulements souterrains.

La connaissance de la géométrie des réseaux naturels de fractures conditionne grandement les possibilités d'analyse et de résolution de multiples problèmes actuels tels que le stockage des déchets, l'exploitation des ressources naturelles, la réhabilitation d'aquifères contaminés (Bodin et Razack, 1999).

La modélisation des milieux fracturés, suppose une meilleure connaissance des paramètres géométriques. En effet, plusieurs grandeurs doivent être prises en compte notamment la taille des fractures, l'orientation, la densité, l'espacement, la rugosité, l'ouverture, la position spatiale, la connectivité, etc., en vue d'approcher la connaissance des écoulements souterrains et du transport de masses, de polluants et de chaleur. La représentation des milieux fracturés reste souvent difficile et les modèles demeurent simples et assez éloignés de la réalité pour rendre compte des réseaux de fractures naturelles dans toutes leurs complexités. Une meilleure connaissance des caractéristiques et des propriétés du réseau de fractures naturelles se justifie en vue d'une meilleure modélisation, protection et gestion durable des ressources en eau souterraines. En effet, les propriétés mécaniques et hydrogéologiques des massifs rocheux dépendent essentiellement des caractéristiques du champ de fractures qui leur sont associées (Chilès, 1989).

La géométrie des systèmes de fractures est le principal facteur qui contrôle l'écoulement et le transport de masses et de polluants dans les roches fracturées.

L'objectif de ce travail est d'analyser la fracturation des roches du socle précambrien de Bondoukou (est de la Côte d'Ivoire) suivant les approches statistiques et géostatistiques. Dans cette région, la fracturation des roches cristallines a pu être mesurée de façon significative au cours de travaux antérieurs (Youan Ta, 2002). Deux paramètres géométriques de la fracturation seront principalement analysés dans le cadre de cette étude. Ce sont la taille des fractures et la densité de fracturation. Ces grandeurs jouent un rôle crucial dans l'organisation du réseau et ses propriétés de transport (Bodin et Razack, 1999; Lasm, 2000; Lasm et Razack, 2001; Kouamé *et al.*, 2005).

## 2. Cadre D'étude et Contexte Géologique

La région d'étude est située dans la partie nord-est de la Côte d'Ivoire entre les latitudes 7°55' et 8°30' Nord et les longitudes 2°40' et 3°20' Ouest, à l'Est de la l'accident majeur du Sassandra (Figure 1). Elle fait partie du domaine Baoulé-Mossi de Côte d'Ivoire. Ce domaine comporte des formations volcanique, sub-volcanique et sédimentaire déposées dans des sillons ou bassins intracratoniques dans lesquels se sont mis en place les granites du cycle Eburnéen (Kouamélan, 1996). Ces formations se sont différenciées du manteau entre 2200 Ma et 2300 Ma et caractérisent le birimien.

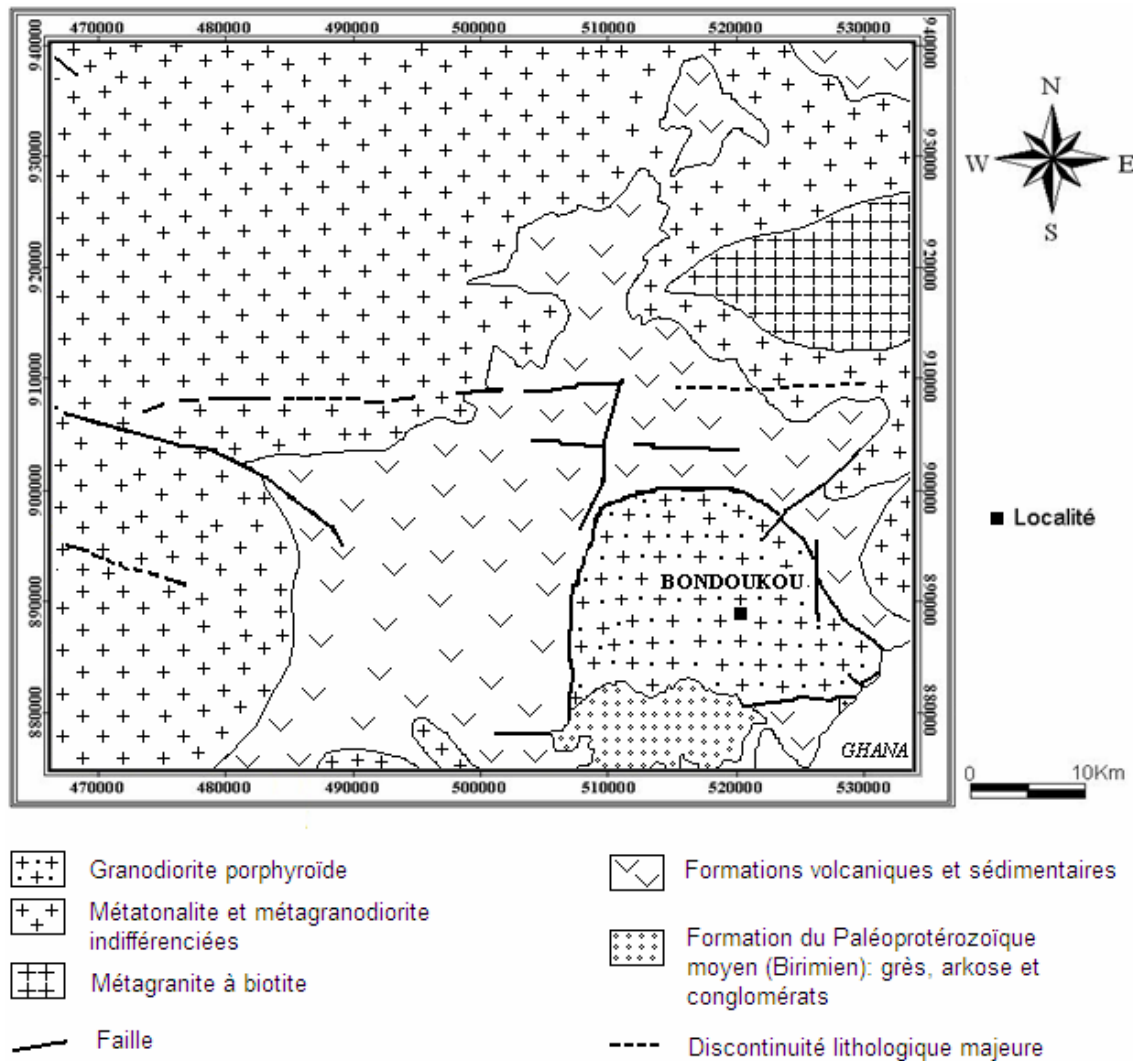
On y distingue au niveau du secteur d'étude trois grands ensembles d'un point de vue lithologique (Figure 2):

- i) Un ensemble volcanique et sédimentaire, constitué de plusieurs unités pétrographiques différentes, affleurant dans les régions sud et centre du secteur;
- ii) Un ensemble intrusif constitué essentiellement de granodiorites plus ou moins métamorphisé et secondairement de granites, de tonalites;
- iii) Un ensemble tarkwaïen constitué de formations détritiques post-tectonique représentées par les conglomérats, les grès et les arkoses.

Au plan tectonique, la région est très fracturée comme l'attestent les travaux antérieurs (Youan Ta, 2002). Cette tectonique semble complexe et polyphasée à l'instar des autres provinces fracturées de socle de la Côte d'Ivoire (Zeade *et al.*, 1995; Delor *et al.*, 1995).

**Figure 1:** Localisation de la zone d'étude sur la carte de la Côte d'Ivoire.

**Figure 2:** Carte géologique de la région de Bondoukou (Côte d'Ivoire).

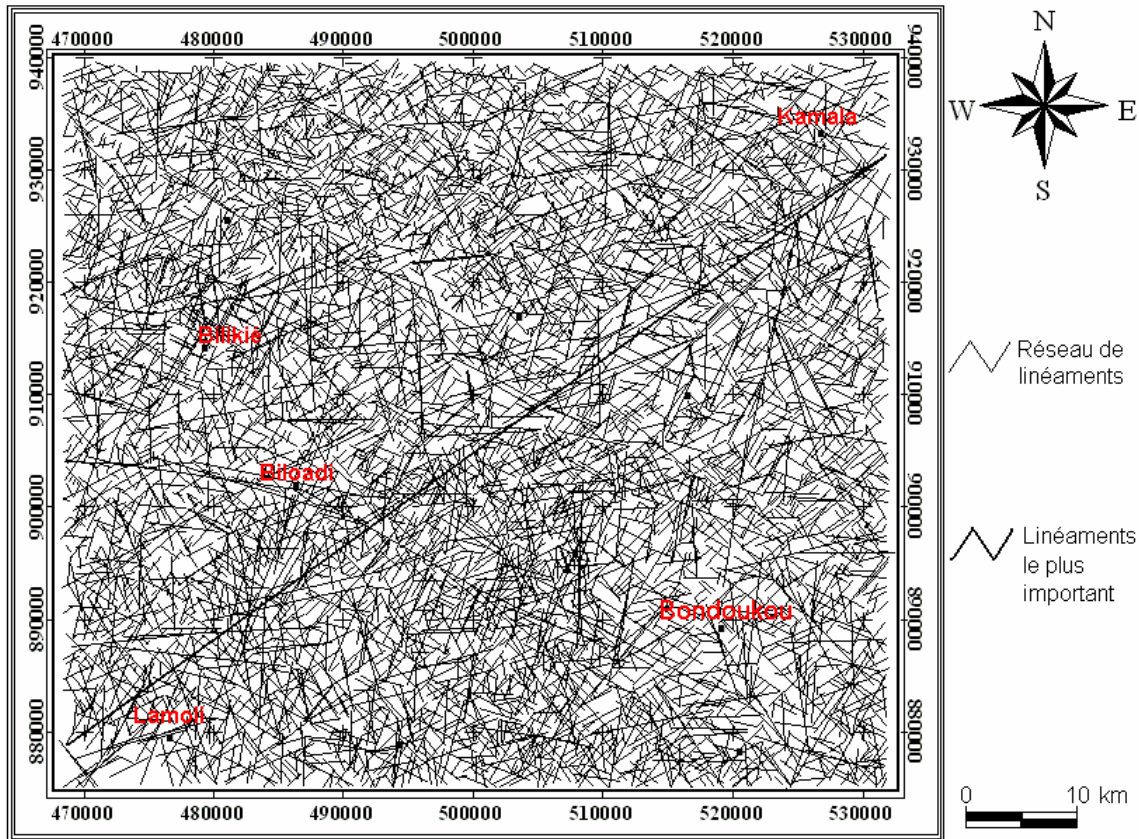


### 3. Matériel et Méthodes

#### 3.1. Matériel

Ce travail a été possible grâce à l'usage de la carte de fracturation issue du traitement des images satellitaires du capteur ETM+ du satellite Landsat 7 (Figure 3). La carte de fracturation obtenue a été par la suite validée sur la base des connaissances de terrains, des cartes géologiques et photogéologiques existantes. Au cours de la phase de validation, les linéaments ayant une origine autre que tectonique ont été supprimés si bien que les linéaments cartographiés ont une valeur de fracturation.

La carte de fracturation bien que n'étant pas exhaustive reste cependant très représentative des structures géologiques de la région de Bondoukou. Elle peut donc être utilisée pour conduire une analyse des paramètres géométriques de la fracturation qui gouvernent les écoulements souterrains.

**Figure 3:** Réseaux de fractures de la région de Bondoukou extraits des images ETM+.

### 3.2. Méthodes

La fracturation des roches dures cristallines a été analysée suivant les techniques de l'analyse statistique. Il s'agit essentiellement de l'étude des lois de distribution du paramètre de taille.

Le champ des réseaux de fractures de la région de Bondoukou a été soumis à un traitement numérique sous le logiciel LINEAM (Bodin et Razack, 1999) pour permettre l'extraction des longueurs des fractures qui vont être utilisées pour l'analyse statistique.

Le logiciel STATISTICA 6.0. a été utilisé pour l'analyse statistique. Les réseaux de fractures ont été analysés aussi suivant les concepts de la géostatistique notamment l'analyse du variogramme. L'outil mathématique de la géostatistique est le variogramme expérimental. Il est défini par la relation:

$$\gamma(h) = \frac{1}{2} \text{VAR} [Z(x+h) - Z(x)] \quad (1)$$

Avec:

VAR [Z(x)]: variance de la variable régionalisée au point x;

h: vecteur de module (x-x');

$\gamma(h)$  est le demi-variogramme.

Pour les besoins de cette analyse, la carte de fracturation (Figure 3) a été discrétisée en un maillage carré de dimension 4 x 4 km<sup>2</sup>. La variable analysée est la densité de fracturation, exprimée en longueurs cumulées (LC) par maille. L'analyse du variogramme portera sur la fracturation globale et sur les familles de fractures majoritaires, susceptibles de jouer un rôle hydrogéologique important. Il s'agit des familles de fractures NE-SW et NW-SE.

De nombreux logiciels sont disponibles sur Internet et peuvent être utilisés pour l'analyse géostatistique: VARIOWIN (Panatier, 1996), GSLIB (Deutsch et Journel, 1992), GEO-EAS (Englund et Sparks, 1991), GSTAT (Pebesma et Wesseling, 1998).

Les paramètres de régionalisations des variogrammes expérimentaux sont déterminés après ajustement aux modèles théoriques (sphérique, exponentiel, gaussien, etc.). Le modèle exponentiel a



été retenu dans le cadre de cette étude comme l'ont préconisé Razack (1984) et Lasm (2000) dont l'expression générale est donnée par l'équation ci-dessous (2).

$$\gamma(h) = C_0 + C_1 \left[ 1 - \exp\left(\frac{-3h}{a}\right) \right] \quad (2)$$

où  $C_0$  est l'effet de pépité,  $C = C_0 + C_1$  est le palier,  $a$  est la portée pratique (distance à partir de laquelle 95% du palier est atteint),  $h$  est la distance entre deux points d'appui.

La fracturation étudiée ici, est considérée indépendamment de son contexte cinématique. Il s'agit donc d'une approche purement quantitative, c'est à dire les fractures étant différenciées uniquement en fonction de leur direction et leur intensité. L'approche qualitative n'a pas été abordée dans le cadre de cette étude car il sort des limites de ce travail. Cette approche a été abordée par d'autres auteurs (Zeade *et al.*, 1995; Delor *et al.*, 1995).

## 4. Résultats

### 4.1. Analyse statistique des longueurs de fractures

La carte de fracturation obtenue après divers traitements compte environ 4 000 fractures de tailles variables, comprises dans l'intervalle [73 m; 11 857 m]. Les tailles des fractures s'échelonnent donc sur plusieurs ordres de grandeurs indiquant ainsi l'hétérogénéité géologique.

Les longueurs de fractures ont été ajustées aux modèles théoriques (exponentiel, lognormal, gamma et puissance, etc.). Le test de conformité du Khi-2 est négatif pour les trois premiers modèles au seuil de signification de 10 %. Cependant la loi de puissance donne des résultats satisfaisants (Figure 4). En effet, sur le graphe de la Figure 4, nous distinguons une portion linéaire ( $\ell \geq 2,23$  km) sur laquelle il est possible d'ajuster une loi de puissance. Cette loi de puissance est définie par l'expression (3):

$$N(\ell) = 17\,022 \times \ell^{-2,98} \quad (3)$$

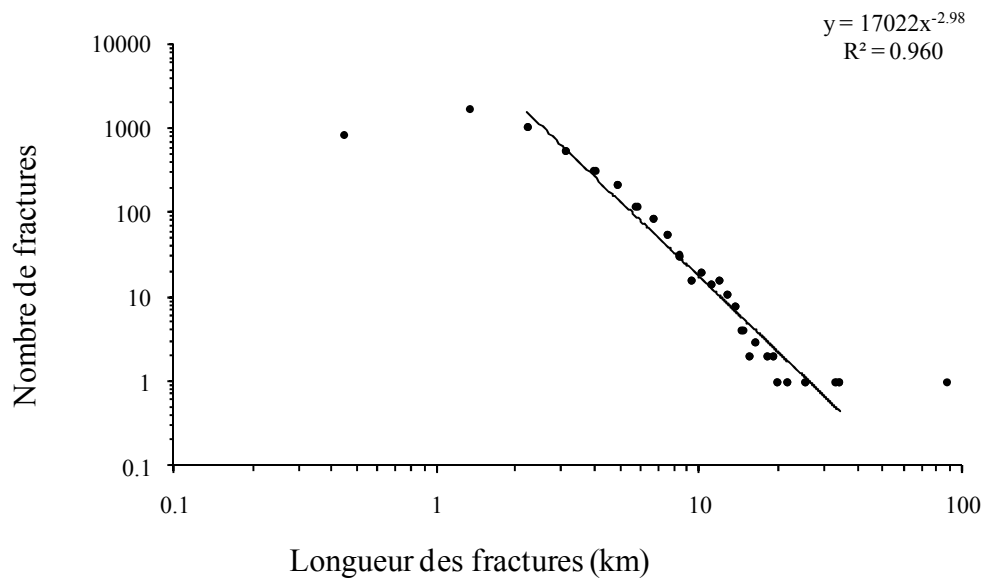
avec:

$$R^2 = 0,96 \text{ (} R^2 \text{ étant calculé pour les } \ell \geq 2,23 \text{ km).}$$

L'exposant caractéristique de la loi de puissance vaut ici  $\alpha = 2,98$ ; cette valeur de  $\alpha$  est très proche de 3. La valeur de  $a$  trouvée est en accord avec les données de la littérature comprises généralement entre 1 et 3. Ce résultat montre que le réseau de fractures caractérisé ( $\ell \geq 2,23$  km) s'identifie à un réseau percolant dont l'exposant caractéristique est supérieur ou égal à 3.

Pour les valeurs inférieures à 2,23 km, l'on s'éloigne très significativement de la droite linéaire théorique mettant en évidence les limites de résolution avec une certaine rupture de pente.

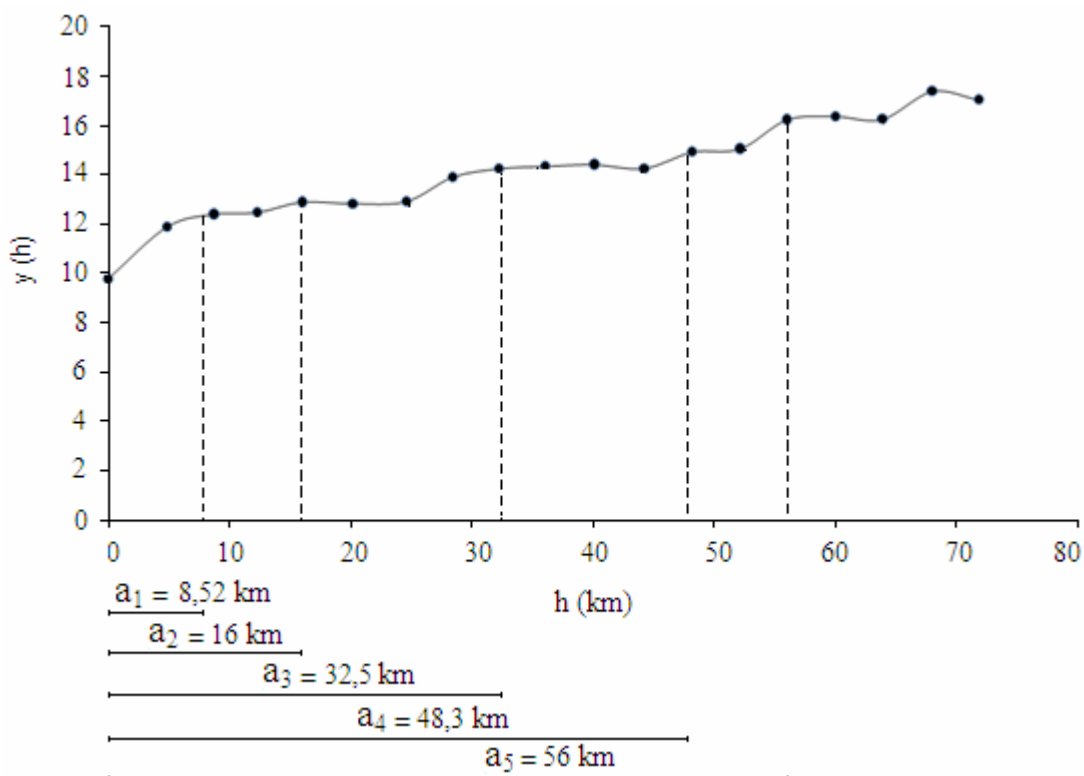
**Figure 4:** Diagramme Log-Log de la distribution des fréquences des longueurs de fractures. Ajustement à une loi de puissance.



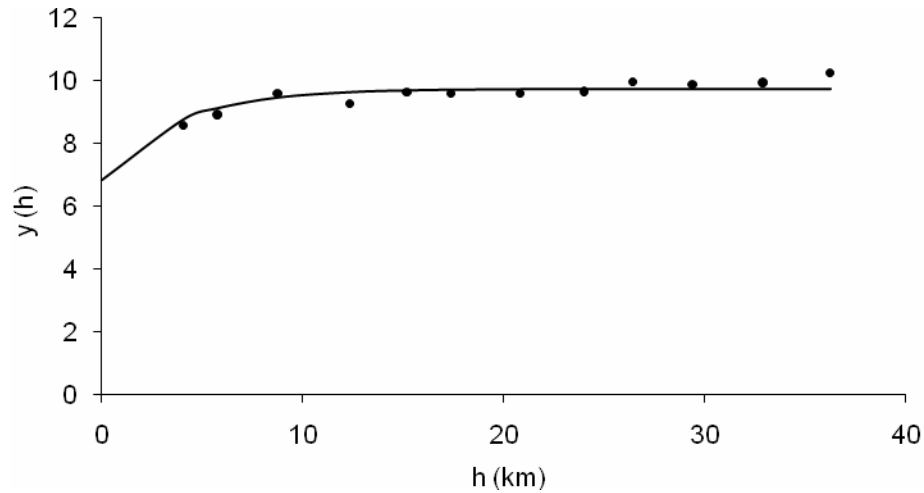
#### 4.2. Analyse géostatistique de la fracturation

Plusieurs variogrammes expérimentaux ont été calculés. Il s'agit des variogrammes de la fracturation tous azimuts et des familles de fractures NE-SW et NW-SE (Figures 5, 6 et 7).

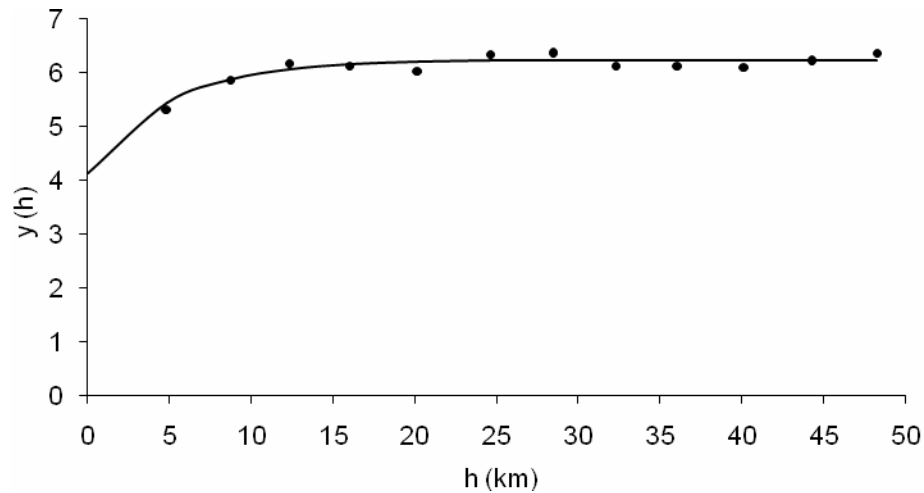
**Figure 5:** Variogramme de la fracturation tous azimuts. Ajustement à un modèle exponentiel.



**Figure 6:** Variogramme de la famille de fractures NE-SW. Ajustement à un modèle exponentiel.



**Figure 7:** Variogramme de la famille de fractures NW-SE. Ajustement à un modèle exponentiel



Sur les différents variogrammes, on note les caractéristiques suivantes: existence d'un palier « $C$ », valeur autour de laquelle se stabilise le variogramme; existence d'une portée « $a$ », valeur à partir de laquelle le palier est atteint; existence d'un effet de pépité plus ou moins marqué « $C_0$ », valeur de  $y(h)$  quand  $h$  tend vers 0. Elle représente la discontinuité à l'origine. En somme, les variogrammes sont spatialement structurés. La présence de ces caractéristiques au niveau des variogrammes permet de dire que la fracturation est spatialement structurée. Autrement dit, le déploiement de la fracturation, support de circulation des eaux souterraines dans la région de Bondoukou ne se fait pas de façon aléatoire mais plutôt de manière organisée dans l'espace. La densité de fracturation exprimée en longueurs cumulées s'apparente sans ambiguïté à une variable régionalisée.

L'ajustement des variogrammes expérimentaux aux modèles théoriques (sphérique, exponentiel, gaussien, etc.) est une étape importante dans la détermination et l'interprétation des paramètres de régionalisation.

Le variogramme expérimental de la fracturation globale (tous azimuts) présente un comportement particulier caractérisé par plusieurs paliers (figure 5). Ceci peut être l'indication d'un emboîtement (structure gigogne) de plusieurs structures à plusieurs échelles différentes. Autrement dit la fracturation globale est caractérisée par une multi-régionalisation ou multi-structuration. Dans ce cas, le variogramme est modélisé comme la somme des variogrammes élémentaires dont l'équation générale est donnée par l'expression (4).

$$\gamma(h) = \gamma_1(h) + \gamma_2(h) + \gamma_3(h) + \gamma_4(h) + \gamma_5(h) + \dots + \gamma_n(h) \quad (4)$$

L'expression générale du premier variogramme élémentaire est représentée par l'équation (5).

$$\gamma_1(h) = 9,75 + 2,85 \times \left[ 1 - \exp\left(\frac{-3h}{8,64}\right) \right] \quad (5)$$

L'effet de pépite représente au niveau de la fracturation tous azimuts 77,38 % de la dispersion totale, cette valeur oscille entre 66,13 % et 71,15 % au niveau des variogrammes des familles de fractures. D'une manière générale, la dispersion est très importante au niveau de ces variogrammes.

Le variogramme de la fracturation globale est multi-structuré avec six paliers bien distincts dont le dernier n'est pas complet. Cinq portées pratiques ont été déterminées respectivement à  $a_1 = 8,52$ ,  $a_2 = 16$ ,  $a_3 = 32,5$ ,  $a_4 = 48,3$  et  $a_5 = 56$  km. La portée maximale du variogramme est donc de 56 km. La structuration des réseaux de fractures est donc importante. La distance de structuration des familles de fractures NE-SW et NW-SE est respectivement:  $a_{NE-SW} = 11,1$  et  $a_{NW-SE} = 14,92$  km. Les équations de modélisation de ces variogrammes sont représentées par les expressions (6) et (7) ci-dessous:

$$\gamma_{NE-SW}(h) = 6,84 + 2,91 \times \left[ 1 - \exp\left(\frac{-3h}{11,1}\right) \right] \quad (6)$$

$$\gamma_{NW-SE}(h) = 4,12 + 2,11 \times \left[ 1 - \exp\left(\frac{-3h}{14,92}\right) \right] \quad (7)$$

Ces valeurs de ces portées pratiques sont différentes d'un point de vue statistique indiquant que le comportement de la fracturation n'est pas identique dans les différentes directions de l'espace. Au-delà de cette distance, il y a une indépendance entre les différents points. Ce résultat met en évidence la complexité dans la structuration spatiale des réseaux de fractures de la région de Bondoukou et renseigne sur les déformations ayant affecté la région.

## 5. Discussion

Les réseaux de fractures de la région de Bondoukou tout comme ceux des autres régions de socle de Côte d'Ivoire (Man-Danané, Toubia, Daloa, Oumé, Dimbokro, Korhogo, etc.) ont des tailles variables allant de quelques mètres à plusieurs kilomètres. La distribution de ses est de type puissance. La caractérisation d'une loi de puissance, de part sa nature, requiert des données relevées sur un minimum de deux ou trois ordres de grandeur ainsi qu'un nombre d'éléments de l'ordre de quelques centaines. C'est le cas des réseaux étudiés dont les tailles s'échelonnent sur 3 ordres de grandeur et dont le nombre vaut environ 4000. L'exposant caractéristique ( $\alpha$ ) de cette loi de puissance est égal à 2,98 et très proche de la valeur 3. Il peut varier d'une région à une autre comme l'attestent les travaux de nombreux auteurs (Bodin et Razack, 1999; Lasm, 2000; de Dreuzy, 2000; Darcel, 2002; Jourda, 2005). Cet exposant  $\alpha$  fixe la proportion de grandes fractures par rapport aux petites. Les variations de  $\alpha$  est le signe que les réseaux observés dans la nature sont à différents stades de développement (Lasm, 2000; de Dreuzy, 2000, Darcel, 2002). Déterminer la nature de la distribution des longueurs de fractures d'après des données de terrain pose avant tout un problème d'échantillonnage et de mesure. Les résultats des travaux de simulations numériques et de données expérimentales sur la fracturation montrent que la distribution des longueurs peut évoluer au cours de la croissance du réseau, et correspondre à une distribution exponentielle, lognormale ou en loi de puissance (Darcel, 2002). Ceci

pourrait donc expliquer la variabilité de la loi de distribution des longueurs de fractures signalée dans la littérature (Lasm, 2000).

La loi de puissance apparaît comme un bon modèle pour représenter les distributions de longueurs d'un grand nombre de réseaux de fractures. Elle présente l'avantage de n'avoir pas de longueurs caractéristiques en dehors des limites physiques du système.

Ce résultat indique aussi que les réseaux de fractures étudiés possèdent des propriétés d'auto-similarité (Bodin et Razack, 1999; Lasm, 2000; Lasm et Razack, 2001).

D'après cette loi de puissance, la fracturation de la région de Bondoukou auraient atteint un stade de développement très avancé (de Dreuzy, 2000; Lasm, 2000; Lasm et Razack, 2001; Darcel, 2002). En effet, Pour ces auteurs, tous les réseaux de fractures naturels au terme de leur développement devraient avoir leurs longueurs de fractures distribuées suivant une loi de puissance, comme c'est le cas à Bondoukou. Des résultats analogues ont été obtenus par différents auteurs (Bodin et Razack, 1999; Lasm, 2000, de Dreuzy, 2000; Lasm et Razack, 2001; Darcel, 2002). La loi de distribution constitue donc un indicateur de stade de développement des réseaux de fractures dont le stade final correspond à une loi de puissance (Lasm, 2000). Pour les fractures de tailles inférieures à 2,23 km, il y a un problème de sous échantillonnage qui ne permet pas de rendre compte des petites fractures (Bodin et Razack, 1999; Lasm, 2000).

L'analyse géostatistique des réseaux de fractures, souligne que la fracturation étudiée se comporte comme une variable régionalisée. L'existence d'un palier au niveau du variogramme traduit un phénomène stationnaire d'ordre 2 (Razack, 1984). L'effet de pépité sur les variogrammes indique que la variable étudiée est très irrégulière. C'est un phénomène couramment rencontré dans l'analyse géostatistique des milieux fracturés (Massoud, 1988; Lasm *et al.*, 2004). L'effet de pépité est interprété comme l'action combinée des hétérogénéités spatiales à plus petite échelle et des incertitudes de mesures. Il est difficile sur un variogramme expérimental de séparer l'effet de pépité en microstructure de l'erreur de mesure (Massoud, 1988; Lasm, 2000). L'effet de pépité représente plus de 66 % de la dispersion totale de la variance (66,13 à 70,15 %) impliquant une forte hétérogénéité dans les données.

La multi régionalisation de la fracturation globale caractérisée par l'emboîtement des plusieurs structures témoigne de la complexité des systèmes de fractures de la région de Bondoukou. Le variogramme de la famille de fractures NW-SE est mieux structurée que celui de la famille NE-SW. Ce résultat implique le comportement de la fracturation n'est pas identique dans les différentes directions de l'espace mettant en évidence les hétérogénéités dans les formations géologiques. Il peut être interprété en termes de contraintes géologiques au cours de la déformation. Plusieurs travaux menés dans différentes régions de la Côte d'Ivoire: Man-Danané (Lasm, 2000), Korhogo (Jourda, 2005) ont abouti à des résultats similaires.

La structuration des réseaux de fractures de Bondoukou est similaire à celle de la région de Man-Danané (ouest de la Côte d'Ivoire) comme l'attestent les travaux de Lasm (2000) et Lasm *et al.* (2004). Les régions de Bondoukou et de Man-Danané sont situées dans deux domaines géologiquement différents séparés par l'accident majeur du Sassandra, domaines Baoulé-Mossi (Protérozoïque) et archéen respectivement. La faille du Sassandra aurait joué un rôle important dans l'isolement du noyau archéen de Côte d'Ivoire vis-à-vis des contraintes tectoniques éburnéennes (Camil, 1984). Ce résultat impliquerait que ces deux régions ont subi des déformations similaires. Les analyses statistiques des réseaux de fractures de ces deux sites militent en faveur de cette hypothèse. En effet, les coefficients  $\alpha$  caractéristique de la loi de puissance valent 2,98 et 2,91 respectivement pour la fracturation de Bondoukou et de Man-Danané, et sont d'un point de vue statistique identiques.

## 6. Conclusion

Cette étude avait pour objectif une meilleure connaissance des paramètres géométriques de la fracturation dans les roches dures cristallines de la région de Bondoukou au nord-est de la Côte

d'Ivoire. Le secteur d'étude couvre une superficie de 4900 km<sup>2</sup>. Les principaux résultats de cette étude sont résumés comme suit:

1. Les longueurs de fractures s'échelonnent sur plusieurs ordres de grandeur soulignant l'hétérogénéité des formations géologiques et l'intensité de la déformation.
2. La distribution des longueurs de fractures obéit à une loi de puissance mettant en évidence le caractère auto-similaire de ces réseaux. La valeur de la pente est égal à  $\alpha = 2,98$ . Ceci n'est vrai que pour les longueurs de fractures  $\ell$  supérieures à 2,23 km. Pour les valeurs de  $\ell < 2,23$  km, l'on est confronté à un problème de sous échantillonnage.
3. La loi de puissance indique que les réseaux de fractures de la région de Bondoukou auraient atteint un stade de développement très avancé. Elle peut être utilisée comme un indicateur de stade de développement de la fracturation.
4. La fracturation globale s'identifie à une variable régionalisée. Les variogrammes présentent tous des discontinuités à l'origine traduisant l'hétérogénéité à plus petite échelle.
5. Les réseaux de fractures de Bondoukou sont caractérisés par une multi régionalisation caractérisée pas la présence de plusieurs paliers au niveau du variogramme.
6. Le comportement des familles de fractures n'est pas identique dans les différentes directions de l'espace. En effet, la famille de fractures NW-SE apparait mieux organisée que la famille de fractures NE-SW.

D'une manière générale, l'ensemble des connaissances acquises sur la fracturation de Bondoukou œuvre à une meilleure connaissance de la géométrie du système fracturé.

Dans le futur, nous envisageons aborder le problème des écoulements souterrains dans le système fracturé à travers une modélisation.

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## Comparative Chemical Composition of Lipids in Some *Jatropha* Species

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### Abstract

The chemical compositions of lipids from leaves of three species of *Jatropha* (*J. curcas*, *J. gossypifolia*, and *J. multifida* L) have been determined by gas chromatography-mass spectrometry. A total of 18 compounds representing between 72.0 and 90.9 % of the total lipid extracts were identified. *J. curcas* and *J. gossypifolia* have 2-pentenoic acid, arabitol, and glycerol as their major components. *J. multifida* has Lup-20(29)-en-3-one and betulin as its major constituent. The variations in chemical composition of the lipid extracts allow the differentiation of *J. multifida* from the other two species.

**Keywords:** *J. curcas*; *J. gossypifolia*; *J. multifida* L.; Lipids; Arabitol; Glycerol; Betulin; Chemotaxonomy

### 1.0. Introduction

The *Jatropha* genus belongs to the family of *Euphorbiaceae* and comprises about 175 succulent plants, shrub and trees. It is a native of Central America but has now become naturalized in many tropical and subtropical areas, including India, Africa and North America. A number of *Jatropha* species are of economic importance while some are extremely toxic. For example, *J. curcas* seed have been reported to contain about 40% oil which can be processed to produce high-quality biodiesel (Gubitz et. al., 1999; Pramanik, 2003). Several diterpenes and lignans have previously been reported for seed, roots and stem of different species of *Jatropha* (Das and Banerji, 1988; Das and Venkataiah, 1999; Schmeda-Hirschmann et. al. 1992; Aiyelaagbe et. al. 2007). A number of flavonoids have also been reported from leaves of *Jatropha gossypifolia* (Subramanian et. al. 1971). However, chemotaxonomic data of the lipids composition of *Jatropha* species have not been reported. This paper presents data on the lipid composition of leaves in three species of *Jatropha*.

## 2.0. Materials and Method

### 2.1. Plant material

Fresh leaves of the plants were collected from the Botanical garden of the University of Ibadan, Nigeria and authenticated at the Forest Herbarium, Ibadan (FHI). The leaves were freeze-dried and crushed to a fine powder. Prior to lipid extraction, the powdered leaves were stored in a freezer to prevent degradation by bacteria and fungi.

### 2.2. Extraction and Derivatisation

The freeze-dried samples were extensively extracted ultrasonically using dichloromethane/methanol (1:1; v/v). The lipid extract was filtered and concentrated by use of a rotary evaporator and then blow-down under nitrogen gas. Aliquots of the lipid extracts of the samples were converted to methylsilyl derivatives by reaction with N,O-bis-(methylsilyly) trifluoroacetamide (BSTFA) and pyridine for 3 hrs at 70°C.

### 2.3. Gas chromatography-Mass spectrometry (GC-MS)

Gas chromatography (GC) was carried out on a Varian CP-3800 gas chromatograph fitted with a flame ionization detector (FID) and CP Sil 5 capillary column (30 x 0.25mm), 0.25µm film thickness. Helium was used as carrier gas (1ml/min). The GC oven temperature was programmed at 60°C (hold for 2 min), heated to 315°C at 4°Cmin<sup>-1</sup>, with final hold time of 20 min.

The gas chromatography-mass spectrometry (GC-MS) analysis was carried out on a Varian CP-3800 GC with split/spiltless injector interfaced to a 1200 mass spectrometer operated at 70Ev with a mass range of m/z 50 - 650. The same temperature program as for GC was used. Compounds were identified by their retention time and comparison of mass spectra with those available in the library. The relative concentration of each compound was calculated by integration of the GC peak areas. Retention indices of the compounds were determined relative to the retention times of a series of n-alkanes under the same conditions.

## 3.0. Results and Discussion

The identified constituents of the lipid extracts for the three species, with their retention indices and percentage compositions are listed in Table 1. A total of 18 compounds were identified in the lipid extracts. 2-pentenoic acid (13.7%), arabitol (12.3%) and glycerol (12.0%) were the major components in *J. gossypifolia*. Similarly, *J. curcas* also has 2-pentenoic acid (19.7%), arabitol (9.3%) and glycerol (10.7%) as its major constituents. *J. multifida* has a total different chemical composition when compare with *J. curcas* and *J. gossypifolia*. Most of the compounds identified in *J. curcas* and *J. gossypifolia* were found to be below detectable limit in *J. multifida*. The major constituents identified in *J. multifida* were Lup-20(29)-en-3-one (37.8%) and Betulin (36.4%). These distributions distinguish *J. multifida* from the other two species. The differences in the distributions and abundance of compounds in the three species studied shows how chemical composition of leaf lipids can serve as a useful taxonomic marker in *Jatropha* species.

**Table 1:** Chemical composition of the lipid extracts from leaves of *J. curcas*, *J. gossypifolia*, and *J. multifida* L

Compound Name	MW	Composition	RT	RI	Relative abundance (%)		
					<i>J. gossypifolia</i>	<i>J. curcas</i>	<i>J. multifida</i>
Propanoic acid	74	C <sub>3</sub> H <sub>6</sub> O <sub>2</sub>	9.291		0.9	1.0	n.d
Glycerol	92	C <sub>3</sub> H <sub>8</sub> O <sub>3</sub>	16.552	1266	12.0	10.7	n.d
2-pentenoic acid	100	C <sub>5</sub> H <sub>8</sub> O	19.928	1470	13.7	19.7	n.d
Arabitol	252	C <sub>5</sub> H <sub>12</sub> O <sub>5</sub>	29.761	1704	12.3	9.3	n.d
3,7,11,15-tetramethyl-2-hexadecen-1-ol	296	C <sub>20</sub> H <sub>40</sub>	32.886	1823	2.0	1.4	n.d
D-Xylofuranose	140	C <sub>5</sub> H <sub>10</sub> O <sub>5</sub>	31.938	1886	n.d	1.7	n.d
D- Mannitol	102	C <sub>6</sub> H <sub>14</sub> O	34.898	2004	0.7	1.3	n.d
Hexadecanoic acid	256	C <sub>16</sub> H <sub>32</sub> O <sub>2</sub>	37.993	2135	7.8	6.6	n.d
Inositol	180	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	38.555	2160	n.d	n.d	n.d
Oleic acid	282	C <sub>18</sub> H <sub>34</sub> O <sub>2</sub>	41.641	2299	6.3	1.3	n.d
Octadecanoic acid	284	C <sub>18</sub> H <sub>36</sub> O <sub>2</sub>	42.276	2328	2.7	4.7	n.d
Octacosane	394	C <sub>28</sub> H <sub>58</sub>	57.744	3160	n.d	n.d	5.4
Octacosanol	410	C <sub>28</sub> H <sub>58</sub> O	58.346	3215	2.3	1.7	0.8
Stigmasterol	412	C <sub>29</sub> H <sub>48</sub> O	59.993	3325	2.5	1.9	2.8
α- Sitosterol	414	C <sub>29</sub> H <sub>50</sub> O	60.896	3386	8.8	6.6	5.6
α- Amyrin	426	C <sub>30</sub> H <sub>50</sub> O	61.148	3403	n.d	n.d	2.1
Lup-20(29)-en-3-one	424	C <sub>30</sub> H <sub>48</sub> O	61.526	3430	n.d	n.d	37.8
Betulin	442	C <sub>30</sub> H <sub>50</sub> O <sub>2</sub>	61.995	3462	n.d	n.d	36.4
<b>Total identified</b>					<b>72.0</b>	<b>67.9</b>	<b>90.9</b>

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# Visualization of Constrained Data by Rational Cubics

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## Abstract

A  $C^1$  piecewise rational cubic function in its most generalized form has been used to visualize constrained data in the view of constrained curves. The rational cubic function is then extended to rational bicubic function. Data dependent sufficient conditions are developed on shape parameters in the description of rational bicubic function to preserve the shape of constrained data arranged over rectangular grid in the view of constrained surfaces. Moreover, four other shape parameters are available at user choice to ensure pleasant visual display of data. The scheme developed is not only shape preserving and visually pleasant but computationally economical as well.

**Keywords:** Rational cubic function; Constrained data; Visualization.

## 1. Introduction

The problem of constrained visualization is a generalized case of problem of positive data visualization. This problem usually arises in the comparative study of data. Constrained surfaces can be of the form

$$Z(x, y) = a_n x^n + a_{n-1} x^{n-1} + b_n y^n + b_{n-1} y^{n-1} + c_n x^{n-1} y + \dots + c_0 x y^{n-1} + e,$$

where  $n$  is a nonnegative integer. These constrained surfaces can be either upper or lower bounds of the data. In this paper the constraint  $Z(x, y)$  is considered as lower bound for  $n = 1$ .

Many authors have discussed the problem of visualization of positive data [1-20], but only few have focused on constrained data visualization. A brief review is: Asim and Brodlie [1] discussed the problem of positivity. They used piecewise cubic Hermite interpolant to fit a curve to given values and slopes at the data points. In any interval where positivity is lost, extra knots are added to the piecewise cubic interpolant in such a way that results in a visually satisfactory curve. Finally the problem was extended to allow a curve to be drawn between two other curves. Brodlie, Mashwama and Butt [3] addressed the problem of interpolation subject to simple linear constraints. They constructed a piecewise bicubic function  $f(x, y)$  from data on a rectangular mesh, such that  $f(x, y)$  is positive.

Sufficient conditions for positivity are derived in terms of the first partial derivatives and mixed partial derivatives at the grid points. These conditions form the basis of a positive interpolation algorithm. The problem of positivity is generalized to the case of linearly constrained interpolation, where it is required that  $f(x, y)$  lie between bounds which are linear functions of  $x$  and  $y$ . Brodlie, Asim and Unsworth [4] proposed the method of visualizing constrained data. They modified the quadratic Shepard method, which interpolates scattered data of any dimensionality to preserve positivity. They forced quadratic basis functions to be positive. They extended the method to handle other types of constraints including lower bound zero and upper bound 1 as occurs for functional data. They further extended the method for general range restrictions, creating an interpolant that lies between any two specified functions as the lower and upper bound. Chan and Ong [5] described a local scheme for scattered data range restricted  $C^1$  interpolation. The interpolating surface is piecewise convex combination of three cubic Bézier patches. As the coefficients of the convex combination involve rational functions, thus the interpolant is piecewise rational patch. Sufficient conditions for the non-negativity of cubic Bézier triangle are derived and these conditions prescribed lower bounds to Bézier ordinates. Non-negativity is achieved by modifying if necessary the first order partial derivatives of data sites and some Bézier ordinates. Piah, Goodman and Unsworth [10] constructed the interpolating surfaces comprising cubic Bézier triangular patches. They imposed sufficient conditions on the ordinates of the Bézier control net in each triangle to generate preservation of positivity. The derivatives at the data points are specified to be consistent with these conditions.

The organization of paper has been made in the following way: In Section 2 piecewise  $C^1$  rational cubic function [11] used in this paper is rewritten In Section 3 problem of visualization of 2D constrained data has been considered. In Section 4 rational cubic is extended to the rational bicubic function. In Section 5 a scheme is developed to visualize 3D constrained data. The results developed in Section 3 and 5 are verified through numerical examples in Section 6. Finally, Section 7 concludes the paper.

## 2. Rational Cubic Function

In this section, we introduce the piecewise rational cubic function used in this paper which was initially developed by Sarfraz in [11]. Let  $(x_i, f_i)$ ,  $i = 0, 1, 2, \dots, n$ , be a given set of data points where  $x_0 < x_1 < x_2 < \dots < x_n$ . Let

$$h_i = x_{i+1} - x_i, \Delta_i = \frac{f_{i+1} - f_i}{h_i}. \quad (1)$$

In each interval  $I_i = [x_i, x_{i+1}]$ , a rational function  $S_i(x)$  in cubic form may be defined as:

$$S_i(x) = \frac{p_i(\theta)}{q_i(\theta)}, \quad (2)$$

with

$$\begin{aligned} p_i(\theta) &= r_i f_i (1-\theta)^3 + (u_i f_i + h_i r_i d_i)(1-\theta)^2 \theta + (v_i f_{i+1} - h_i w_i d_{i+1})(1-\theta) \theta^2 + w_i f_{i+1} \theta^3, \\ q_i(\theta) &= r_i (1-\theta)^3 + u_i (1-\theta)^2 \theta + v_i (1-\theta) \theta^2 + w_i \theta^3, \end{aligned}$$

where

$$\theta = \frac{x - x_i}{h_i}. \quad (3)$$

The rational cubic function (2) has the following properties:

$$\left. \begin{aligned} S(x_i) &= f_i, \quad S(x_{i+1}) = f_{i+1}, \\ S^{(1)}(x_i) &= d_i, \quad S^{(1)}(x_{i+1}) = d_{i+1}. \end{aligned} \right\} \quad (4)$$

Here  $S^{(1)}$  denotes derivative with respect to  $x$  and  $d_i$  denotes derivative values (given or estimated by some method) at the knots  $x_i$ .  $S(x) \in C^1[x_0, x_n]$  has freedom of  $r_i, u_i, v_i, w_i$  as parameters in the interval  $[x_i, x_{i+1}]$ .

It can be noted that in each interval  $I_i$ , when we take  $r_i = w_i = 1$  and  $u_i = v_i = 3$ , the piecewise rational cubic function reduces to standard cubic Hermite. The case of  $r_i = w_i = 1$  and  $u_i = v_i$  provides the special case of rational cubic of [12].

### 3. Visualization of 2D Constrained Data

In Butt and Brodlie [2], the positivity problem is extended to a more general case. They consider, positivity as an interpolant lying above the straight line  $f=0$  and then determine an interpolant which lies above any straight line  $f=mx+c$  provided given data also lies above this straight line, i.e.,

$$f_i = mx_i + c \text{ for all } i = 0, 1, \dots, n.$$

We require

$$S_i(x) = \frac{p_i(\theta)}{q_i(\theta)} > mx + c, \quad \forall x \in [x_i, x_{i+1}].$$

We assume that  $m > 0$ . The case  $m < 0$  can be handled in a similar way.

In each interval  $mx + c$  can be expressed as

$$a_i(1-\theta) + b_i\theta,$$

where

$$a_i = mx_i + c,$$

$$b_i = mx_{i+1} + c.$$

We thus require

$$S_i(x) = \frac{p_i(\theta)}{q_i(\theta)} > a_i(1-\theta) + b_i\theta, \quad i = 0, 1, \dots, n-1.$$

As  $q_i(\theta) > 0$  for all  $r_i, u_i, v_i, w_i > 0$ , we require:

$$U_i(x) = p_i(\theta) - \{a_i(1-\theta) + b_i\theta\} q_i(\theta) > 0,$$

where  $U_i(x)$  is a polynomial of degree 4.

It can be expressed as:

$$U_i(x) = \lambda_i\theta^4 + \mu_i\theta^3(1-\theta) + \nu_i\theta^2(1-\theta)^2 + \sigma_i\theta(1-\theta)^3 + \chi_i(1-\theta)^4,$$

where

$$\lambda_i = w_i(f_{i+1} - b_i),$$

$$\mu_i = v_i(f_{i+1} - b_i) + w_i(f_{i+1} - a_i) - h_i w_i d_{i+1},$$

$$\nu_i = v_i(f_{i+1} - a_i) + u_i(f_i - b_i) - h_i(r_i d_i - w_i d_{i+1}),$$

$$\sigma_i = u_i(f_i - a_i) + r_i(f_i - b_i) + h_i r_i d_i,$$

$$\chi_i = r_i(f_i - a_i).$$

As  $\lambda_i > 0, \chi_i > 0$ , so  $U_i(x) > 0$  if and only if  $\mu_i > 0, \nu_i > 0$  and  $\sigma_i > 0$ . We so obtain:

$$u_i > \text{Max} \left\{ 0, \frac{-h_i r_i d_i - r_i(f_i - b_i)}{f_i - a_i} \right\}, \quad (5)$$

$$v_i > \text{Max} \left\{ 0, \frac{h_i w_i d_{i+1} - w_i(f_{i+1} - a_i)}{f_{i+1} - b_i}, \frac{h_i(r_i d_i - w_i d_{i+1}) - u_i(f_i - b_i)}{f_{i+1} - a_i} \right\}. \quad (6)$$

**Theorem 3.1.**

The rational cubic (2) lies above the given straight line if and only if  $u_i$  and  $v_i$  satisfy (5) and (6) respectively.

Once again, we note that both  $r_i$  and  $w_i$  are free parameters and thus can be used for the further improvement of the default curve.

**4. Bivariate Description**

The rational cubic function (2) is extended to the rational bicubic function defined over a rectangular mesh  $D = [x_0, x_m] \times [y_0, y_n]$ . Let  $\pi : a = x_0 < x_1 < \dots < x_m = b$  be a partition of  $[a, b]$  and let  $\hat{\pi} : c = y_0 < y_1 < \dots < y_n = d$  be a partition of  $[c, d]$ . Rational bicubic function is defined over each rectangular patch  $[x_i, x_{i+1}] \times [y_j, y_{j+1}]$ ,  $i = 0, 1, \dots, m-1$ ;  $j = 0, 1, \dots, n-1$  as follows:

$$S(x, y) = S_{i,j}(x, y) = A_i(\theta)F(i, j)\hat{A}_j^T(\phi), \quad (7)$$

where

$$\theta = \frac{x - x_i}{h_i}, \quad \phi = \frac{y - y_j}{\hat{h}_j},$$

$$F(i, j) = \begin{bmatrix} F_{i,j} & F_{i,j+1} & F_{i,j}^y & F_{i,j+1}^y \\ F_{i+1,j} & F_{i+1,j+1} & F_{i+1,j}^y & F_{i+1,j+1}^y \\ F_{i,j}^x & F_{i,j+1}^x & F_{i,j}^{xy} & F_{i,j+1}^{xy} \\ F_{i+1,j}^x & F_{i+1,j+1}^x & F_{i+1,j}^{xy} & F_{i+1,j+1}^{xy} \end{bmatrix}, \quad (8)$$

$$A_i(\theta) = [a_0(\theta) \quad a_1(\theta) \quad a_2(\theta) \quad a_3(\theta)], \quad (9)$$

$$\hat{A}_j(\phi) = [\hat{a}_0(\phi) \quad \hat{a}_1(\phi) \quad \hat{a}_2(\phi) \quad \hat{a}_3(\phi)], \quad (10)$$

and

$$a_0 = \frac{r_{i,j}(1-\theta)^3 + u_{i,j}\theta(1-\theta)^2}{q_i(\theta)}, \quad a_1 = \frac{w_{i,j}\theta^3 + v_{i,j}\theta^2(1-\theta)}{q_i(\theta)},$$

$$a_2 = \frac{h_i r_{i,j}\theta(1-\theta)^2}{q_i(\theta)}, \quad a_3 = \frac{-h_i w_{i,j}\theta^2(1-\theta)}{q_i(\theta)},$$

$$q_i(\theta) = r_{i,j}(1-\theta)^3 + u_{i,j}(1-\theta)^2\theta + v_{i,j}(1-\theta)\theta^2 + w_{i,j}\theta^3,$$

$$\hat{a}_0 = \frac{\hat{r}_{i,j}(1-\phi)^3 + \hat{u}_{i,j}\phi(1-\phi)^2}{q_j(\phi)}, \quad \hat{a}_1 = \frac{\hat{w}_{i,j}\phi^3 + \hat{v}_{i,j}\phi^2(1-\phi)}{q_j(\phi)},$$

$$\hat{a}_2 = \frac{\hat{h}_j \hat{r}_{i,j}\phi(1-\phi)^2}{q_j(\phi)}, \quad \hat{a}_3 = \frac{-\hat{h}_j \hat{w}_{i,j}\phi^2(1-\phi)}{q_j(\phi)},$$

$$q_j(\phi) = \hat{r}_{i,j}(1-\phi)^3 + \hat{u}_{i,j}(1-\phi)^2\phi + \hat{v}_{i,j}(1-\phi)\phi^2 + \hat{w}_{i,j}\phi^3.$$

$F(i, j)$  is the square matrix of order 4 with its entries as the first and mixed first partial derivatives at the four corner positions of the cubic patch.

Substituting the values of  $A$ ,  $F$  and  $\hat{A}$  in equation (7) the rational bicubic function  $S(x, y)$  can be expressed as:

$$S(x, y) = \frac{(1-\theta)^3 \alpha_{i,j} + (1-\theta)^2 \theta \beta_{i,j} + (1-\theta)\theta^2 \gamma_{i,j} + \theta^3 \delta_{i,j}}{(1-\theta)^3 r_{i,j} + (1-\theta)^2 \theta u_{i,j} + (1-\theta)\theta^2 v_{i,j} + \theta^3 w_{i,j}}, \quad (11)$$

where

$$\alpha_{i,j} = \frac{\left[ (1-\phi)^3 r_{i,j} \hat{r}_{i,j} F_{i,j} + (1-\phi)^2 \phi r_{i,j} (\hat{u}_{i,j} F_{i,j} + \hat{h}_j \hat{r}_{i,j} F_{i,j}^y) + (1-\phi) \phi^2 r_{i,j} (\hat{v}_{i,j} F_{i,j+1} - \hat{h}_j \hat{w}_{i,j} F_{i,j+1}^y) + \phi^3 r_{i,j} \hat{w}_{i,j} F_{i,j+1} \right]}{q_j(\phi)}, \quad (12)$$

$$\beta_{i,j} = \frac{\left[ (1-\phi)^3 \hat{r}_{i,j} (u_{i,j} F_{i,j} - h_j r_{i,j} F_{i,j}^x) + (1-\phi)^2 \phi \{ \hat{u}_{i,j} (u_{i,j} F_{i,j} - h_j r_{i,j} F_{i,j}^x) + \hat{h}_j \hat{r}_{i,j} (u_{i,j} F_{i,j}^y - h_j r_{i,j} F_{i,j}^{xy}) \} + (1-\phi) \phi^2 \{ \hat{v}_{i,j} (u_{i,j} F_{i,j+1} - h_j r_{i,j} F_{i,j+1}^x) - \hat{h}_j \hat{w}_{i,j} (u_{i,j} F_{i,j+1}^y - h_j r_{i,j} F_{i,j+1}^{xy}) \} + \phi^3 \hat{w}_{i,j} (u_{i,j} F_{i,j+1} - h_j r_{i,j} F_{i,j+1}^x) \right]}{q_j(\phi)}, \quad (13)$$

$$\gamma_{i,j} = \frac{\left[ (1-\phi)^3 \hat{r}_{i,j} (v_{i,j} F_{i+1,j} - h_j w_{i,j} F_{i+1,j}^x) + (1-\phi)^2 \phi \{ \hat{u}_{i,j} (v_{i,j} F_{i+1,j} - h_j w_{i,j} F_{i+1,j}^x) + \hat{h}_j \hat{r}_{i,j} (v_{i,j} F_{i+1,j}^y - h_j w_{i,j} F_{i+1,j}^{xy}) \} + (1-\phi) \phi^2 \{ \hat{v}_{i,j} (v_{i,j} F_{i+1,j+1} - h_j w_{i,j} F_{i+1,j+1}^x) - \hat{h}_j \hat{w}_{i,j} (v_{i,j} F_{i+1,j+1}^y - h_j w_{i,j} F_{i+1,j+1}^{xy}) \} + \phi^3 \hat{w}_{i,j} (v_{i,j} F_{i+1,j+1} - h_j w_{i,j} F_{i+1,j+1}^x) \right]}{q_j(\phi)}, \quad (14)$$

$$\delta_{i,j} = \frac{\left[ (1-\phi)^3 \hat{r}_{i,j} w_{i,j} F_{i+1,j} + (1-\phi)^2 \phi w_{i,j} (\hat{u}_{i,j} F_{i+1,j} + \hat{h}_j \hat{r}_{i,j} F_{i+1,j}^y) + (1-\phi) \phi^2 w_{i,j} (\hat{v}_{i,j} F_{i+1,j+1} - \hat{h}_j \hat{w}_{i,j} F_{i+1,j+1}^y) + \phi^3 \hat{w}_{i,j} w_{i,j} F_{i+1,j+1} \right]}{q_j(\phi)}. \quad (15)$$

## 5. Visualization of 3D Constrained Data

Let  $(x_i, y_j, F_{i,j})$ ,  $i = 0, 1, 2, \dots, m$ ;  $j = 0, 1, 2, \dots, n$  be given set of data points lying above the plane

$$F_{i,j} > Z_{i,j}, \quad \forall i, j, \quad (16)$$

where

$$Z = C \left[ 1 - \frac{x}{A} - \frac{y}{B} \right].$$

It is required that surface generated by the rational bicubic function (11) will lie on the same side of plane as that of data. This situation is expressed mathematically as

$$S(x, y) > C \left[ 1 - \frac{x}{A} - \frac{y}{B} \right]. \quad (17)$$

The parametric equation of plane is

$$Z = Z_{i,j} + \theta(Z_{i+1,j} - Z_{i,j}) + \phi(Z_{i,j+1} - Z_{i,j}), \quad (18)$$

where

$$Z_{i,j} = C \left[ 1 - \frac{x_i}{A} - \frac{y_j}{B} \right]. \quad (19)$$

$A, B$  and  $C$  are  $x, y$  and  $z$  intercepts respectively. Substituting the values from (11) and (18) in (17), condition (17) can be expressed as

$$\frac{(1-\theta)^3 \alpha_{i,j} + (1-\theta)^2 \theta \beta_{i,j} + (1-\theta) \theta^2 \gamma_{i,j} + \theta^3 \delta_{i,j}}{(1-\theta)^3 r_{i,j} + (1-\theta)^2 \theta u_{i,j} + (1-\theta) \theta^2 v_{i,j} + \theta^3 w_{i,j}} > Z_{i,j} + \theta(Z_{i+1,j} - Z_{i,j}) + \phi(Z_{i,j+1} - Z_{i,j}),$$

or



$$U_{i,j}(\theta, \phi) = (1-\theta)^3 \alpha_{i,j} + (1-\theta)^2 \theta \beta_{i,j} + (1-\theta) \theta^2 \gamma_{i,j} + \theta^3 \delta_{i,j} - \left\{ (1-\theta)^3 r_{i,j} + (1-\theta)^2 \theta u_{i,j} + (1-\theta) \theta^2 v_{i,j} + \theta^3 w_{i,j} \right\} \left\{ Z_{i,j} + \theta(Z_{i+1,j} - Z_{i,j}) + \phi(Z_{i,j+1} - Z_{i,j}) \right\}. \quad (20)$$

After some rearrangement above relation can be expressed as

$$U_{i,j}(\theta, \phi) = \sum_{i=0}^4 (1-\theta)^{4-i} \theta^i A_i, \quad (21)$$

where

$$A_0 = \frac{\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{0,j}}{q_j(\phi)}, \quad (22)$$

with

$$\begin{aligned} A_{0,0} &= r_{i,j} \hat{r}_{i,j} (F_{i,j} - Z_{i,j}), \\ A_{0,1} &= r_{i,j} \left\{ \hat{u}_{i,j} (F_{i,j} - Z_{i,j}) + \hat{r}_{i,j} (F_{i,j} + \hat{h}_j F_{i,j}^y - Z_{i,j+1}) \right\}, \\ A_{0,2} &= r_{i,j} \left\{ \hat{u}_{i,j} (F_{i,j} - Z_{i,j}) + \hat{v}_{i,j} (F_{i,j+1} - Z_{i,j+1}) + (\hat{u}_{i,j} - \hat{v}_{i,j}) (Z_{i,j} - Z_{i,j+1}) + \hat{h}_j \hat{r}_{i,j} F_{i,j}^y - \hat{h}_j \hat{w}_{i,j} F_{i,j+1}^y \right\}, \\ A_{0,3} &= r_{i,j} \left\{ \hat{v}_{i,j} (F_{i,j+1} - Z_{i,j+1}) + \hat{w}_{i,j} (F_{i,j+1} - \hat{h}_j F_{i,j+1}^y - Z_{i,j}) \right\}, \\ A_{0,4} &= r_{i,j} \hat{w}_{i,j} (F_{i,j+1} - Z_{i,j+1}), \\ A_1 &= \frac{\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{1,j}}{q_j(\phi)}, \quad (23) \\ A_{1,0} &= \hat{r}_{i,j} \left\{ u_{i,j} (F_{i,j} - Z_{i,j}) + r_{i,j} (F_{i,j} - Z_{i+1,j} - h_i F_{i,j}^x) \right\}, \\ A_{1,1} &= (\hat{r}_{i,j} + \hat{u}_{i,j}) \left\{ r_{i,j} F_{i,j} + u_{i,j} F_{i,j} - h_i r_{i,j} F_{i,j}^x - (u_{i,j} Z_{i,j} + r_{i,j} Z_{i+1,j}) \right\} \\ &\quad + \hat{r}_{i,j} \left\{ r_{i,j} \hat{h}_j F_{i,j}^y + \hat{h}_j (u_{i,j} F_{i,j}^y - h_i r_{i,j} F_{i,j}^{xy}) - (r_{i,j} + u_{i,j}) (Z_{i,j+1} - Z_{i,j}) \right\}, \\ A_{1,2} &= \hat{u}_{i,j} \left\{ u_{i,j} (F_{i,j} - Z_{i,j}) + r_{i,j} (F_{i,j} - Z_{i+1,j} - h_i F_{i,j}^x) \right\} + \hat{v}_{i,j} \left\{ u_{i,j} (F_{i,j+1} - Z_{i,j+1}) + r_{i,j} (F_{i,j+1} - h_i F_{i,j+1}^x - Z_{i+1,j} - Z_{i,j+1} + Z_{i,j}) \right\} \\ &\quad + (\hat{v}_{i,j} - \hat{u}_{i,j}) (r_{i,j} + u_{i,j}) (Z_{i,j+1} - Z_{i,j}) \\ &\quad + \hat{r}_{i,j} \hat{h}_j \left\{ r_{i,j} F_{i,j}^y + u_{i,j} F_{i,j}^y - h_i r_{i,j} F_{i,j}^{xy} \right\} + \hat{h}_j \hat{w}_{i,j} \left\{ -r_{i,j} F_{i,j+1}^y - u_{i,j} F_{i,j+1}^y + h_i r_{i,j} F_{i,j+1}^{xy} \right\}, \\ A_{1,3} &= (\hat{v}_{i,j} + \hat{w}_{i,j}) \left\{ r_{i,j} F_{i,j+1} + u_{i,j} F_{i,j+1} - h_i r_{i,j} F_{i,j+1}^x - (u_{i,j} Z_{i,j} + r_{i,j} Z_{i+1,j}) - (r_{i,j} + u_{i,j}) (Z_{i,j+1} - Z_{i,j}) \right\} \\ &\quad + \hat{w}_{i,j} \left\{ (r_{i,j} + u_{i,j}) (Z_{i,j+1} - Z_{i,j}) - \hat{h}_j r_{i,j} F_{i,j+1}^y - \hat{h}_j (u_{i,j} F_{i,j+1}^y - h_i r_{i,j} F_{i,j+1}^{xy}) \right\}, \\ A_{1,4} &= \hat{w}_{i,j} \left\{ u_{i,j} (F_{i,j+1} - Z_{i,j+1}) + r_{i,j} (F_{i,j+1} - h_i F_{i,j+1}^x - Z_{i+1,j} - Z_{i,j+1} + Z_{i,j}) \right\}, \\ A_2 &= \frac{\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{2,j}}{q_j(\phi)}, \quad (24) \\ A_{2,0} &= \hat{r}_{i,j} \left\{ u_{i,j} (F_{i,j} - Z_{i,j}) + v_{i,j} (F_{i+1,j} - Z_{i+1,j}) + (u_{i,j} - v_{i,j}) (Z_{i,j} - Z_{i+1,j}) - h_i r_{i,j} F_{i,j}^x - h_i w_{i,j} F_{i+1,j}^x \right\}, \end{aligned}$$

$$\begin{aligned}
A_{2,1} &= (\hat{r}_{i,j} + \hat{u}_{i,j}) \left\{ (u_{i,j} F_{i,j} - h_i r_{i,j} F_{i,j}^x) + (v_{i,j} F_{i+1,j} - h_i w_{i,j} F_{i+1,j}^x) - (v_{i,j} Z_{i,j} + u_{i,j} Z_{i+1,j}) \right\} \\
&\quad + \hat{r}_{i,j} \left\{ \hat{h}_j (u_{i,j} F_{i,j}^y - h_i r_{i,j} F_{i,j}^{xy}) + \hat{h}_j (v_{i,j} F_{i+1,j}^y - h_i w_{i,j} F_{i+1,j}^{xy}) - (v_{i,j} + u_{i,j}) (Z_{i,j+1} - Z_{i,j}) \right\}, \\
A_{2,2} &= \hat{u}_{i,j} \left\{ u_{i,j} (F_{i,j} - Z_{i,j}) + F_{i,j} - r_{i,j} Z_{i+1,j} - h_i r_{i,j} F_{i,j}^x \right\} + \hat{v}_{i,j} \left\{ u_{i,j} (F_{i,j+1} - Z_{i,j+1}) + F_{i,j+1} \right. \\
&\quad \left. - r_{i,j} (h_i F_{i,j+1}^x + Z_{i+1,j} + Z_{i,j+1} - Z_{i,j}) \right\} + (\hat{v}_{i,j} - \hat{u}_{i,j}) (v_{i,j} + u_{i,j}) (Z_{i,j+1} - Z_{i,j}) \\
&\quad + \hat{r}_{i,j} \hat{h}_j \left\{ u_{i,j} F_{i,j}^y - h_i r_{i,j} F_{i,j}^{xy} + v_{i,j} F_{i+1,j}^y - h_i w_{i,j} F_{i+1,j}^{xy} \right\} - \hat{h}_j \hat{w}_{i,j} \left\{ u_{i,j} F_{i,j+1}^y - h_i r_{i,j} F_{i,j+1}^{xy} \right. \\
&\quad \left. - v_{i,j} F_{i+1,j+1}^y + h_i w_{i,j} F_{i+1,j+1}^{xy} \right\}, \\
A_{2,3} &= (\hat{v}_{i,j} + \hat{w}_{i,j}) \left\{ (u_{i,j} F_{i,j+1} - h_i r_{i,j} F_{i,j+1}^x) + (v_{i,j} F_{i+1,j+1} - h_i w_{i,j} F_{i+1,j+1}^x) - (u_{i,j} Z_{i+1,j} + v_{i,j} Z_{i,j}) \right. \\
&\quad \left. - (v_{i,j} + u_{i,j}) (Z_{i,j+1} - Z_{i,j}) \right\} + \hat{w}_{i,j} \left\{ -\hat{h}_j (u_{i,j} F_{i,j+1}^y - h_i r_{i,j} F_{i,j+1}^{xy}) + (v_{i,j} + u_{i,j}) (Z_{i,j+1} - Z_{i,j}) \right. \\
&\quad \left. - \hat{h}_j (v_{i,j} F_{i+1,j+1}^y - h_i w_{i,j} F_{i+1,j+1}^{xy}) \right\}, \\
A_{2,4} &= \hat{w}_{i,j} \left\{ u_{i,j} (F_{i,j+1} - Z_{i,j+1}) + v_{i,j} (F_{i+1,j+1} - Z_{i+1,j} - Z_{i,j+1} + Z_{i,j}) + (u_{i,j} - v_{i,j}) (Z_{i,j} - Z_{i+1,j}) \right. \\
&\quad \left. - h_i r_{i,j} F_{i,j+1}^x - h_i w_{i,j} F_{i+1,j+1}^x \right\}, \\
A_3 &= \frac{\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{3,j}}{q_j(\phi)}, \tag{25}
\end{aligned}$$

$$\begin{aligned}
A_{3,0} &= \hat{r}_{i,j} \left\{ v_{i,j} (F_{i+1,j} - Z_{i+1,j}) + w_{i,j} (F_{i+1,j} - Z_{i,j} - h_i F_{i+1,j}^x) \right\}, \\
A_{3,1} &= (\hat{r}_{i,j} + \hat{u}_{i,j}) \left\{ w_{i,j} F_{i+1,j} + v_{i,j} F_{i+1,j} - h_i w_{i,j} F_{i+1,j}^x - (v_{i,j} Z_{i+1,j} + w_{i,j} Z_{i,j}) \right\} \\
&\quad + \hat{r}_{i,j} \left\{ w_{i,j} \hat{h}_j F_{i+1,j}^y + \hat{h}_j (v_{i,j} F_{i+1,j}^y - h_i w_{i,j} F_{i+1,j}^{xy}) - (v_{i,j} + w_{i,j}) (Z_{i,j+1} - Z_{i,j}) \right\}, \\
A_{3,2} &= \hat{u}_{i,j} \left\{ v_{i,j} (F_{i+1,j} - Z_{i+1,j}) + w_{i,j} (F_{i+1,j} + Z_{i,j} - h_i F_{i+1,j}^x) \right\} + \hat{v}_{i,j} \left\{ v_{i,j} (F_{i+1,j+1} - Z_{i,j+1} - Z_{i+1,j} \right. \\
&\quad \left. + Z_{i,j}) + w_{i,j} (F_{i+1,j+1} - h_i F_{i+1,j+1}^x - Z_{i,j+1}) \right\} + (\hat{v}_{i,j} - \hat{u}_{i,j}) (v_{i,j} + w_{i,j}) (Z_{i,j+1} - Z_{i,j}) \\
&\quad + \hat{r}_{i,j} \hat{h}_j \left\{ w_{i,j} F_{i+1,j}^y + v_{i,j} F_{i+1,j}^y - h_i w_{i,j} F_{i+1,j}^{xy} \right\} + \hat{h}_j \hat{w}_{i,j} \left\{ -w_{i,j} F_{i+1,j+1}^y - v_{i,j} F_{i+1,j+1}^y \right. \\
&\quad \left. + h_i w_{i,j} F_{i+1,j+1}^{xy} \right\}, \\
A_{3,3} &= (\hat{v}_{i,j} + \hat{w}_{i,j}) \left\{ w_{i,j} F_{i+1,j+1} + v_{i,j} F_{i+1,j+1} - h_i w_{i,j} F_{i+1,j+1}^x - (v_{i,j} Z_{i+1,j} + w_{i,j} Z_{i,j}) \right. \\
&\quad \left. - (w_{i,j} + v_{i,j}) (Z_{i,j+1} - Z_{i,j}) \right\} + \hat{w}_{i,j} \left\{ -\hat{h}_j w_{i,j} F_{i+1,j+1}^y - \hat{h}_j (v_{i,j} F_{i+1,j+1}^y - h_i w_{i,j} F_{i+1,j+1}^{xy}) \right. \\
&\quad \left. + (v_{i,j} + w_{i,j}) (Z_{i,j+1} - Z_{i,j}) \right\}, \\
A_{3,4} &= \hat{w}_{i,j} \left\{ v_{i,j} (F_{i+1,j+1} - Z_{i,j+1} - Z_{i+1,j} + Z_{i,j}) + w_{i,j} (F_{i+1,j+1} - h_i F_{i+1,j+1}^x - Z_{i,j+1}) \right\}, \\
A_4 &= \frac{\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{4,j}}{q_j(\phi)}, \tag{26}
\end{aligned}$$

$$\begin{aligned}
A_{4,0} &= w_{i,j} \hat{r}_{i,j} (F_{i+1,j} - Z_{i+1,j}), \\
A_{4,1} &= w_{i,j} \left\{ (\hat{r}_{i,j} + \hat{u}_{i,j}) (F_{i+1,j} - Z_{i+1,j}) + r_{i,j} \hat{r}_{i,j} (\hat{h}_j F_{i+1,j}^y - Z_{i,j+1} + Z_{i,j}) \right\},
\end{aligned}$$

$$A_{4,2} = w_{i,j} \left\{ \hat{u}_{i,j} (F_{i+1,j} - Z_{i+1,j}) + \hat{v}_{i,j} (F_{i,j+1} - Z_{i+1,j} - Z_{i,j+1} + Z_{i,j}) + (\hat{u}_{i,j} - \hat{v}_{i,j})(Z_{i,j} - Z_{i,j+1}) \right\} \\ + \hat{h}_j \hat{r}_{i,j} F_{i+1,j}^y - \hat{h}_j \hat{w}_{i,j} F_{i+1,j+1}^y$$

$$A_{4,3} = w_{i,j} \left\{ \hat{v}_{i,j} (F_{i+1,j+1} - Z_{i+1,j} - Z_{i,j+1} + Z_{i,j}) + \hat{w}_{i,j} (F_{i+1,j+1} - \hat{h}_j F_{i+1,j+1}^y - Z_{i+1,j}) \right\},$$

$$A_{4,4} = w_{i,j} \hat{w}_{i,j} (F_{i+1,j+1} - Z_{i+1,j} - Z_{i,j+1} + Z_{i,j}).$$

$$U_{i,j}(\theta, \phi) > 0 \text{ if}$$

$$A_i, \quad i = 0, 1, 2, 3, 4.$$

$$A_0 > 0 \text{ if}$$

$$\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{0,j} > 0 \text{ and } q_j(\phi) > 0.$$

$$q_j(\phi) > 0 \text{ if}$$

$$\hat{r}_{i,j} > 0, \hat{u}_{i,j} > 0, \hat{v}_{i,j} > 0 \text{ and } \hat{w}_{i,j} > 0. \quad (27)$$

$$\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{0,j} > 0 \text{ if}$$

$$\hat{u}_{i,j} = \hat{v}_{i,j}, \quad (28)$$

$$\hat{u}_{i,j} > \text{Max} \left\{ \frac{-\hat{h}_j \hat{r}_{i,j} F_{i,j}^y}{F_{i,j} - Z_{i,j}}, \frac{-\hat{r}_{i,j} (F_{i,j} + \hat{h}_j F_{i,j}^y - Z_{i,j+1})}{F_{i,j} - Z_{i,j}} \right\}, \quad (29)$$

$$\hat{v}_{i,j} > \text{Max} \left\{ \frac{\hat{h}_j \hat{w}_{i,j} F_{i,j}^y}{F_{i,j+1} - Z_{i,j+1}}, \frac{-\hat{w}_{i,j} (F_{i,j+1} - \hat{h}_j F_{i,j+1}^y - Z_{i,j})}{F_{i,j+1} - Z_{i,j+1}} \right\}. \quad (30)$$

$$A_1 > 0 \text{ if}$$

$$\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{1,j} > 0 \text{ and } q_j(\phi) > 0.$$

$$q_j(\phi) > 0 \text{ if}$$

$$\hat{r}_{i,j} > 0, \hat{u}_{i,j} > 0, \hat{v}_{i,j} > 0 \text{ and } \hat{w}_{i,j} > 0. \quad (31)$$

$$\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{1,j} > 0 \text{ if}$$

$$\hat{u}_{i,j} = \hat{v}_{i,j}, \quad (32)$$

$$u_{i,j} > \text{Max} \{C_i, i = 1, 2, \dots, 6\}, \quad (33)$$

where

$$C_1 = \frac{h_i r_{i,j} F_{i,j}^{xy}}{F_{i,j}^y},$$

$$C_2 = \frac{h_i r_{i,j} F_{i,j+1}^{xy}}{F_{i,j+1}^y},$$

$$C_3 = \frac{r_{i,j} (h_i F_{i,j}^x + Z_{i+1,j} - Z_{i,j})}{F_{i,j} - Z_{i,j}},$$

$$C_4 = \frac{r_{i,j} (h_i F_{i,j+1}^x + Z_{i+1,j} - Z_{i,j})}{F_{i,j+1} - Z_{i,j+1}},$$

$$C_5 = \frac{r_{i,j} h_i \hat{h}_j F_{i,j}^{xy}}{\hat{h}_j F_{i,j}^y - Z_{i,j+1} + Z_{i,j}},$$

$$C_6 = \frac{-r_{i,j} h_i \hat{h}_j F_{i,j+1}^{xy}}{Z_{i,j+1} - Z_{i,j} - \hat{h}_j F_{i,j+1}^y}.$$

$$A_2 > 0 \text{ if}$$

$$\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{2,j} > 0 \text{ and } q_j(\phi) > 0.$$

$$q_j(\phi) > 0 \text{ if}$$

$$\hat{r}_{i,j} > 0, \hat{u}_{i,j} > 0, \hat{v}_{i,j} > 0 \text{ and } \hat{w}_{i,j} > 0. \quad (34)$$

$$\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{2,j} > 0 \text{ if}$$

$$\hat{u}_{i,j} = \hat{v}_{i,j}, \quad (35)$$

$$u_{i,j} > \text{Max}\{C_i, i = 7, 8, \dots, 12\}, \quad (36)$$

$$v_{i,j} > \text{Max}\{C_i, i = 13, 14, \dots, 18\}, \quad (37)$$

where

$$C_7 = \frac{h_i r_{i,j} F_{i,j}^x}{F_{i,j} - Z_{i,j}},$$

$$C_8 = \frac{h_i r_{i,j} F_{i,j+1}^x}{F_{i,j+1} - Z_{i,j+1}},$$

$$C_9 = \frac{r_{i,j} h_i \hat{h}_j F_{i,j}^{xy}}{\hat{h}_j F_{i,j}^y - Z_{i,j+1} + Z_{i,j}},$$

$$C_{10} = \frac{-r_{i,j} h_i \hat{h}_j F_{i,j+1}^{xy}}{Z_{i,j+1} - Z_{i,j} - \hat{h}_j F_{i,j+1}^y},$$

$$C_{11} = \frac{h_i r_{i,j} F_{i,j}^{xy}}{F_{i,j}^y},$$

$$C_{12} = \frac{h_i r_{i,j} F_{i,j+1}^{xy}}{F_{i,j+1}^y},$$

$$C_{13} = \frac{h_i w_{i,j} F_{i+1,j}^x}{F_{i+1,j} - Z_{i+1,j}},$$

$$C_{14} = \frac{h_i w_{i,j} F_{i+1,j+1}^x}{F_{i+1,j+1} - Z_{i,j+1} - Z_{i+1,j} + Z_{i,j}},$$

$$C_{15} = \frac{w_{i,j} h_i \hat{h}_j F_{i+1,j}^{xy}}{\hat{h}_j F_{i+1,j}^y - Z_{i,j+1} + Z_{i,j}},$$

$$C_{16} = \frac{-w_{i,j} h_i \hat{h}_j F_{i+1,j+1}^{xy}}{Z_{i,j+1} - Z_{i,j} - \hat{h}_j F_{i+1,j+1}^y},$$

$$C_{17} = \frac{h_i w_{i,j} F_{i+1,j}^{xy}}{F_{i+1,j}^y},$$

$$C_{18} = \frac{h_i w_{i,j} F_{i+1,j+1}^{xy}}{F_{i+1,j+1}^y}.$$

$$A_3 > 0 \text{ if}$$

$$\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{3,j} > 0 \text{ and } q_j(\phi) > 0.$$

$$q_j(\phi) > 0 \text{ if}$$

$$\hat{r}_{i,j} > 0, \hat{u}_{i,j} > 0, \hat{v}_{i,j} > 0 \text{ and } \hat{w}_{i,j} > 0. \quad (38)$$

$$\sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{3,j} > 0 \text{ if}$$

$$\hat{u}_{i,j} = \hat{v}_{i,j}, \quad (39)$$

$$v_{i,j} > \text{Max}\{C_i, i = 19, 20, \dots, 24\}, \quad (40)$$

$$C_{19} = \frac{h_i w_{i,j} F_{i+1,j}^{xy}}{F_{i+1,j}^y},$$

$$C_{20} = \frac{h_i w_{i,j} F_{i+1,j+1}^{xy}}{F_{i+1,j+1}^y},$$

$$C_{21} = \frac{-w_{i,j} (-h_i F_{i+1,j}^x + F_{i+1,j} - Z_{i,j})}{F_{i+1,j} - Z_{i+1,j}},$$

$$C_{22} = \frac{-w_{i,j} (-h_i F_{i+1,j+1}^x + F_{i+1,j+1} - Z_{i,j+1})}{F_{i+1,j+1} - Z_{i,j+1} - Z_{i+1,j} + Z_{i,j}},$$

$$C_{23} = \frac{w_{i,j} h_i \hat{h}_j F_{i+1,j}^{xy}}{\hat{h}_j F_{i+1,j}^y - Z_{i,j+1} + Z_{i,j}},$$

$$C_{24} = \frac{-w_{i,j} h_i \hat{h}_j F_{i+1,j+1}^{xy}}{Z_{i,j+1} - Z_{i,j} - \hat{h}_j F_{i+1,j+1}^y}.$$

$$\begin{aligned}
& A_4 > 0 \text{ if} \\
& \sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{4,j} > 0 \text{ and } q_j(\phi) > 0. \\
& q_j(\phi) > 0 \text{ if} \\
& \hat{r}_{i,j} > 0, \hat{u}_{i,j} > 0, \hat{v}_{i,j} > 0 \text{ and } \hat{w}_{i,j} > 0.
\end{aligned} \tag{41}$$

$$\begin{aligned}
& \sum_{j=0}^4 (1-\phi)^{4-i} \phi^i A_{4,j} > 0 \text{ if} \\
& \hat{u}_{i,j} = \hat{v}_{i,j},
\end{aligned} \tag{42}$$

$$\hat{u}_{i,j} > \text{Max} \left\{ \frac{-\hat{h}_j \hat{r}_{i,j} F_{i+1,j}^y}{F_{i+1,j} - Z_{i+1,j}}, \frac{-\hat{r}_{i,j} (h_j F_{i+1,j}^y - Z_{i,j+1} + Z_{i,j})}{F_{i+1,j} - Z_{i+1,j}} \right\}, \tag{43}$$

$$\hat{v}_{i,j} > \text{Max} \left\{ \frac{\hat{h}_j \hat{w}_{i,j} F_{i+1,j+1}^y}{F_{i+1,j+1} - Z_{i,j+1} - Z_{i+1,j} + Z_{i,j}}, \frac{-\hat{w}_{i,j} (-\hat{h}_j F_{i+1,j+1}^y + F_{i+1,j+1} - Z_{i+1,j})}{F_{i+1,j+1} - Z_{i,j+1} - Z_{i+1,j} + Z_{i,j}} \right\}. \tag{44}$$

**Theorem 5.1.**

The rational bicubic function (11) generates surface that lie on the same side of the plane as that of data if free parameters  $\hat{u}_{i,j}$ ,  $\hat{v}_{i,j}$ ,  $u_{i,j}$  and  $v_{i,j}$  satisfy the following conditions:

$$\begin{aligned}
\hat{u}_{i,j} &> \text{Max} \left\{ 0, \frac{-\hat{h}_j \hat{r}_{i,j} F_{i,j}^y}{F_{i,j} - Z_{i,j}}, \frac{-\hat{h}_j \hat{r}_{i,j} F_{i+1,j}^y}{F_{i+1,j} - Z_{i+1,j}}, \frac{-\hat{r}_{i,j} (F_{i,j} + \hat{h}_j F_{i,j}^y - Z_{i,j+1})}{F_{i,j} - Z_{i,j}}, \frac{-\hat{r}_{i,j} (h_j F_{i+1,j}^y - Z_{i,j+1} + Z_{i,j})}{F_{i+1,j} - Z_{i+1,j}} \right\}. \\
\hat{v}_{i,j} &> \text{Max} \left\{ 0, \frac{\hat{h}_j \hat{w}_{i,j} F_{i,j+1}^y}{F_{i,j+1} - Z_{i,j+1}}, \frac{\hat{h}_j \hat{w}_{i,j} F_{i+1,j+1}^y}{F_{i+1,j+1} - Z_{i,j+1} - Z_{i+1,j} + Z_{i,j}}, \frac{-\hat{w}_{i,j} (F_{i,j+1} - \hat{h}_j F_{i,j+1}^y - Z_{i,j})}{F_{i,j+1} - Z_{i,j+1}}, \right. \\
&\quad \left. \frac{-\hat{w}_{i,j} (-\hat{h}_j F_{i+1,j+1}^y + F_{i+1,j+1} - Z_{i+1,j})}{F_{i+1,j+1} - Z_{i,j+1} - Z_{i+1,j} + Z_{i,j}} \right\}.
\end{aligned}$$

$$u_{i,j} > \text{Max} \{0, \text{Con}_i, i = 1, 2, \dots, 8\},$$

$$v_{i,j} > \text{Max} \{0, \text{Con}_i, i = 9, 10, \dots, 16\},$$

where

$$\text{Con}_1 = \frac{h_i r_{i,j} F_{i,j}^{xy}}{F_{i,j}^y},$$

$$\text{Con}_2 = \frac{h_i r_{i,j} F_{i,j+1}^{xy}}{F_{i,j+1}^y},$$

$$\text{Con}_3 = \frac{h_i r_{i,j} F_{i,j}^x}{F_{i,j} - Z_{i,j}},$$

$$\text{Con}_4 = \frac{h_i r_{i,j} F_{i,j+1}^x}{F_{i,j+1} - Z_{i,j+1}},$$

$$\text{Con}_5 = \frac{r_{i,j} (h_i F_{i,j}^x + Z_{i+1,j} - Z_{i,j})}{F_{i,j} - Z_{i,j}},$$

$$\text{Con}_6 = \frac{r_{i,j} (h_i F_{i,j+1}^x + Z_{i+1,j} - Z_{i,j})}{F_{i,j+1} - Z_{i,j+1}},$$

$$\text{Con}_7 = \frac{r_{i,j} h_i \hat{h}_j F_{i,j}^{xy}}{\hat{h}_j F_{i,j}^y - Z_{i,j+1} + Z_{i,j}},$$

$$\text{Con}_8 = \frac{-r_{i,j} h_i \hat{h}_j F_{i,j+1}^{xy}}{Z_{i,j+1} - Z_{i,j} - \hat{h}_j F_{i,j+1}^y},$$

$$\begin{aligned}
Con_9 &= \frac{h_i w_{i,j} F_{i+1,j}^{xy}}{F_{i+1,j}^y}, & Con_{10} &= \frac{h_i w_{i,j} F_{i+1,j+1}^{xy}}{F_{i+1,j+1}^y}, \\
Con_{11} &= \frac{-w_{i,j} (-h_i F_{i+1,j}^x + F_{i+1,j} - Z_{i,j})}{F_{i+1,j} - Z_{i+1,j}}, & Con_{12} &= \frac{-w_{i,j} (-h_i F_{i+1,j+1}^x + F_{i+1,j+1} - Z_{i,j+1})}{F_{i+1,j+1} - Z_{i,j+1} - Z_{i+1,j} + Z_{i,j}}, \\
Con_{13} &= \frac{w_{i,j} h_i \hat{h}_j F_{i+1,j}^{xy}}{\hat{h}_j F_{i+1,j}^y - Z_{i,j+1} + Z_{i,j}}, & Con_{14} &= \frac{-w_{i,j} h_i \hat{h}_j F_{i+1,j+1}^{xy}}{Z_{i,j+1} - Z_{i,j} - \hat{h}_j F_{i+1,j+1}^y}, \\
Con_{15} &= \frac{h_i w_{i,j} F_{i+1,j}^x}{F_{i+1,j} - Z_{i+1,j}}, & Con_{16} &= \frac{h_i w_{i,j} F_{i+1,j+1}^x}{F_{i+1,j+1} - Z_{i,j+1} - Z_{i+1,j} + Z_{i,j}}.
\end{aligned}$$

## 6. Numerical Applications

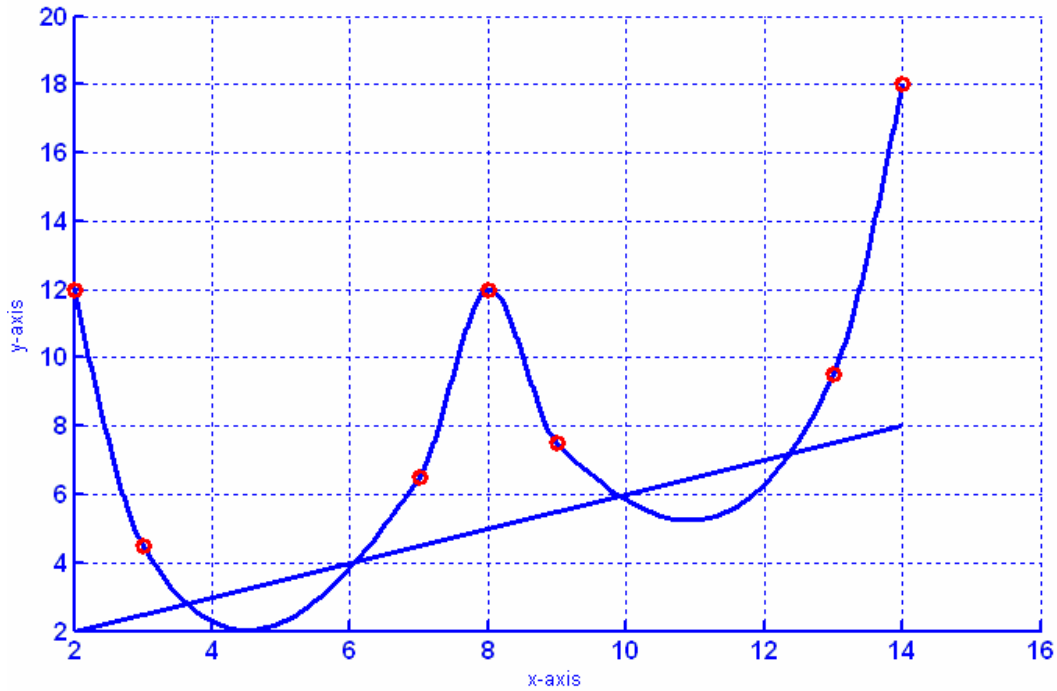
In this Section shape preserving schemes developed in Section 3 and 5 are illustrated numerically.

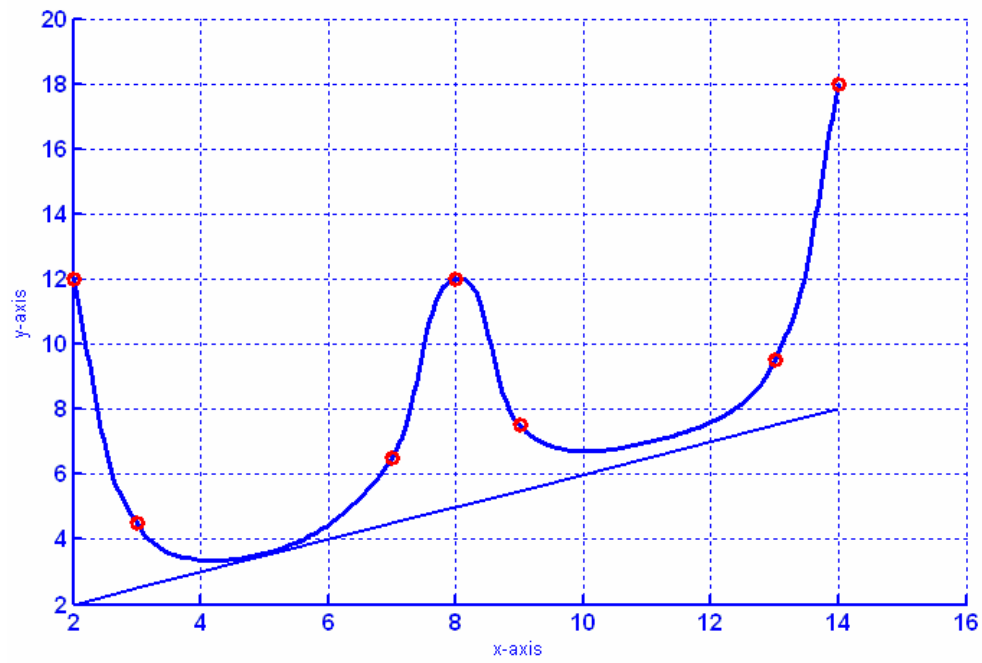
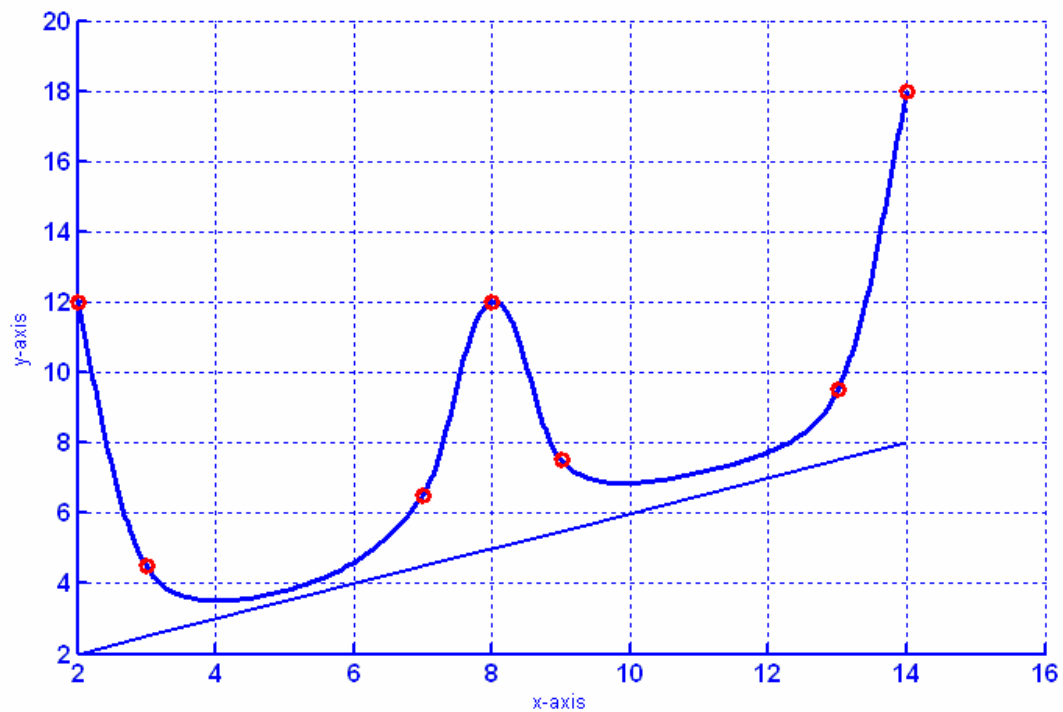
**Table 1:** The data lying above the  $y = \frac{x}{2} + 1$ .

x	2	3	7	8	9	13	14
y	12	4.5	6.5	12	7.5	9.5	18

The data set in Table 1 is lying above the line  $y = \frac{x}{2} + 1$ .

**Figure 1:** Cubic Hermite spline.



**Figure 2:** Rational cubic function with  $r_i = w_i = 0.5$ .**Figure 3:** Rational cubic function with  $r_i = w_i = 0.25$ .

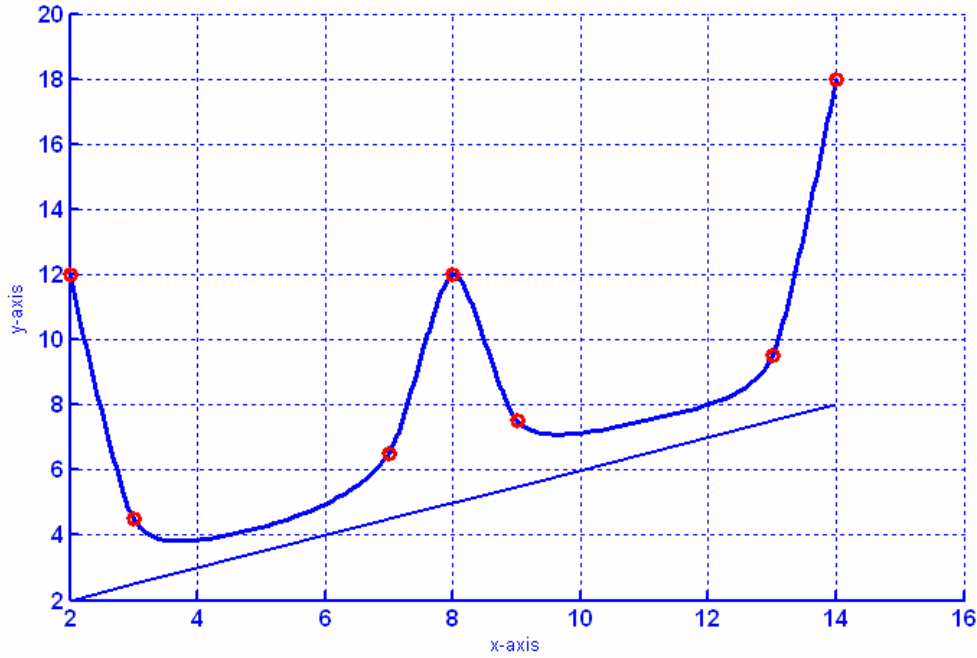
**Figure 4:** Rational cubic function with  $r_i = w_i = 0.1$ .

Fig. 1 is produced using the cubic hermite spline. The cubic hermite spline is a special case of rational cubic function for  $r_i = w_i = 1$  and  $u_i = v_i = 3$ . From the figure it is clear that curve is lying below the line which is a contradiction. Fig. 2 is produced by using the scheme developed in Section 3 with  $r_i = w_i = 0.5$ . From the figure it seems that curve is lying just on the line but when we zoom it becomes clear that curve is above the line. This flaw is recovered nicely in Fig. 3 by using the scheme developed in Section 3 and setting  $r_i = w_i = 0.25$ . In Fig. 3 not only the shape of data has been preserved but the curve is visually pleasant as well. When the value of free parameters are changed to  $r_i = w_i = 0.1$  in Fig. 4, the shape of data is preserved but the curve get tightened. Hence the optimal curve is obtained in Fig. 3.

The data set in Table 2 is generated from the following function:

$$F(x, y) = \sin(|x| + |y|) + 1.2, 1 \leq x, y \leq 6.$$

**Table 2:** Data generated from function  $F(x, y) = \sin(|x| + |y|) + 1.2, 1 \leq x, y \leq 6$  (truncated up to 4 d.p.).

y/x	1	2	3	4	5	6
1	2.1093	1.3411	0.4432	0.2411	0.9206	1.8570
2	1.3411	0.4432	0.2411	0.9206	1.8570	2.1894
3	0.4433	0.2411	0.9206	1.8570	2.1894	1.6121
4	0.2411	0.9206	1.8570	2.1894	1.6121	0.6560
5	0.9206	1.8570	2.1894	1.6121	0.6560	0.2000
6	1.8570	2.1894	1.6121	0.6560	0.2000	0.6634

This data is lying above the plane:

$$Z = \left(1 - \frac{x}{6} - \frac{y}{6}\right), 1 \leq x, y \leq 6.$$

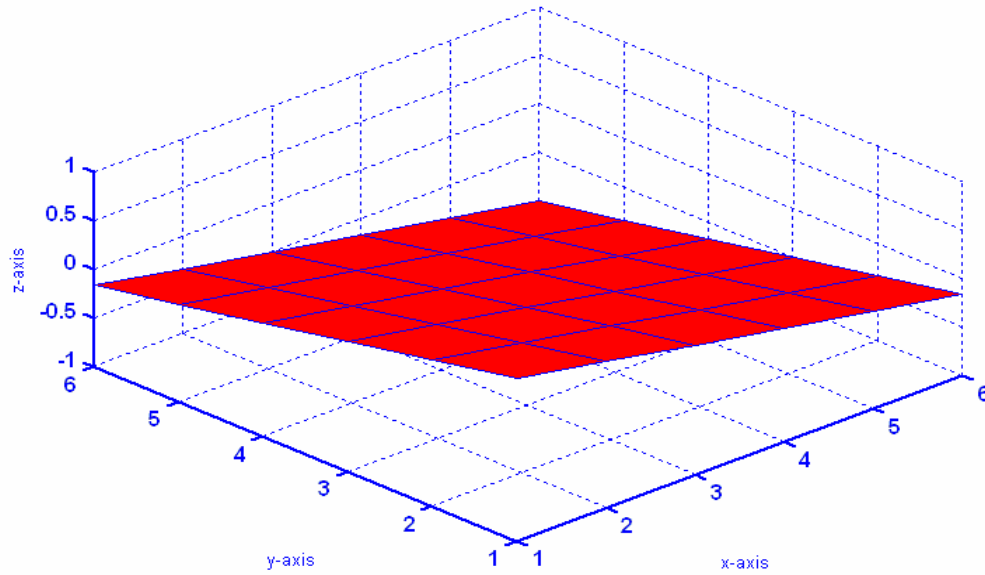
Table 3 contains the data generated by the plane  $Z$ .



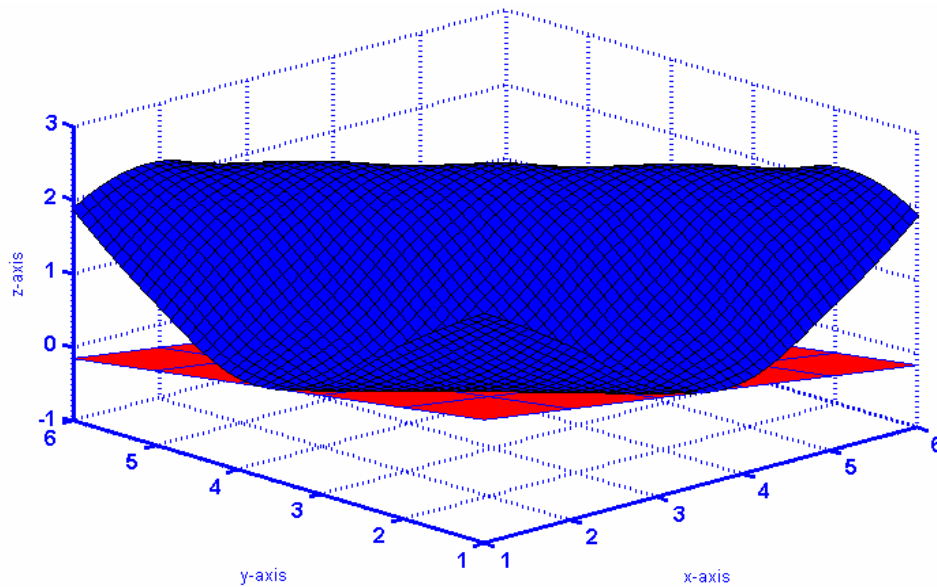
**Table 3:** Data generated from plane  $Z = \left(1 - \frac{x}{6} - \frac{y}{6}\right)$ ,  $1 \leq x, y \leq 6$ .

y/x	1	2	3	4	5	6
1	0.6667	0.5000	0.3333	0.1667	0.0000	-0.1667
2	0.5000	0.3333	0.1667	0.0000	-0.1667	-0.3333
3	0.3333	0.1667	0.0000	-0.1667	-0.3333	-0.5000
4	0.1667	0.0000	-0.1667	-0.3333	-0.5000	-0.6667
5	0.0000	-0.1667	-0.3333	-0.5000	-0.6667	-0.8333
6	-0.1667	-0.3333	-0.5000	-0.6667	-0.8333	-1.0000

**Figure 5:** Plane generated by  $Z = \left(1 - \frac{x}{6} - \frac{y}{6}\right)$ ,  $1 \leq x, y \leq 6$ .



**Figure 6:** Surface generated by bicubic function for  $r_{i,j} = w_{i,j} = \hat{r}_{i,j} = \hat{w}_{i,j} = 1$  and  $u_{i,j} = v_{i,j} = \hat{u}_{i,j} = \hat{v}_{i,j} = 3$  in Eq. 11.



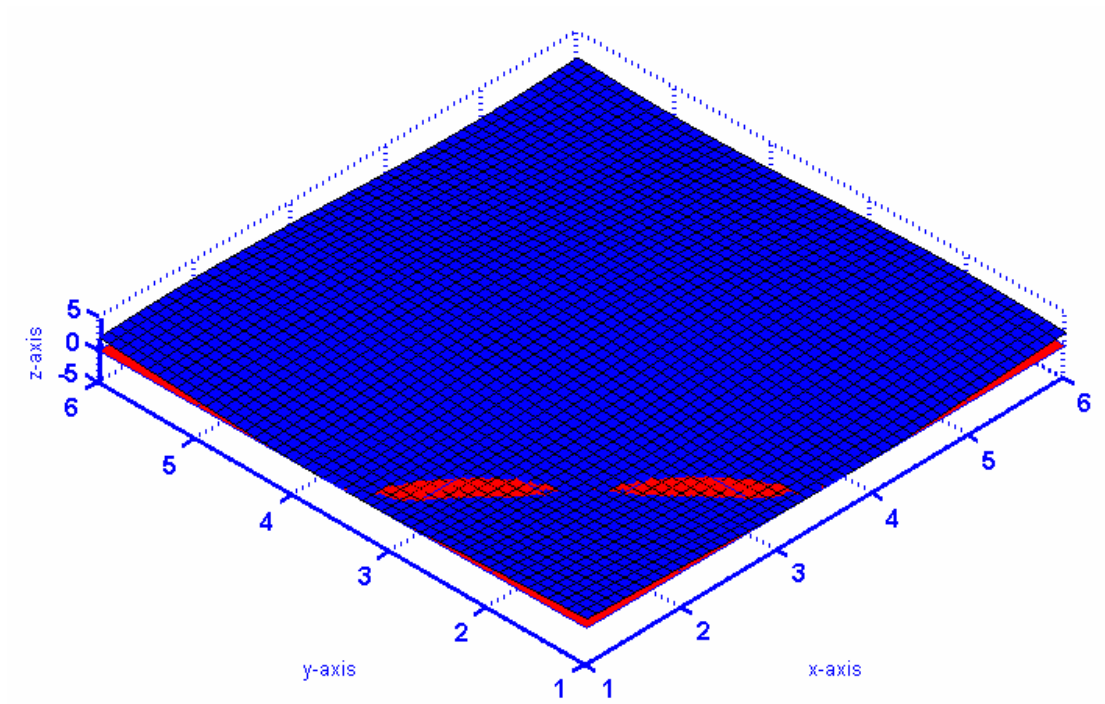
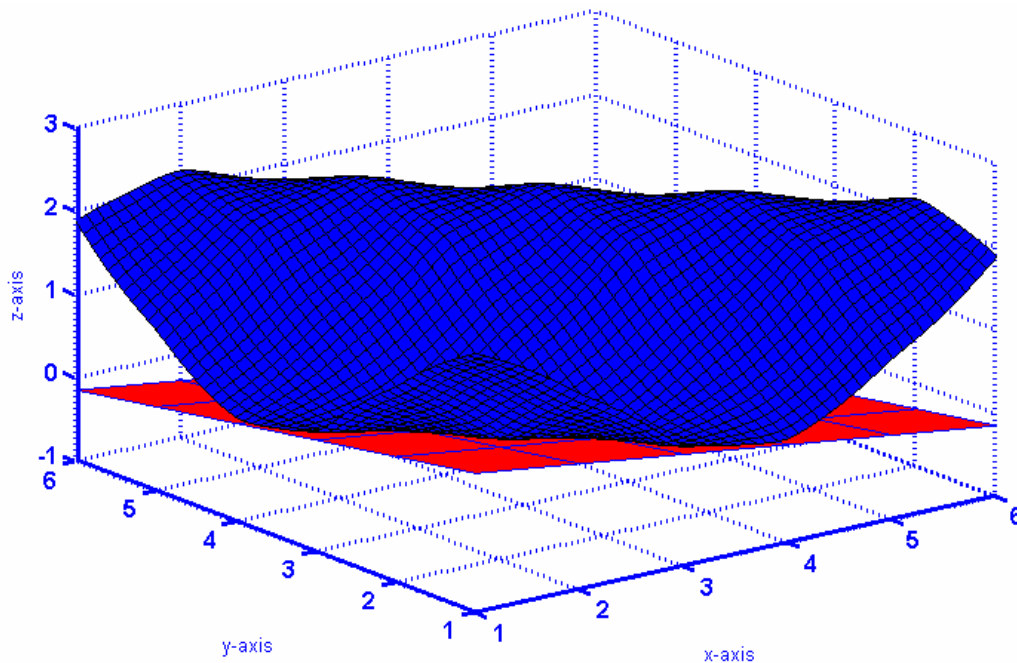
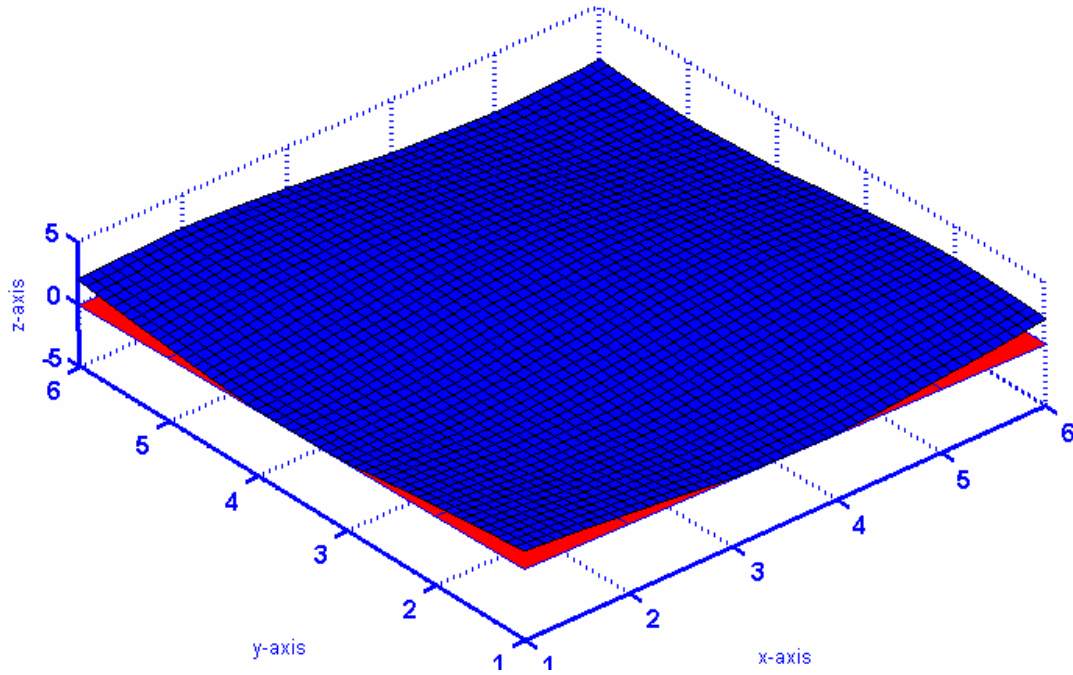
**Figure 7:** After rotation of Fig. 6.

Fig. 5 is of the plane  $Z = \left(1 - \frac{x}{6} - \frac{y}{6}\right)$ ,  $1 \leq x, y \leq 6$ . Fig. 6 is generated by bicubic function.

Bicubic function is an especial case of rational bicubic function for  $r_{i,j} = w_{i,j} = \hat{r}_{i,j} = \hat{w}_{i,j} = 1$  and  $u_{i,j} = v_{i,j} = \hat{u}_{i,j} = \hat{v}_{i,j} = 3$ . Surface is of blue colour and plane is of red. Fig. 7 is obtained after rotation of Fig. 6. Red coloured plane is beneath the surface in blue. But some part of red coloured plane is above the surface which is a contradiction as surface is lying above the plane.

**Figure 8:** Surface generated by scheme developed in Section 5 for  $r_{i,j} = w_{i,j} = \hat{r}_{i,j} = \hat{w}_{i,j} = 0.8$ .

**Figure 9:** After rotation of Fig. 8. Plane is beneath the surface.

This flaw is recovered nicely in Fig. 8 by using the scheme developed in Section 5 for  $r_{i,j} = w_{i,j} = \hat{r}_{i,j} = \hat{w}_{i,j} = 0.8$ . From the figure it is clear that surface  $F$  is lying above the plane  $Z$ . To make it more clear Fig. 8 is rotated in Fig. 9. From the figure it is clear that red coloured plane is lying below the blue coloured surface  $F$ . Hence the rational cubic function with scheme developed in Section 5 preserved the shape of data.

## 7. Conclusion

The  $C^1$  piecewise rational cubic function, in a most generalized form, has been used to visualize constrained data. This piecewise rational cubic function involves four shape parameters in each subinterval. Data dependent shape constraints are derived on two shape parameters to preserve the shape of constrained data while the other two are left at the user's freedom. Moreover, the rational cubic function is extended to rational bicubic function for the visualization of constrained data arranged over rectangular grid. This rational bicubic function involves eight shape parameters in each rectangular patch, four along each coordinate direction. The scheme has been derived by imposing some constraints upon the middle parameters in the description of rational bicubic function, where as the remaining parameters have been left free at the wish of the users. The proposed curve and surface schemes have been demonstrated through different numerical examples and visually pleasant results have been observed. Arithmetic mean choice for derivative computation has been adopted but developed schemes are independent of choice of derivatives. Moreover, arithmetic mean choice of derivatives is not the optimal choice. What is optimal choice of derivatives for shape preserving interpolation problems? It is an open question. Authors are hopeful to find its answer in future.

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