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HIGHLIGHTS

- Bath Deposited Antimony
- Incompressible Elastic
- Biotechnological Process
- Geomagnetic Indices

Aurora
above Bear Lake, Alaska

Volume 12 | Issue 2 | Version 1.0

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Optical, Structural and Morphological Studies of Chemical Bath Deposited Antimony Sulphide Thin Film

By M.D. Jeroh & D.N. Okoli
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Abstract - Thin films of antimony sulphide were successfully deposited on glass substrates by chemical bath deposition technique. Morphological studies and structural analysis were performed by scanning electron microscopy (SEM) and x-ray diffraction (XRD) respectively. Optical characterization was done using an AVASPEC - 2048 UV - VIS - NIR spectrophoto - meter in the wavelength range of 200-900nm. Optical studies reveal a direct band gap of about 1.6eV. The thickness of the film was calculated from surface profile analysis and estimated at about 0.7μm.

Keywords : Thin films, antimony sulphide, chemical bath deposition, scanning electron microscopy, x-ray diffraction, band gap, optical studies, morphological studies, structural analysis.

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OPTICAL, STRUCTURAL AND MORPHOLOGICAL STUDIES OF CHEMICAL BATH DEPOSITED ANTIMONY SULPHIDE THIN FILM

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M.D. Jeroh[α] & D.N. Okoli[σ]

Abstract - Thin films of antimony sulphide were successfully deposited on glass substrates by chemical bath deposition technique. Morphological studies and structural analysis were performed by scanning electron microscopy **(SEM)** and x-ray diffraction **(XRD)** respectively. Optical characterization was done using an **AVASPEC-2048 UV-VIS-NIR** spectrophoto - meter in the wavelength range of 200-900nm. Optical studies reveal a direct band gap of about **1.6eV**. The thickness of the film was calculated from surface profile analysis and estimated at about 0.7μm.

Keywords : Thin films, antimony sulphide, chemical bath deposition, scanning electron microscopy, x-ray diffraction, band gap, optical studies, morphological studies, structural analysis.

I. Introduction

Over the years, semiconductors have gained wide usage in fabricating electronic devices. Although, silicon-based technology is by far the most advanced amongst semiconductor technology, there has been an increasing interest in the use of compound semiconductors such as GaAs, ZnO, CdTe, etc which possesses electrical and optical properties that are absent in silicon. This fact has led to increased study of binary semiconductors in the last ten years for their possible applications in electronic and photovoltaic devices respectively. Sb_2S_3 is a binary metal chalcogenide compound which can be used as target material for television cameras and as an absorber material for photovoltaic applications such as solar cells. The properties exhibited by Sb_2S_3 makes it suitable for thin film deposition.

Several techniques such as chemical bath deposition (Asogwa, P.U., 2010, Maghraoui, H.M., et al, 2010, Srikanth, S., et al, 2011), vacuum evaporation (Tigau, N., et al, 2010, Aousgi, F. and Kanzari, M., 2011), spray pyrolysis (Srikanth, S., et al, 2010) have previously been used to deposit antimony sulphide thin films.

In this research, thin films of Sb_2S_3 were deposited on glass substrates by chemical bath deposition technique. Transmittance and reflectance measurements were obtained using an AVASPEC-2048 UV-VIS-NIR spectrophotometer in the wavelength range of 200-900nm. The structural and morphological studies of the film were done by XRD and SEM respectively. All measurements were made at room temperature.

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II. Experimental Details

a) *Materials and Methods*

All the chemicals used for the deposition process were analytical grade. They were obtained from BDH chemicals Ltd, Poole, England.

For the first time, 5ml of 1M of $SbCl_3$, 2ml of TEA, 5ml of 1M of $Na_2S_2O_3$ and 38ml of distilled water were put into a 50ml beaker in that order. Four experimental setup were made in which deposition time was varied at 12hrs, 24hrs, 36hrs and 48hrs respectively. Clean microslides were inserted vertically into each of the experimental setup and left undisturbed until the appropriate deposition time was reached. After deposition, the coated glass substrates were removed, washed well with distilled water and allowed to dry in open air for 2hrs. After drying, they were placed in an air-tight box to avoid contact with air and kept for further characterization. It is pertinent to state here that only the film deposited at 24hr dip time was used for the analysis of the result presented in this research.

III. Results And Discussions

a) *Structural Characterization*

The structural property of the Sb_2S_3 thin film was investigated by means of x-ray diffraction (XRD) using an X'PERT PRO MPD diffractometer with CuKα radiation (λ = 1.54060Å). The accelerating voltage and current were respectively 40KV and 30mA. The Sb_2S_3 thin film was scanned continuously between 0˚ and 80˚ at a step size of 0.004 and at a time per step of 3.175secs.

A typical XRD pattern for the as-deposited Sb_2S_3 thin film is shown in fig. 1. From the figure, sharp diffraction lines are not observed for the film, indicating that the Sb_2S_3 thin film deposited at room temperature has an amorphous nature. The findings presented in this research are in agreement with previous reports (Tigau, N., et al, 2010) on this material.

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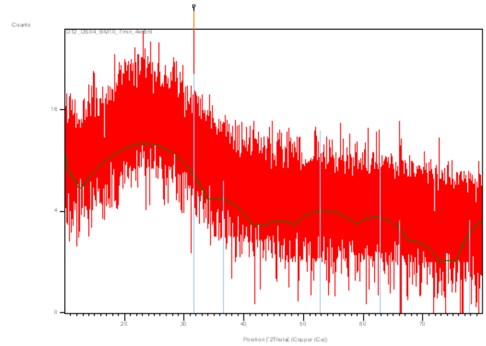

Fig. 1: Typical XRD pattern of as-deposited Sb_2S_3 thin film.

b) Morphological Studies

The surface micrograph of the film was obtained by scanning electron microscope at a magnification of 5.00KX. The surface micrograph of the as-deposited Sb_2S_3 thin film is displayed in fig. 2. The surface micrograph of the film appears to be smooth, dense and homogeneous with large spheres irregularly distributed over the surface of the film, indicating the amorphous nature of the film. This result is confirmed from XRD pattern of the grown film.

The thickness of the film was estimated to be 0.7μm from the lower part of the Data XY chart from surface profile analysis. This is shown in fig. 3.

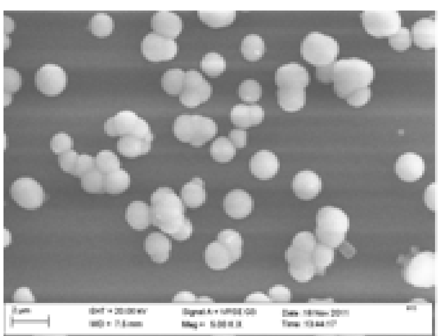

Fig. 2 : SEM micrograph of Sb_2S_3 thin film.

Fig. 3 : Surface profile analysis of the Sb_2S_3 thin film.

c) Optical Studies

The transmittance (T%) and reflectance (R%) spectra of the film were recorded on an AVASPEC-2048 UV-VIS-NIR spectrophotometer in the wavelength range of 200-900nm with an uncoated glass substrate as a reference frame.

Fig. 4 displays the spectra transmission of the Sb_2S_3 thin film deposited at room temperature. The sample show poor transmission of solar radiation which is an indication of high absorbance of solar radiation by the film. This is in agreement with the result previously reported by Ezema, F.I., et al, (2009) for as-deposited Sb_2S_3 thin film grown by chemical bath deposition technique. Fig. 4 is displayed below.

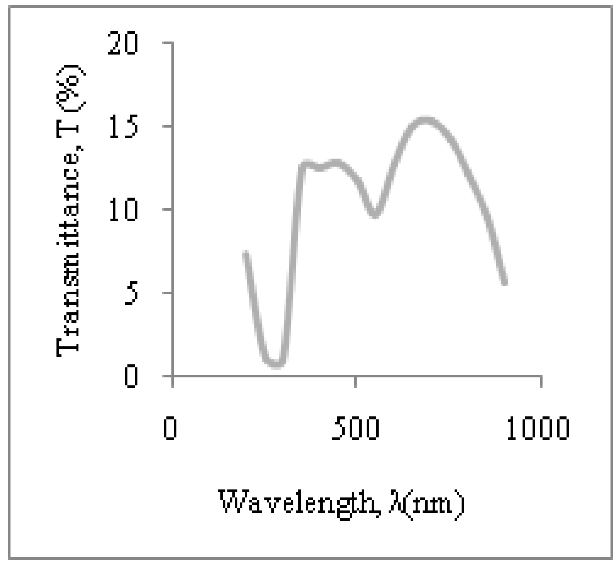

Fig. 4 : Transmittance curve for as-deposited Sb_2S_3 thin *film*

A close observation of the transmittance curve shows that the film exhibited interference pattern. This is due to optical interference which arises as a result of differences in refractive index of the thin film and glass substrate used. A similar result has been reported by Tigau, N., et al, 2010.

Fig. 5 shows the spectra reflectance of the Sb_2S_3 thin film.

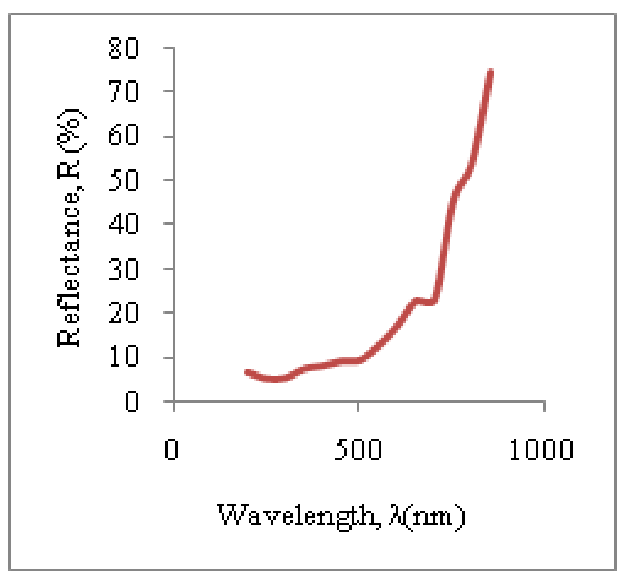

Fig. 5 : Reflectance curve of Sb_2S_3 thin film.

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From fig. 5, it is observed that the reflectance of the sample show a gradual increase as wavelength increases. The sample show high reflectance of about 74% in the IR region of the electromagnetic spectrum. The high reflectance exhibited by this material makes it useful in manufacturing highly reflectance mirrors commonly found in desktop scanners, photocopy machines, astronomical telescope, car head lamps and halogen lamps.

The absorbance of the film was calculated from transmittance and reflectance values using the expression:

$$A + T + R = 1,$$

So that, $$A = 1 - (T + R)$$

The absorbance curve for the Sb_2S_3 thin film is displayed in fig. 6. The absorbance curve decreases with increasing wavelength. The sample shows high absorbance of solar radiation above 60% in the wavelength range of 200-700nm, corresponding to the UV-VIS region of the electromagnetic spectrum with the highest absorption of about 85.8% at a wavelength of 200nm. The high absorbance exhibited by this material makes it a potential absorber in devices for photovoltaic conversion of solar energy.

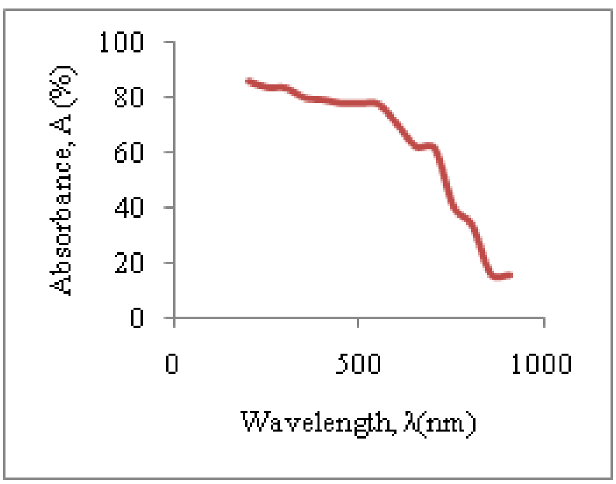

Fig. 6 : Absorbance curve for as-deposited Sb_2S_3 thin *film.*

d) Band Gap Analysis

The absorption coefficient was calculated from transmittance values using the relation:

$$\alpha = -\frac{[\ \ln T\ ]}{t}$$

where, α is absorption coefficient, T is transmittance and t is the thickness of the film.

Absorption coefficient, α, and photon energy, $h\upsilon$, are related by the expression:

$$(\alpha h\upsilon) = B(h\upsilon - E_g)^{n/2},$$

where is a constant, n is a number that characterizes the transition process and is theoretically equal to 1 and 4 for direct and indirect transitions respectively, E_g is the optical band gap of the material.

The direct band gap of the as-deposited Sb_2S_3 thin film was obtained from the plot of $(\alpha h\upsilon)^2$ versus the photon energy, $h\upsilon$ and extrapolating the linear portion of the curve to the point on the horizontal axis where $(\alpha h\upsilon)^2 = 0$ as shown in fig. 7. The direct band gap for this material was found to be about 1.6eV.

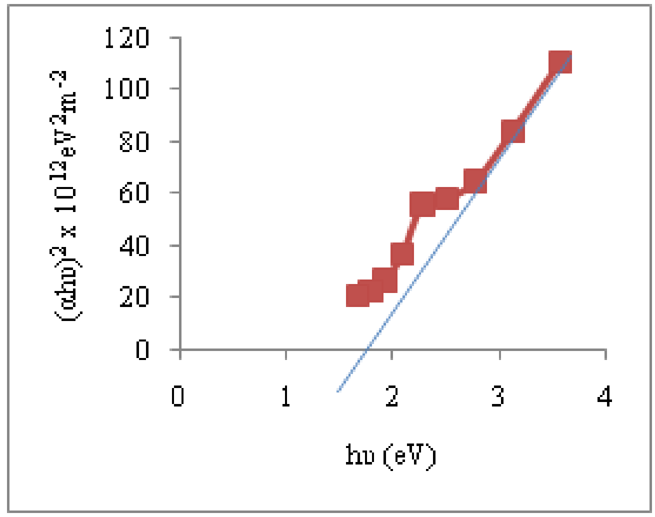

Fig. 7 : Plot of $(\alpha h\upsilon)^2$ versus $h\upsilon$ for Sb_2S_3 thin film.

Manolache, S.A., et al, (2007) previously reported that one of the requirements for an ideal absorber solar cell material is that it must have a direct band gap in the range of 0.7-2.0eV. Since the value (1.6eV) obtained in this research fall within this range (0.7eV to 2.0eV), we therefore propose a high efficiency solid state solar cell (SSSC) using antimony sulphide as an absorber material for the photovoltaic conversion of solar energy.

IV. Conclusion

Antimony sulphide thin film was successfully deposited on glass substrate at room temperature and characterized accordingly.

Optical studies conducted on the film show that the film has relatively high absorbance and reflectance, poor transmittance of solar radiation. A direct band gap of 1.6eV was obtained for the as-deposited film in this research. SEM and XRD measurements conducted on the sample confirm the amorphous nature of the Sb_2S_3 thin film grown at room temperature.

V. Acknowledgement

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Qualitative Analysis of Biotechnological Process Viscosity

By Ivan Edissonov , Elena Nikolova & Sergei Ranchev
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Abstract - A mathematical model of the lyzin biosynthesis process during periodic cultivation of Brevibacterium flavum type microbial population is proposed. A parametric identification of the model's kinetic variables is carried out. As a result the evaluation of the parameter values is obtained. On the basis of the qualitative theory of ordinary differential equations a bifurcation analysis of the microbial population behaviour is done regarding the cultural medium viscosity in the plane of kinetic variables-biomass concentration and oxygen concentration. With the fjelp of the bifurcation analysis, it can be predicted whether the dissolved oxigen concentration in the 'bioreactor is larger than the critical one and the prescription of the technology' of the microorganisms cultivation is executed strictly by the cultural medium viscosity only. It is investigated theoretically at which viscosity values the specific biotechnologi- cal process can cross from unstable to stable state.

Keywords : Lyzin biosynthesis process, viscosity, kinetic variable, cultural medium, mass-exchange parameter, parametrical identification, qualitative analysis, phase and bifurcation analysis.

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Keywords : *Lyzin biosynthesis process, viscosity, kinetic variable, cultural medium, mass-exchange parameter, parametrical identification, qualitative analysis, phase and bifurcation analysis.*

I. Introduction

In the proposed paper a specific lyzin biosynthesis process during periodical cultivation of Brevibacterium flavum type microbial population is considered. A bioreactor with a capacity of $10 m^3$ is charged with sterilized nutritive medium, that has a definite initial concentration of the substratum (sugar) and microbial culture (highly concentrated suspension of microorganisms). The biotechnological process starts (beginning of the cycle) from the moment the bioreactor is charged with the microbial culture, the volume of which is much smaller than the volume of the nutritive medium. The biotechnological process is terminated (end of the cycle) at the moment the increase of the biomass concentration stops. After the end of the cycle, the lyzin (amino acid) produced in the bioreactor and intended for the needs of stockbreeding is extracted. The periodicity of the cultivation is expressed in the recurrence of this cycle. For the specific periodical biotechnological process all the parameters (temperature, pressure, mixer's velocity of rotation, maximum quantity of the dissolved oxygen in a unit of capacity of cultural medium, velocity of oxygen aeration)are constant. The control of the biosynthesis processes ensures an optimal proportion of the substance concentrations in the bioreactor, at which the obtained metabolism product reaches to maximum value. However, in our case the observed yield and kinetics of the microorganisms cultivation can be regarded as a function only of the cultural medium viscosity, since all other parameters are constants. This fact can be explained with the help of the diffusion processes in the kinetic oxygen equation, which has the following general form [1,2]:

$$\frac{dC}{dt} = -\frac{1}{Y_{X,C}}\frac{dX}{dt} - \frac{1}{Y_{L,C}}\frac{dL}{dt} - rX + y(C_0 - C), \qquad (1)$$

where:

X – biomass concentration [g/1];

C – oxygen concentration [g/1];

L – lyzin concentration [g/1];

Y_{XC} = dX/dC – stoichiometry of the biomass to the oxygen [-];

Y_{LC} = dL/dC – stoichiometry of the lyzin to the oxygen[-];

r – parameter reflecting the vital activity of microorganisms $[s^{-1}]$;

y – mass-exchange parameter $[s^{-1}]$;

C_0 – maximum quantity of the dissolved oxigen in a unit of capacity of the cultural medium (initial oxigen concentration) [g/1].

The right hand side of equation (1) consists of four members: the first one reflects the use of oxygen for the biomass growth, the second – for the metabolism product formation (lyzin), the third – for supporting the vital activity of microorganisms, and the fourth one reflects the oxygen diffusion in the cultural medium of the bioreactor.

It is seen from (1) that the concentration of the dissolved oxygen in the cultural medium of the bioreactor can be supported as constant by changing of the mass-exchange parameter *(y)* during the different phases of the periodical cultivation only. In the general case y is dependent on the cultural medium viscosity, the mixer's velocity of rotation, and the velocity of oxygen aeration. Such a general dependence is proposed by Vasilev *et al.* [2] in the following form:

$$y = \varepsilon\omega^{\alpha}\upsilon^{\beta}\eta^{\gamma} \qquad (2)$$

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where:

ω – mixer's velocity of rotation $[tur.s^{-1}]$;
ν – velocity of oxygen aeration $[m^3.s^{-1}]$;
η – cultural medium viscosity $[mPa.s]$;
ε – constant $[(tur.m^3.mPa)^{-1}]$;
α, β, γ – constants $[–]$.

It is obviously that the control of the specific periodical biotechnological process can be carried out by changing of the mass-exchange parameter (y) only. Since in our case y is constant there is a danger the dissolved oxygen concentration during the different phases of the periodical cultivation to become less than the minimum admissible one (critical concentration – C_K). Because of that it is searched such a value of y, at which the oxygen concentration is larger than critical one during the whole cultivation period. y_k is the critical value of the mass-exchange parameter (y), when $C = C_K$. If $y > y_k$ and $C > C_K$ the oxygen consumption velocity *(dC/dt)* in the cultural medium is dependent on the biomass growth velocity only. As a result the increase of the oxygen consumption velocity is connected with the increase of the oxygen diffusion velocity from the gas phase to the liquid one, since the concentrations difference $(C_0 – C)$ becomes larger. If $y < y_k$ and $C < C_K$ the increase of the microorganisms oxygen consumption isn't connected with the increase of the oxygen diffusion velocity and is dependent on the exchange possibilities of the substratum only.

The cultural medium of the periodical biotechnological processes consists of the substances with constant composition. As a result the control of these processes can be realized by changing of C_0 or y only. In the general case the cultural medium viscosity (η) isn't constant during the different phases of the periodical cultivation, because of that its influence on the growing population behavior must be investigated. For the specific biotechnological process the values of $C_0 = 0.0061$ $[g/1]$, $\acute{\omega} = 4$ $[tur.s^{-1}]$ and $\upsilon = 0.1$ $[m^3.s^{-1}]$ are constant. In this case the mass-exchange parameter (y) is dependent on the cultural medium viscosity (η) only, and it can't be used in the control process. Thus the presented facts up to now don't guarantee $C > C_K$ during the whole cultivation period, since the viscosity isn't constant.

There exist publications in which the dynamic rheological models are proposed [3, 4]. However, in our paper by applying of the bifurcation analysis two possibilities are investigated regarding the cultural medium viscosity: (a.) it can be predicted whether the dissolved oxygen concentration (C) is larger than the critical one (C_K) at every moment of the periodical cultivation; (b.) it can be predicted whether the prescription of the technology of the microorganisms cultivation is executed strictly. As well by applying of this analysis it can be predicted theoretically, at which the viscosity values the specific biotechnological process can cross from unstable to stable state.

II. Mathematical Model

This paper uses experimental data from a specific lyzin biosynthesis process during the periodical cultivation of *Brevibacterium flavum* type microbial population. Nine_replicable experiments have been carried out under identical conditions in a bioreactor with a capacity of 10 m^3 by applying of the technology of microorganisms cultivation to implement the process of lyzin biosynthesis.

The experimental data of the biomass (X), sugar (S), oxygen (C), and lyzin (L) concentrations and the experimental data of the cultural medium viscosity (η) were obtained through laboratory analysis taking samples from the bioreactor at every four hours. These experimental data were processed by using of the fuzzy sets apparatus [5]. The smoothed experimental values for X, S, C, L and η at the different moments of time are shown in Table 1 marked with "E".

The mathematical model that takes into account the material balance of the major components of the cultural medium (biomass, sugar, oxygen, lyzin) is developed as a variant of the proposed model by Edissonov [6].

Table 1 : Obtained Experimental "E" and Theoretical "T" Values of the Biomass, Sugar, Oxygen, and Lyzin Concentrations and Experimental Values of the Cultural Medium Viscosity at the Different Moments of Time.

Time	*X[g/l]*		*S[g/l]*		*C[mg/l]*		*L[g/l]*		*η[mPa.s]*
[h]	***E***	***T***	***E***	***T***	***E***	***T***	***E***	***T***	***E***
0	3.0	3.00	120.0	120.00	6.1	6.10	0.0	0.00	28.7
4	3.4	3.40	114.7	114.61	6.0	6.01	1.7	1.71	28.8
8	3.8	3.84	108.8	108.59	5.9	5.90	3.5	3.63	28.9
12	4.3	4.34	102.2	101.90	5.8	5.77	5.6	5.76	29.0
16	4.9	4.89	95.0	94.48	5.7	5.62	7.9	8.11	29.2
20	5.5	5.49	86.8	86.31	5.5	5.46	10.4	10.69	29.4
24	6.2	6.14	78.0	77.38	5.3	5.29	13.2	13.51	29.6
28	6.9	6.85	68.3	67.72	5.1	5.12	16.3	16.56	29.8
32	7.7	7.60	58.0	57.40	5.0	4.94	19.5	19.79	30.0
36	8.5	8.39	47.0	46.58	4.8	4.76	22.8	23.18	30.2

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40	9.4	9.19	35.6	35.55	4.6	4.59	26.3	26.62	30.5
44	10.2	9.97	24.4	24.81	4.4	4.43	29.7	29.96	30.8
48	10.9	10.66	14.2	15.12	4.3	4.30	32.9	32.96	31.0
52	11.5	11.20	6.4	7.58	4.2	4.20	35.3	35.28	31.1
56	11.8	11.53	2.0	3.00	4.1	4.13	36.6	36.69	31.2
60	12.0	11.67	0.5	0.97	4.1	4.10	37.0	37.30	31.3

This model has the form:

$$\frac{dX}{dt} = \mu_m \frac{S}{K_S + S}\frac{C}{K_C + C}X,$$

$$\frac{dS}{dt} = -\frac{1}{Y_{X,S}}\frac{dX}{dt} - \frac{1}{Y_{L,S}}\frac{dL}{dt},$$

$$\frac{dC}{dt} = -\frac{1}{Y_{X,C}}\frac{dX}{dt} - \frac{1}{Y_{L,C}}\frac{dL}{dt} - rX + y(C_0 - C),$$

$$\frac{dL}{dt} = Y_{L,X}\frac{dX}{dt}, \qquad (3)$$

where: S-sugar concentration *[g/1]*;

μ_m - maximum relative velocity of the biomass growth *[s^{-1}]*;

$Y_{X,S} = dX/dS$ - stoichiometry of the biomass to the sugar *[-]*;

$Y_{L,S} = dL/dS$ - stoichiometry of the lyzin to the sugar *[-]*;

$Y_{L,X} = dL/dX$ - stoichiometry of the lyzin to the biomass *[-]*;

$K_S = k_{x,s}/k_{x,s}^D$, where $k_{x,s}^D$ is the velocity of the transformation of the biomass and sugar in biomass-sugar complex (*XS*), and $k_{x,s}$ is the velocity of the transformation of the biomass-sugar complex in biomass and sugar [7];

$K_C = k_{x,c}/k_{x,c}^D$, where $k_{x,c}^D$ is the velocity of the transformation of the biomass and oxygen in biomass-oxygen complex (*XC*), and $k_{x,c}$ is the velocity of the transformation of the biomass-oxygen complex in biomass and oxygen [7].

The meaning of the kinetic variables *X, C, L* and the parameters Y_{XC}, Y_{LC}, r, y, C_0 is explained in Section 1. It can be seen from system (3) that in our case there is a proportional relationship between the increase of the biomass concentration and the increase of the lyzin concentration, since the biotechnological process is terminated at the moment the increase of the biomass concentration stops. Otherwise equation (4) in system (3) will be of another type [8, 9]. The fact that equation (4) is linearly dependent doesn't influence on the application of the phase and bifurcation analysis. The sugar is an inhibiting factor for this biotechnological process, but the inhibiting effect occurs at some time between 52-th and 60-th hour only, when its concentration becomes less than 2.5 *[g/1]* and the biomass concentration stops to increase. However, this fact doesn't influence essentially the choice of equation (4) in model (3), since after 60-th hour the process ends.

The numeric values of the parameters in system (3) $\mu_m, K_S, K_C, Y_{X,S}, Y_{L,S}, Y_{X,C}, Y_{L,C}, r, y$ *and* $Y_{L,X}$ can be found by minimizing of the following functional:

$$J = \sum_{i=1}^{15}[(X_i^E - X_i^T)^2 + (S_i^E - S_i^T)^2 + (C_i^E - C_i^T)^2 + (L_i^E - L_i^T)^2] \qquad (4)$$

where: $F_i^E = \{X_i^E, S_i^E, C_i^E, L_i^E\}$ is a vector of the smoothed experimental values of the biomass, sugar, oxygen, and lyzin concentrations at the *i*-th moment of time (Tab. 1);

$F_i^T = \{X_i^T, S_i^T, C_i^T, L_i^T\}$ is a vector of the values of the biomass, sugar, oxygen, and lyzin concentrations at the *i*-th moment of time, obtained theoretically by solving of the system of ordinary differential equations (3).

System (3) can be solved employing the method of Runge-Kutta. The initial values of the parameters $\mu_m, K_S, K_C, Y_{X,S}, Y_{L,S}, Y_{X,C}, Y_{L,C}, r, y$ *and* $Y_{L,X}$ in System (3) can be solved employing the method of Runge-Kutta. The initial values of the parameters in system (3) are determined on the basis of data available in the specialized publications on similar biotechnological processes [9] and taking into account the specificity of the actual process of lyzin biosynthesis. If no a priori information about the initial values of the parameters is available, they are determined randomly. However, in this case the values of the model's parameters obtained by minimizing of functional (4) may be unacceptable from a physical point of view. The initial parameter values of the specific process of lyzin biosynthesis are represented in Table 2, column 1.

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Table 2 : First Column – Parameters Initial Values, Second Column – Parameter Values Obtained at the Parametric Identification

No	*1.*	*2.*
μ_m	0.05	0.1096
K_S	10.0	15.38
K_C	0.01	0.0117
$Y_{X,S}$	0.1	0.4749
$Y_{L,S}$	0.1	0.3630
$Y_{X,C}$	1000	9367.1
$Y_{L,C}$	1000	3626.2
r	0.001	0.0009
y	1.0	5.590
$Y_{L,X}$	1.0	4.301

The minimum of functional (4) can be found by using of the optimization adaptive method of random search developed by Edissonov [10]. As a result of the accomplished parametric identification such numeric parameter values of the specific process of lyzin biosynthesis are obtained, that are physically acceptable and guarantee a minimum of the chosen root-mean-square criterion (the parameter values are represented in Tab. 2, column 2). The theoretical results, marked in Table 1 with "*T*" of the biomass, sugar, oxygen, and lyzin concentrations at different moments of tme, are obtained precisely for these parameter values at which functional (4) has a minimum.

It can be seen from Table 1 that the deviation of the smoothed experimental data from the theoretically obtained results is by a negligible margin, which suggests the conclusion that nonlinear model (system 3) describes the actual biotechnological process in a sufficiently accurate way.

The phase and bifurcation analysis can be applied for autonomous systems only. The average (integral) value of the mass-exchange parameter (y = 5.590) is obtained by minimizing of the functional (4) (see Tab. 2). The average (integral) of the cultural medium viscosity $(\eta = \sum_{i=1}^{16} \eta_i = 30 mPa.s)$ is obtained by using of the experimental data in Table 1. In this way system (3) is transformed from non - autonomous to autonomous. For the specific biotechnological process

$$\omega = 4\,[tur.s^{-1}],\ \upsilon = 0.1[m^3.s^{-1}],\ \eta = 30[mPa.s]\ and\ y = 5.590[s^{-1}].$$

After substitution of these values in (2), at the condition that $\acute{\alpha}=\beta=\gamma = 1$, the equation (2) is transformed into:

$$y = F(\eta) = \varepsilon^D \eta = 0.1863\eta \qquad (5)$$

where: $\varepsilon^D = 0.1863$ is constant [$mPa^{-1}.s^{-2}$].

As a result the influence of the cultural medium viscosity ($\acute{\eta}$) the kinetics of the microorganisms cultivation can be investigated with the help of the bifurcation analysis.

III. Phase Analysis [11]

The equations (2) and (4) of system (3) are transformed in the form:

$$dS = \frac{2}{Y_{X,S}} dX \quad and \quad dL = Y_{L,X} dX \qquad (6)$$

After integrating these equations' left- and right-hand parts for S and L the following formulae are obtained:

$$S = S_0 - \frac{2}{Y_{X,S}}(X - X_0) \quad and \quad L = L_0 + Y_{L,X}(X - X_0) \qquad (7)$$

By using of (6) and (7) system (3) from four to two differential equations is transformed into:

$$Z = \mu_m \frac{S_0 - 2/Y_{X,S}(X - X_0)}{K_S + S_0 - 2/Y_{X,S}(X - X_0)} \frac{C}{K_C + C},$$

$$\frac{dX}{dt} = ZX,$$
$$\frac{dC}{dt} = -\frac{2}{Y_{X,C}} ZX - rX + y(C_0 - C) \qquad (8)$$

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The dimensionless system (8) has the following form:

$$\frac{dx}{d\tau}=\frac{s_0-\delta(x-x_0)}{1+s_0-\delta(x-x_0)}.\frac{c}{1+c}x,$$
$$\frac{dc}{d\tau}=-k\frac{s_0-\delta(x-x_0)}{1+s_0-\delta(x-x_0)}.\frac{c}{1+c}x-r^Dx+y^D(c_0-c), \quad (9)$$

where:

$$x=X/K_C,\quad s=S/K_S,\quad c=C/K_C,\quad \tau=t\mu_m,\quad x_0=X_0/K_C=256.4,$$

$$s_0=S_0/K_S=7.802,\quad c_0=C_0/K_C=0.5214,\quad r^D=r/\mu_m=0.0082,$$

$$y^D=y/\mu_m=51.0,\quad \delta=2K_C/\ Y_{X,S}/K_S=0.0032,\quad k=2/Y_{X,C}=0.0002$$

The numeric values of the parameters, obtained as a result of the parametrical identification (Tab. 2), are used for finding the numeric values of the parameters and the initial values of the variables in the dimensionless system (9). The numeric values of x_0, s_0, c_0, r^D, y^D, δ, k are substituted in system (9) and its final form is following:

$$\frac{dx}{d\tau}=\frac{8.6225-0.0032x}{9.6225-0.0032x}.\frac{c}{1+c}x,$$
$$\frac{dc}{d\tau}=(-0.0002)\frac{8.6225-0.0032x}{9.6225-0.0032x}.\frac{c}{1+c}x-0.0082x+51(0.5214-c) \quad (10)$$

The obtained final form of system (10) is autonomous and can be investigated in the plane of kinetic variables—biomass concentration and oxygen concentration qualitatively.

System (10) has three fixed points whose coordinates are:

$$1st\quad fixed\quad point \Rightarrow \phi_1=2694.5,\quad \theta_1=0.0882;$$

$$2nd\quad fixed\quad point \Rightarrow \phi_2=0,\quad \theta_2=0.5214;$$

$$3rd\quad fixed\quad point \Rightarrow \phi_3=3242.8,\quad \theta_3=0.$$

In (10) the differential equations' right-hand parts for x and c are expanded into a Taylor series in some neighbourhood of each fixed point $(\phi_i,\theta_i),\ i=1\div 3.$ Then for each i system (10) is transformed into:

$$dx/d\tau=a_i(x-\phi_i)+b_i(c-\theta_i)+R_1(x,c)=F_1(x,c),$$
$$dc/d\tau=e_i(x-\phi_i)+d_i(c-\theta_i)+R_2(x,c)=F_2(x,c). \quad (11)$$

By applying of the linearization theorem [11] for the fixed points $(\phi_i,\theta_i),\ i=1\div 3.$, the following matrices are obtained:

$$A_i=\begin{bmatrix} a_i & b_i \\ e_i & d_i \end{bmatrix}=\left.\begin{bmatrix} \frac{\partial F_1}{\partial x} & \frac{\partial F_1}{\partial c} \\ \frac{\partial F_2}{\partial x} & \frac{\partial F_2}{\partial c} \end{bmatrix}\right|_{(x,c)=(\phi_i,\theta_i),\ i=1\div 3} \quad (12)$$

By using of (12) the matrices' values A_i, of system (11) for the different fixed points are:

$$A_1=\begin{bmatrix} -0.69885 & 0 \\ -0.00806 & -51 \end{bmatrix}, A_2=\begin{bmatrix} 0.30710 & 0 \\ -0.00826 & -51 \end{bmatrix}, A_3=\begin{bmatrix} 0 & 754.9734 \\ -0.0082 & -51.151 \end{bmatrix} \quad (13)$$

The matrices A_i in (13) are transformed into the following canonical ones J_i:

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$$J_1 = \begin{bmatrix} -0.69885 & 0 \\ 0 & -51 \end{bmatrix}, J_2 = \begin{bmatrix} 0.30710 & 0 \\ 0 & -51 \end{bmatrix}, J_3 = \begin{bmatrix} -0.12130 & 0 \\ 0 & -51.030 \end{bmatrix} \quad (14)$$

by using of the characteristic polynome

$$\lambda^2 - (a_i + d_i)\lambda + a_i d_i - b_i e_i = 0, \quad i = 1 \div 3. \quad (15)$$

It is seen from (14) that the first and third fixed points generate stable nodes, and the second - a saddle in the phase plane of the kinetic variables – biomass concentration *(x)* and oxygen concentration *(c)*.

For the specific process of lyzin biosynthesis the biomass concentration (X) is changed into the limits from 3 to 12 [g/1], and the oxygen concentration (C) from 4.1 to 6.1 [mg/1]. In our case the critical oxygen concentration (C_K) is equal to 2 [mg/1]. These limits are determined depending on the technology of the microorganisms cultivation. It is seen from the phase analysis, that the obtained stable fixed points in the plane of the kinetic variables x and c aren't in the physically admissible limits. This fact is typical of the periodical biotechnological processes, since they are always found in an unstable state. Because of that by applying of the bifurcation analysis the influence of the cultural medium viscosity (η) on the kinetics of the microorganisms cultivation must be investigated.

IV. Bifurcation Analysis

In our paper y is the bifurcation parameter, since this parameter is changed depending on the cultural medium viscosity (η). It is seen from (5) that $y = F(\eta) = \varepsilon^D \eta = 0.1863\eta$. By applying of the bifurcation analysis we can determine theoretically, at which values of η the specific periodical biotechnological process can cross from unstable to stable state, and the dissolved oxygen concentration becomes larger than the critical one (C_K) during the different phases of the microorganisms cultivation.

The Routh-Hurvitz stability conditions applyed from linearized system (11) are:

$$p_i = -(a_i + d_i) > 0 \quad and \quad q_i = a_i d_i - b_i e_i > 0, \quad i = 1 \div 3. \quad (16)$$

The characteristic polynome (15) has two complex roots, if in (16) the first condition

$$p_i = -(a_i + d_i) = 0 \quad (17)$$

In this case system (11) is found of the stability limit.

By using of (17) the following values of $y^D = \lambda^*$ for each fixed point, $y = 1 \div 3$, are obtained:

$$\begin{aligned}
&1st \quad fixed \quad point - \lambda_1^* = 18.3805, \quad \lambda_2^* = -6.8128 \quad for \\
&\qquad \phi_1 = 2694.5, \quad \theta_1 = 0.5214 - 22.0949/\lambda; \\
&2nd \quad fixed \quad point - \lambda^* = (-\infty, +\infty) \quad for \quad \phi_2 = 0, \quad \theta_2 = 0.5214; \\
&3rd \quad fixed \quad point - \lambda_1^* = 0, \quad \lambda_2^* = 47.2202 \quad for \quad \phi_3 = 63.585\lambda, \quad \theta_3 = 0.
\end{aligned} \quad (18)$$

The first fixed point (18) represents special interest to us, since the other fixed points are found quite far away from the physically admissible limits in the plane of the kinetic variables x and c. By using of (5) and (18) in the following five major case the values of η and y are:

$$\begin{aligned}
&1st \quad case - if \quad \eta_k = 37.0853[mPa.s], \quad y_k = 6.9090[s^{-1}] \\
&\Rightarrow y_k^D = \lambda_k = 63.0382, \quad \phi_{1k} = 2694.5, \quad \theta_{1k} = 0.1709 \ (C = C_k = 2[mg/l]); \\
&2nd \quad case - if \quad \eta = 31.3[mPa.s], \quad y = 5.8312[s^{-1}] \quad (see \quad 60th \quad hour \quad in \quad Table \ 1) \\
&\Rightarrow y^D = \lambda = 53.2044, \quad \phi_1 = 2694.5, \quad \theta_1 = 0.1061 \ (C = 1.2[mg/l] < C_K = 2[mg/l]); \\
&3rd \quad case - if \quad \eta = 28.7[mPa.s], \quad y = 5.3468[s^{-1}] \quad (see \quad sub-zero \quad in \quad Table \ 1) \\
&\Rightarrow y^D = \lambda = 48.7827, \quad \phi_1 = 2694.5, \quad \theta_1 = 0.0685 \ (C = 0.8[mg/l] < C_K = 2[mg/l]);
\end{aligned}$$

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$$4th\ \ case-if\quad \eta_0 = 24.9297\left[mPa.s\right],\quad y_0 = 4.6444[s^{-1}]$$
$$\Rightarrow y_0^D = \lambda_0 = 42.3761,\quad \phi_{10} = 2694.5,\quad \theta_{10} = 0\ \ (C = 0\ [mg\,/\,l]);$$

$$5th\ \ case-if\quad \eta^* = 10.8132\left[mPa.s\right],\quad y^* = 2.0145[s^{-1}]$$
$$\Rightarrow y^{D*} = \lambda_1^* = 18.3805,\quad \phi_1^* = 2694.5,\quad \theta_1^* = -0.6807\ \ (C = -8.0\ [mg\,/\,l] < 0).$$

In the cases (1), (2) and (3) it is seen that $C > C_K$ when the cultural medium viscosity (η) is changed from 28.7 *[mPa.s]* to 37.0853 *[mPa.s]*. This is due to the fact that in these cases the fixed points are found quite far away from the physically admissible limits, since if x=2694.5=>X = 31.53 *[g/l]* » X = 12 *[g/1]* at the 60-th hour. In the fifth case when λ_1*=18.3805 the dissolved oxygen concentration has a negative value. This shows that for the specific biotechnological process such a value of the bifurcation parameter (y) can't be found, at which for the physically admissible concentrations of the dissolved oxygen this process is stable. Thus the biotechnological process considered in our paper will always be unstable at all the admissible values of the bifurcation parameter ($y = F(\eta)$). In the fourth case this fact is confirmed as well. As a result we can predict regarding the cultural medium viscosity only whether the prescription of the technology of the microorganisms cultivation is executed strictly. For example, if the cultural medium viscosity (η) isn't in the limits from 28.7 *[mPa.s]* to 37.0853 *[mPa.s]* and $C > C_K$, we can assert that the cultivation technology isn't executed strictly. In this situation the biotechnological process is terminated, since in the bioreactor the interrelation between the concentration' components of the cultural medium is disturbed.

V. Conclusion

The results obtained in the paper show that it can be predicted regarding the cultural medium viscosity only whether the specific biotechnological process is realized in conformity with the prescription of the cultivation technology from a microbiological point of view. Moreover, it can be predicted as well as whether the dissolved oxygen concentration in the cultural medium is larger or less than the critical one. These two facts provide a possibility the cultivation process to be terminated at the moment when the above requirements are disturbed. The prescription of the technology of the microorganisms cultivation must be executed strictly, since the biotechnological processes continue a long time, they are difficult to replicate and are very expensive. Thus the spending of surplus resources, intended for the receiving of vital important metabolism products, can be avoided by the periodical measuring of the viscosity in the cultural medium.

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Modelling of Incompressible Elastic Thin Plastic Plate

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Modelling of Incompressible Elastic Thin Plastic Plate

A. Ait Moussa[α] & M. Verid Ould M. Moulaye[σ]

Abstract - The aim of this work to study the asymptotic behavior of an elasticity problem, of containing structure, in incompressible elastic thin oscillating layer of thickness and stiffness depending of small parameter. We use the epi-convergence method to approximate the limit problem modeling.

Keywords : Limit behavior, elasticity problem, epi-convergence method, global subadditive theorem, limit problems. 1

I. Introduction

The study of the inclusion between two elastic adherents bodies involves introducing a very thin third body, filled by adhesive with an oscillating boundary, between them. In general, the computation of solution using numerical methods is very difficult. In one hind, this is because the thickness of the adhesive requires a fine mesh, which in turn implies an increase of the degrees of exible than the adherents, and this produces numerical instabilities in the stiffness matrix. To overcame this difficulties, thanks to Goland and Reissner [4] find a limit problem in which the adhesive is treated on this theoretical approach, see for example A. Ait Moussa and J. Messaho [1], A. Ait Moussa and L. Zla ji [3], Licht and Michail [2], and Acerbi, Buttazzo and Perceivable [6].

This work is specially intereted in approximating a minimization problem $(\mathbb{P}_\epsilon)$ where ϵ is a small parameter linked to the thickness and the stiffness of the adhesive. In particular, we associate to each component of gradient an independent of stiffness parameter. We use epi-convergent method introduced in a paper by De Giorgi and Franzoni in [9],to proof a weak limit of a $(\mathbb{P}_\epsilon)$- minimizing sequence with is a solution of $(\mathbb{P})$.

This paper is organized in the following way. In section 2, we express the problem to study, and we give some notation and we define functional spaces for this study in the section 3. In the section 4, we study the problem (4.0). The section 5 is reserved to the determination of the limits problems and our main result.

II. Notation and Preliminaries

we consider a structure, occupying a bonded domain $\Omega \in \mathbb{R}^3$ with Lipschitzian boundary $\partial\Omega$. It is constituted of two elastic bodies joined together by an incompressible rigid thin layer with oscillating boundary, the latter obeys to nonlinear elastic low of power type. More precisely, the stress field is related to the displacement's field by

$$\sigma^\varepsilon = \lambda\, |e(u^\varepsilon)|^{-1}\, e(u^\varepsilon), \qquad \lambda > 0.$$

The structure occupies the regular domain $\Omega = B_\varepsilon \cup \Omega_\varepsilon$, where B_ε is given by $B_\varepsilon = \{x = (x', x_3) \ / \ |x_3| < \frac{\varepsilon}{2}\}$, and $\Omega_\varepsilon = \Omega \setminus B_\varepsilon$ represent the regions occupied by the thin plate and the two elastic bodies, ε being a positive parameter intended to approach 0, and $\Sigma = \{x = (x', x_3) \ / \ |x_3| = 0\}$.

The structure is subjected to a density of forces of volume $f,\ f : \Omega \to \mathbb{R}^3$, and it is fixed on the boundary $\partial\Omega$. Equations which relate the stress field σ^ε, $\sigma^\varepsilon : \Omega \to \mathbb{R}^9_S$, and the field of displacement u^ε, $u^\varepsilon : \Omega \to \mathbb{R}^3$, are

$$\begin{cases} div(\sigma^\varepsilon) + f = 0 \text{ in } \Omega \\ \sigma^\varepsilon_{ij} = a_{ijkh} e_{kh}(u^\varepsilon) \text{ in } \Omega_\varepsilon \\ \sigma^\varepsilon = \lambda |e(u^\varepsilon)|^{-1} e(u^\varepsilon) \text{ in } B_\varepsilon \qquad (\mathbb{P}_\epsilon) \\ div(u^\varepsilon) = 0 \text{ in } B_\varepsilon \\ u^\varepsilon = 0 \text{ on } \partial\Omega \end{cases}$$

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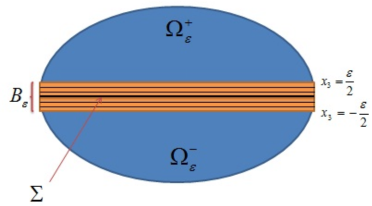
Where a_{ijkh} are the elasticity coefficients and $\mathbb{R}_S^9$ the vector space of the square symmetrical matrices of order three, $e_{ij}(u)$ are the components of the linearized tensor of deformation $e(u)$. In the sequel,we assume that the elasticity coefficients a_{ijkh} satisfy to the following hypotheses :

$$a_{ijkh} \in L^\infty(\Omega) \qquad (2.1)$$

$$a_{ijkh} = a_{jikh} = a_{khij}, \qquad (2.2)$$

$$a_{ijkh}\tau_{ij}\tau_{kh} \geq C\tau_{ij}\tau_{ij}, \ \forall\tau \in \mathbb{R}_S^9 \qquad (2.3)$$



III. Notation and Function Setting

a) Notations

We begin by introducing some notation which is used throughout the paper.

$x = (x', x_3)$, Where $x' = (x_1, x_2)$,
$\tau \otimes \zeta = (\tau_i\zeta_i)_{1\leq i,j\leq 3}$ And

$$\tau \otimes_s \zeta = \frac{\tau \otimes \zeta + \zeta \otimes \tau}{2}, \ \forall\tau,\zeta \in \mathbb{R}^3$$

In the following C will denote any constant with respect to ε, $[v]$ is the jump of displacement field v through Σ, and ν , H_2 respectively the Lebesgue Hausdorff measures. Also, we use the convention $0.(+\infty)$.

To describe a global subadditive theorem, we consider $\mathcal{B}_b(\mathbb{R}^d)$ the family of Borel bounded subsets of $\mathbb{R}^d$ and δ. Euclidean distance in $\mathbb{R}^d$, for every $A \in \mathcal{B}_b(\mathbb{R}^d)$, $\rho(A) = \sup\{r \geq 0 : \exists\overline{B}_r(x) \subset A\}$, where $\overline{B}_r(x) = \{y \in \mathbb{R}^d : \delta(x,y) \leq r\}$. A sequence $(B_n)_{n\in\mathbb{N}} \subset \mathcal{B}_b(\mathbb{R}^d)$ is called regular if there exist an increasing sequence of intervals $(I_n)_n \subset \mathbb{Z}^d$ and a constant C independent of n such that $B_n \subset I_n$ and meas $(I_n) \leq C$ meas(B_n),$\forall n$. The global subadditive theorem is essentially based on subadditive $\mathbb{Z}^d$ -invariant functions.

A function $S : A \in \mathcal{B}_b(\mathbb{R}^d) \to S_A \in \mathbb{R}$ is called subadditive $\mathbb{Z}^d$-periodic if it satisfy the following conditions:

(i) For all $A, B \in \mathcal{B}_b(\mathbb{R}^d)$ such that $A \cap B = \emptyset$, $S_{A\cup B} \leq S_A + S_B$.

(ii) For all $A \in \mathcal{B}_b(\mathbb{R}^d)$, all $z \in \mathbb{Z}^d$, $S_{A+z} = S_A$.

Now, we shall see the global subadditive theorem, firstly used in the setting of the calculus of variation by Licht and Michaille [2]

Theorem 3.1: [2; page24] Let S be a subadditive $\mathbb{Z}^d$- invariant function such that

$$\gamma(S) = \inf\{\frac{S_I}{\text{meas } I} : I = [a, b[, a, b \in \mathbb{Z}^d \ and \ a_i < b_i \forall 1 \leq i \leq d\}$$

$$\gamma(S) > -\infty$$

In addition, we suppose that S satisfies the dominant property: There exists C(S), for every Borel convex subset $A \subset [0,1[^d$, $|S_A| \leq C(S)$. Let $(A_n)_n$ be a regular sequence of Borel convex subsets of $\mathcal{B}_b(\mathbb{R}^d)$ with $\lim_{n\to+\infty} \rho(A_n) = +\infty$. Then $\lim_{n\to+\infty} \frac{S_{A_n}}{\text{meas } A_n}$ exists and is equal to

$$\lim_{n\to+\infty} \frac{S_{A_n}}{\text{meas } A_n} = \inf_{m\in\mathbb{N}^*}\{\frac{S_{[0,m[^d}}{m^d}\} = \gamma(S)$$

We have the following stability result for epiconvergence.

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Proposition 3.2 : [7; p:40] Suppose that F^{ε} epi-convergence to F in $(\mathbb{X},\tau)$ and that $G:\mathbb{X}\to\mathbb{R}\cup\{+\infty\}$, is $\tau-$ continues. Then $F^{\varepsilon}+G$ epi-converges to $F+G$ in $(\mathbb{X},\tau)$

This epi-convergence is a special case of the Γ- convergence introduced by De Giorgi (1979) [9]. It is well suited to the asymptotic analysis of sequences of minimization problems since one has the following fundamental result.

Theorem 3.3 : [7; Theorem1:10]. Suppose that

(1) F^{ε} admits a minimizer on $\mathbb{X}$;

(2) the sequence (u^{ε}) is τ relatively compact

(3) The sequence F^{ε} epi-converges to F in this topology τ. on $\mathbb{X}$

Then every cluster point u^{*} of the sequence (u^{ε}) minimizer F on $\mathbb{X}$ and $\lim\limits_{\varepsilon'\to 0} F^{\varepsilon'}(u^{\varepsilon'})=F(u^{*})$

where $(u^{\varepsilon'})_{\varepsilon'}$ denotes any subsequence of $(u^{\varepsilon})_{\varepsilon}$ which converges to u^{*}

b) Function setting

First, we introduce the space

$$V^{\varepsilon}=\left\{\begin{array}{c} u\in W_0^{1,2}(\Omega_{\varepsilon},\mathbb{R}_s^3)\times W^{1,1}(B_{\varepsilon},\mathbb{R}_s^3),\\ u=0 \text{ on } \partial\Omega \text{ and } div(u)=0 \text{ in } B_{\varepsilon}\end{array}\right\}$$

we easily show that V^{ε} is a Banach space with respect to the norm

$$u\to\|e(u)\|_{L^2(\Omega_{\varepsilon},\mathbb{R}_s^9)}+\|e(u)\|_{L^1(B_{\varepsilon},\mathbb{R}_s^9)}.$$

IV. Study of Problem

Problem $\mathbb{P}_{\varepsilon}$ is equivalent of the minimization problem

$$inf_{v\in V^{\varepsilon}}\left\{\begin{array}{c}\frac{1}{2}\int_{\Omega_{\varepsilon}} aijhke_{ij}(v)e_{hk}(v)dx+\\ +\lambda\int_{B_{\varepsilon}}|e(v)|-\int_{\Omega} fvdx\end{array}\right\}$$

To study problem $\mathbb{P}_{\varepsilon}$, we will study the minimization problem (4.0). The existence and uniqueness of solutions to (4.0) is given in the following proposition.

Proposition 4.1 : Under the hypotheses (2:1), (2:2), (2:3) and for $f\in L^{\infty}$, problem (4:0) admits an unique solution.

Proof. From (2:1) and (2:3), we show easily that the energy functional in (4:0) is weakly lower semicontinuous, strictly convex and coercive over V^{ε}, Since V^{ε} is not reexive, so we may not apply directly result given in Dacorogna [17; p:48], but we can follow our proof by using the compact imbedding to the $W^{1,1}(\Omega)$ Sobolev space, in the reflexivity space $L^{q}(\Omega)$, or $q=\frac{2}{3}$ for more information see you Adams [14; p:95].

On the other hand, let u_n be a minimizing sequence for (4:0), to simplify the writing let

$$F^{\varepsilon}(v)=\frac{1}{2}\int_{\Omega_{\varepsilon}} aijhke_{ij}(v)e_{hk}(v)dx+\lambda\int_{B_{\varepsilon}}|e(v)|$$

$$-\int_{\Omega} fvdx$$

so, we have $F^{\varepsilon}(u_n)\to\inf_{v\in V^{\varepsilon}}F(v)$. Using the coercivity of F^{ε}, we may then deduce that there exists a constant $C>0$, independent of n, such that

$$\|u_n\|_{V^{\varepsilon}}\leq C,$$

then u_n bounded in L^{q}, therefore a subsequence of u_n , still denoted by u_n , there exists $u_0\in V^{\varepsilon}$ such that $u_n\rightharpoonup u_0$ in V^{ε}. The weak lower semicontinuity and the strict convexity of F^{ε} imply then the result.

Lemma 4.2. Assuming that for any sequence $(u^{\varepsilon})_{\varepsilon}\subset V^{\varepsilon}$ there exists a constant $C>0$ such that $F^{\varepsilon}(u^{\varepsilon})\leq C$, under (2:1), (2:3) and for $f\in L^{\infty}(\Omega,\mathbb{R}^3)$, $(u^{\varepsilon})_{\varepsilon>0}$ satisfies

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$$\|e(u^\varepsilon)\|^2_{L^2(\Omega_\varepsilon,\mathbb{R}^9_s)} \le C \qquad (4.1)$$

$$\int_{B_\varepsilon} |e(u^\varepsilon)| \le C. \qquad (4.2)$$

moreover u^ε is bounded in $W_0^{1,1}(\Omega,\mathbb{R}^3)$.

Proof. Science $F^\varepsilon(u^\varepsilon) \le C$, we have

$$\frac{1}{2}\int_{\Omega_\varepsilon} a_{ijhk}e_{ij}(u^\varepsilon)e_{hk}(u^\varepsilon)dx + \lambda\int_{B_\varepsilon}|e(u^\varepsilon)| - \int_\Omega fu^\varepsilon dx \le C$$

Then, taking advantage of the fact that u^ε vanishes on $\partial\Omega$:

$$\int_\Omega fu^\varepsilon dx \le |f|_{L^\infty(\Omega)}|u^\varepsilon|_{L^1(\Omega)} \le C|e(u^\varepsilon)|_{L^1(\Omega)}.$$

by Hölder and Young the inequalities, we obtain

$$|e(u^\varepsilon)|_{L^1(\Omega)} \le C + C\|e(u^\varepsilon)\|_{L^2(\Omega_\varepsilon)} + |e(u^\varepsilon)|_{L^1(B_\varepsilon)}$$

According to (2:3) and (4:3), we have

$$\|e(u^\varepsilon)\|^2_{L^2(\Omega_\varepsilon,\mathbb{R}^9_s)} + \lambda\int_{B_\varepsilon}|e(u^\varepsilon)| \le C + C\int_\Omega fu^\varepsilon dx$$

$$\le C + C\|e(u^\varepsilon)\|_{L^2(\Omega_\varepsilon,\mathbb{R}^9_s)} + \int_{B_\varepsilon}|e(u^\varepsilon)|$$

To facilitate writing, we denote by

$X_1 = \|e(u^\varepsilon)\|_{L^2(\Omega_\varepsilon,\mathbb{R}^9_s)}$, and $X_2 = \int_{B_\varepsilon}|e(u^\varepsilon)|$ We have

$$X_1^2 + X_2 \le C(X_1 + X_2).$$

Then

$$(X_1 - \frac{C}{2})^2 + (1-C)X_2 \le \frac{C^2}{4}$$

according to the values of C,

- If $(1-C) \ge 0$: we see easily the result.
- If $(1-C) < 0$:

$$(X_1 - \frac{C}{4})^2 \le \frac{C^2}{4} - (1-C)X_2,$$

this inequality means that, the tensor of deformation form a straight line on the ground in B_ε,below parable about Ω_ε, which is contradicted to the situation of problem. Therefore, we will have (4:2) and (4:3). In another problem we can supposed that $(1-C) > 0$ and completed the proof.

According to (4:2) and (4:3), and for a small enough ε the sequence (u^ε) is bounded in $W_0^{1,1}(\Omega,\mathbb{R}^3)$.

Remark 4.3. The solution u^ε of the problem (4:0) satisfy to the Lemma 4:2.

To apply the epi-convergence method, we need to characterize the topological spaces containing any cluster point of the solution of the problem (4:0) with respect to the used topology, therefore the weak topology to use is insured by the lemma 4.1. So the topological spaces characterization is given in the following proposition.

Proposition 4.4. The solution u^ε of the problem (4.0) possess a cluster point u^* in $BD(\Omega)\cap L^1(\Omega)$.

Proof. According to the Remark 4.3 and Lemma 4.2, for a small enough ε, the solution u^ε is bounded in $BD(\Omega)$, since there is a compact embedding of $BD(\Omega)$ in $L^1(\varepsilon)$. Hence the result of Temam [13; p:152], there exists

.

$$u^* \in L^1(\Omega), \text{ such that } u^\varepsilon \rightharpoonup u^* \text{ in } L^1(\Omega).$$

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Remark 4.5. Proposition 4.4 remains valid for any weak cluster point of a sequence u^ε in V^ε; that satisfies (4:2) (4:3)

VI. Limit Behavior

Let

$$F_\varepsilon(v) = \begin{cases} \frac{1}{2}\int_{\Omega_\varepsilon} a_{ijhk} e_{ij}(v) e_{hk}(v) dx + \lambda \int_{B_\varepsilon} |e(v)| & \text{if } v \in V^\varepsilon \\ +\infty & \text{if } v \notin V^\varepsilon \end{cases} \quad (5.1)$$

$$G(v) = -\int_\Omega f v dx, \quad \forall v \in V^\varepsilon$$

We design by τ_f the weak topology on the space. In the sequel, we shall characterize, the epi-limit of the energy functional given by (5:1) in the following theorem.

Theorem 5.1. Under (2:2), (2:3), (2:4) and for $f \in L^\infty(\Omega, \mathbb{R}^3)$, there exists a functional F: $W^{1,1}(\Omega) \to \mathbb{R} \cup \{+\infty\}$ such that

$$\tau_f - \lim_\varepsilon F^\varepsilon = F \quad in\ W_0^{1,1}(\Omega)$$

where F is given by

$$F(u) = \begin{cases} \frac{1}{2}\int_\Omega a_{ijhk} e_{ij}(u) e_{hk}(u) dx + \lambda \int_\Sigma |[u] \otimes_s e_3| \\ \quad if\ u \in W_0^{1,1}(\Omega) \\ +\infty \quad if\ u \notin W_0^{1,1}(\Omega) \end{cases} .$$

Before launching our proof of this theorem we need the following lemma

Lemma 5.2.

Let Ω be a Lipschitizian in $\mathbb{R}^3$ and $p > 1$:

(i) – If $\pounds \in W^{-1,s'}(\Omega, \mathbb{R}^3)$ and $< \pounds, \Phi >= 0, \forall \Phi \in W_0^{1,p}(\Omega, \mathbb{R}^3)$, with $\boldsymbol{div}(\Phi) = 0$, then tere exists $q \in L^{q'}$ such that $\pounds = \boldsymbol{grad}(q)$.

(ii) – If $q \in L^q$ and $\int_\Omega q = 0$, then there exists $v \in W_0^{1,p}(\Omega, \mathbb{R}^3)$, such that $\boldsymbol{div}(v) = q$.

Proof. this result is classical if $p = 2$, is less well known if $p = 1$, thus the domain Ω is connected lipschitizian boundary. We can be shown (i) and (ii) such as in Tartar [10; p:29 - 30].

Proof. [theorem 5.1]

- — (a) We are now in position to describe the lower epi-limit.

Let $u \in W_0^{1,1}(\Omega)$ and $(u^\varepsilon) \in V^\varepsilon$ such that $u^\varepsilon \rightharpoonup u$ in $W_0^{1,1}(\Omega)$. If $\liminf_{\varepsilon \to 0} F^\varepsilon(u^\varepsilon) = +\infty$, there is nothing to prove, because

$$\frac{1}{2}\int_\Omega a_{ijhk} e_{ij}(u) e_{hk}(u) dx + \lambda \int_\Sigma |[u] \otimes_s e_3| \leq +\infty.$$

Otherwise, $\liminf_{\varepsilon \to 0} F^\varepsilon(u^\varepsilon) < +\infty$, there exists a subsequence of

$F^\varepsilon(u^\varepsilon) \leq C$, which implies that

$$\|e(u^\varepsilon)\|^2_{L^2(\Omega_\varepsilon, \mathbb{R}^9_s)} \leq C,$$

$$\int_{B_\varepsilon} |e(u^\varepsilon)| \leq C,$$

then $\chi_{\Omega_\varepsilon} e(u^\varepsilon)$ is bounded in $L^2(\Omega, \mathbb{R}^9_s)$, so for a subsequence of $\chi_{\Omega_\varepsilon} e(u^\varepsilon)$, still denoted by $\chi_{\Omega_\varepsilon} e(u^\varepsilon)$, we have

$$\chi_{\Omega_\varepsilon} e(u^\varepsilon) \rightharpoonup e(u) \quad \text{in } L^2(\Omega, \mathbb{R}^9_s).$$

Form the semirespectability's inequality of $u \to \frac{1}{2}\int_{\Omega_\varepsilon} a_{ijhk} e_{ij}(u) e_{hk}(u) dx$, and passing to the lower limit, we obtain

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$$\liminf_{\varepsilon\to 0}\frac{1}{2}\int_{\Omega_\varepsilon} a_{ijhk}e_{ij}(u^\varepsilon)e_{hk}(u^\varepsilon)dx$$
$$\geq \frac{1}{2}\int_{\Omega} a_{ijhk}e_{ij}(u)e_{hk}(u)dx. \qquad (5.2)$$

To describe the lower limit in the domain B^ε, denote by $C_\rho(x_0)$ the cylinder $S_\rho(x_0\,)$ is the open ball in $\mathbb{R}^2$ with radios ρ in centered at x_0 on Σ, it suffices to establish for H_2 which represents the Hausdorff measure, almost all x_0 on Σ

$$\lim_{\rho\to 0}\frac{\nu(C_\rho(x_0))}{H_2(S_\rho(x_0))}\geq [u]\otimes_s e_3,$$

where ν represent the Lebesgue measure in $L^1(\Omega)$, then

$$\frac{\nu(C_\rho(x_0))}{H_2(S_\rho(x_0))}=\lim_{\varepsilon\to 0}\frac{\nu_\varepsilon(C_\rho(x_0))}{H_2(S_\rho(x_0))}$$
$$=\lim_{\varepsilon\to 0}\frac{\lambda}{H_2(S_\rho(x_0))}\int_{S_\rho(x_0)\times]-\varepsilon,\varepsilon[} e(u^\varepsilon)dx. \qquad (5.3)$$

Other way, let u in $W_0^{1,1}(\Omega)$ there exists a sequence u^n in $C_0^\infty(\Omega)$ such that $u^n \rightharpoonup u$ in $W_0^{1,1}(\Omega)$ when $n\to +\infty$ We will use the smoothing operator R_ε, define by

$$R_\varepsilon u=\begin{cases}\frac{[u]^-(x_3)}{2}\Psi_\varepsilon(x)+\frac{[u]^+(x_3)}{2} & \text{if } |x_3|<\frac{\varepsilon}{2}\\ u(x) & \text{if } |x_3|>\frac{\varepsilon}{2}\end{cases}$$

where

$$[u]^+(x_3)=\frac{u(x',|x_3|)+u(x',-|x_3|)}{2},$$

$$[u]^-(x_3)=\frac{u(x',|x_3|)-u(x',-|x_3|)}{2},$$

And

$$\Psi_\varepsilon(x)=sign(x_3)\min(\frac{|x_3|}{\varepsilon},1),$$

We denote by $u^{\varepsilon,n}=R_\varepsilon u^n$, We easily show that

$$e(u^n)=\frac{1}{\varepsilon}[u](x_0)\otimes_s e_3+e(u^n-R_\varepsilon(u^n)). \qquad (5.4)$$

Otherwise, let

$$q^{\varepsilon,n}=\begin{cases}\mathbf{div}u^{\varepsilon,n} & \text{in } B_\varepsilon\\ \frac{1}{\Omega_\varepsilon}\int_{B_\varepsilon}\mathbf{div}u^{\varepsilon,n} & \text{in } \Omega_\varepsilon\end{cases}$$

We have $q^{\varepsilon,n}\in L^1(\Omega)$ and

$$\int_\Omega q^{\varepsilon,n}=0,$$

according to the Lemma 5.2, there exists $v^{\varepsilon,n}\in W_0^{1,1}(\Omega,\mathbb{R}^3)$ such that $q^{\varepsilon,n}=\mathbf{div}v^\varepsilon$ and $v^{\varepsilon,n}$ depending linearly and continuously of $q^{\varepsilon,n}$ so there exists a constant $C>0$ such that

$$\|v^{\varepsilon,n}\|_{W_0^{1,1}}\leq C\|q^{\varepsilon,n}\|_{L^1}$$

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Using that $\int_{\Omega} q^{\varepsilon,n} = 0$, implies $q^{\varepsilon,n} = 0 \;\; p.p$ for this result see you Roudin [15], so we have $v^{\varepsilon,n} \to 0$ in $W_0^{1,1}(\Omega, \mathbb{R}^3)$.

Let

$$w^{\varepsilon,n} = u^{\varepsilon,n} - v^{\varepsilon,n}.$$

Since $\mathbf{div} v^{\varepsilon,n} = \mathbf{div} u^{\varepsilon,n}$ in B_{ε}, so $\mathbf{div} w^{\varepsilon,n} = 0$ in B_{ε}, it follows that $w^{\varepsilon,n} \in V^{\varepsilon}$, and as $u^{\varepsilon,n} \rightharpoonup u^n$ and $v^{\varepsilon,n} \to 0$ in $W_0^{1,1}(\Omega, \mathbb{R}^3)$.

According to the (5:3) and (5:4), we have

$$\lim_{\rho\to 0}\lim_{\varepsilon\to 0}\frac{\lambda}{H_2(S_\rho(x_0))}\int_{S_\rho(x_0)\times]-\varepsilon,\varepsilon[}|e(u^{\varepsilon,n})|dx \tag{5.5}$$

$$= \lim_{\rho\to 0}\lim_{\varepsilon\to 0}\frac{\lambda}{H_2(S_\rho(x_0))}\int_{S_\rho(x_0)\times]-\varepsilon,\varepsilon[}|e(R_\varepsilon(u)) - e(u^{\varepsilon,n} - R_\varepsilon(u))|dx$$

$$= \lim_{\rho\to 0}\lim_{\varepsilon\to 0}\frac{\lambda}{H_2(S_\rho(x_0))}\{$$

$$\int_{S_\rho(x_0)\times]-\varepsilon,\varepsilon[}|\frac{1}{\varepsilon}[u]^-(x_0)\otimes_s e_3 + e(u^{\varepsilon,n} - R_\varepsilon(u))|dx\}.$$

We can modify $u^{\varepsilon,n} - R_\varepsilon(u)$ in the boundary of $S_\rho(x_0)\times]-\varepsilon,\varepsilon[$ by a function $\varphi_\varepsilon \in W_0^{1,1}(S_\rho(x_0)\times]-t(\varepsilon),t(\varepsilon)[,\mathbb{R}^3)$ where $\lim_{\varepsilon\to 0}\frac{t(\varepsilon)}{\varepsilon} = 1$, for more information see you Licht and Michaille [16], so that

$$\lim_{\rho\to 0}\lim_{\varepsilon\to 0}\frac{\lambda}{H_2(S_\rho(x_0))}\{$$

$$\int_{S_\rho(x_0)\times]-\varepsilon,\varepsilon[}|\frac{1}{\varepsilon}[u]^-(x_0)\otimes_s e_3 + e(u^{\varepsilon,n} - R_\varepsilon u)|dx\}$$

$$\geq$$

$$\limsup_{\rho\to 0}\limsup_{\varepsilon\to 0}\frac{\lambda}{H_2(S_\rho(x_0))}\{$$

$$\int_{S_\rho(x_0)\times]-t(\varepsilon),t(\varepsilon)[}|\frac{1}{\varepsilon}[u]^-(x_0)\otimes_s e_3 + e(\varphi_\varepsilon)|dx\}.$$

Recalling (5:5), then

$$\lim_{\rho\to 0}\lim_{\varepsilon\to 0}\frac{\lambda}{H_2(S_\rho(x_0))}\int_{S_\rho(x_0)\times]-\varepsilon,\varepsilon[}|e(u^{\varepsilon,n})|dx$$

$$\geq$$

$$\limsup_{\rho\to 0}\limsup_{\varepsilon\to 0}\frac{1}{|A_\varepsilon|}\inf\{$$

$$\int_{A_\varepsilon}[u]^-(x_0)\otimes_s e_3 + e(\varphi)|dx : \varphi \in W_0^{1,1}(A_s,\mathbb{R}^3)\}$$

where $A_\varepsilon = \frac{1}{\lambda}S_\rho(x_0)\times]-t(\varepsilon),t(\varepsilon)[$, the subadditive process

$$A \to S_A =$$

$$\inf\{\int_A\{[u]^-(x_0)\otimes_s e_3 + e(\varphi)|dx : \varphi \in W_0^{1,1}(A,\mathbb{R}^3)\}$$

satisfies all the condition of the global theorem thus finally obtain

$$\lim_{\varepsilon\to 0}\frac{\lambda}{H_2(S_\rho(x_0))}\{$$

$$\int_{S_\rho(x_0)\times]-\varepsilon,\varepsilon[}e(u^\varepsilon)dx \geq [u]^-(x_0)\otimes_s e_3\}$$

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For $u \in W_0^{1,1}(\Omega)$ and $u^\varepsilon \in V^\varepsilon$, such that $u^\varepsilon \rightharpoonup u$ in $W_0^{1,1}(\Omega)$, Assume that

$$\liminf_{\varepsilon \to 0} F^\varepsilon(u^\varepsilon) < +\infty.$$

So there exists a constant $C > 0$ and a subsequence of $F^\varepsilon(u^\varepsilon)$, still de noted by $F^\varepsilon(u^\varepsilon)$, such that

$$F^\varepsilon(u^\varepsilon) < C.$$

So u^ε verifies the following evaluation (4.2) and (4.3), as $u^\varepsilon \rightharpoonup u$ in $W_0^{1,1}(\Omega)$ thanks to the Remark 4.5 we have $u \in W^{1,1}(\Omega)$ what contracdicts the fact that $u \in W^{1,1}(\Omega) \setminus W_0^{1,1}(\Omega)$, consequently we have

$$\liminf_{\varepsilon \to 0} F^\varepsilon(u^\varepsilon) = +\infty$$

- — (b) We are now in position to determine the upper epi-limit, we have

$$F^\varepsilon(w^{\varepsilon,n}) = \frac{1}{2}\int_{\Omega_\varepsilon} a_{ijhk} e_{ij}(w^{\varepsilon,n}) e_{hk}(w^{\varepsilon,n}) dx + \lambda \int_{B_\varepsilon} |e(w^{\varepsilon,n})|$$

which implies that

$$F^\varepsilon(w^{\varepsilon,n}) = \frac{1}{2}\int_{\Omega_\varepsilon} a_{ijhk} e_{ij}(w^{n}) e_{hk}(w^{n}) dx + \lambda \int_{B_\varepsilon} |e(w^{\varepsilon,n})|$$

$$= S_1 + S_2$$

so that

$$\lim_{\varepsilon \to 0} S_1 = \lim_{\varepsilon \to 0} \frac{1}{2}\int_{\Omega} \chi_{\Omega_\varepsilon} a_{ijhk} e_{ij}(w^{n}) e_{hk}(w^{n}) dx$$

$$= \int_{\Omega} a_{ijhk} e_{ij}(w^{n}) e_{hk}(w^{n}) dx$$

we have

$$S_2 = \lambda \int_{B_\varepsilon} |e(w^{\varepsilon,n})|$$

as in [8] we chow that

$$\lim_{\varepsilon \to 0} |e(w^{\varepsilon,n}) - \frac{1}{\varepsilon}[w^n] \otimes_s e_3|$$

Consequently,

$$\limsup_{\varepsilon \to 0} F^\varepsilon(w^{\varepsilon,n}) =$$

$$= \frac{1}{2}\int_{\Omega} a_{ijhk} e_{ij}(w^{n}) e_{hk}(w^{n}) dx + \lambda \int_{\Sigma} |[w^n] \otimes_s e_3|.$$

Science $w^n \to u$ in $W_0^{1,1}(\Omega)$ because $v^{\varepsilon,n} \to 0$, there fore according to the classic result, digitalization's Lemma, see [7, p.32], there exists a real function $n(\varepsilon) : \mathbb{R}^+ \to \mathbb{N}$ increasing to $+\infty$, such that $w^\varepsilon, n(\varepsilon) \rightharpoonup u$ in $W_0^{1,1}(\Omega)$ when $\varepsilon \to 0$.

Consequently, we have

$$\limsup_{\varepsilon \to 0} F^\varepsilon(w^{\varepsilon,n(\varepsilon)}) \leq \limsup_{\varepsilon \to 0} \limsup_{n \to +\infty} F^\varepsilon(w^{\varepsilon,n})$$

$$\leq \frac{1}{2}\int_{\Omega} a_{ijhk} e_{ij}(w^{n}) e_{hk}(w^{n}) dx + \lambda \int_{\Sigma} |[w^n] \otimes_s e_3|.$$

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For $u \in W_0^{1,1}(\Omega)$, so for any sequence $u^\varepsilon \rightharpoonup u$ in $L^1(\Omega)$, we obtain

$$\limsup_{\varepsilon\to 0} F^\varepsilon(u^\varepsilon) \leq +\infty$$

Hence the proof is complete.

In the sequel, we determine the limit problem linked to (4:0), when ε approaches to zero. Thanks to the epi-convergence results, see section 2 [Theorem 3.3, and Proposition 3.2] and the theorem 5.1, according to the τ_f -continuity of the functional G in $W_0^{1,1}(\Omega)$, we have $F^\varepsilon + G$ τ_f -epiconverges to $F+G$ in $W_0^{1,1}(\Omega)$

Proposition 5.3. For any $f \in L^1(\Omega, \mathbb{R}^3)$, there exists $u^* \in W_0^{1,1}(\Omega, \mathbb{R}^3)$ satisfies

$$u^\varepsilon \rightharpoonup u^* \quad in\ W_0^{1,1}(\Omega, \mathbb{R}^3),$$

$$F(u^*) + G(u^*) = \inf_{u\in W_0^{1,1}(\Omega)} \{F(u) + G(u)\}.$$

Proof. Thanks to Lemma 4.2, the family $(u^\varepsilon)_\varepsilon$ is bounded in $L^1(\Omega)$, therefore it passess a τ_f − cluster point u^* in $L^1(\Omega)$. And thanks to a classical epiconvergence method, theorem 3.3, it follows that u^* is a solution of the problem : Find

$$\inf_{u\in W_0^{1,1}(\Omega)} \{F(u) + G(u)\} \tag{5.2}$$

Since $F = +\infty$ on $W^{1,1}(\Omega) \setminus W_0^{1,1}(\Omega)$, so (5.6) became

$$\inf_{u\in W^{1,1}(\Omega)} \{F(u) + G(u)\}.$$

According to the uniqueness of solutions of problem (5:6), so u^ε admits an unique τ_f -cluster point u^*, and therefore $u^\varepsilon \rightharpoonup u^*$ in $W_0^{1,1}(\Omega)$.

VI. Conclusion

Using the epi-convergence method we showed that the structure, constituted of two elastic bodies joined together by a incompressible elastic thin oscillating layer of thickness, rigidity, and periodicity parameter depending on (ϵ), obeying to a nonlinear elastic law, whose parameters depend on the negative powers of e, behaves at the limit like an elastic body embedded on the boundary and subjected to a density of forces of volume f, according to the powers of ε , the layer behaves like a rather rigid nonlinear elastic material surface with membrane effect, too rigid inextensible material surface, a material surface with effect of infection or the structure is embedded on the interface Σ , We found the same result of A. Ait Moussa and J. Messaho [1].

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Semi-Annual Variation of Geomagnetic Indices for the Period of 1970-2009

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Abstract - Semiannual variations of the geomagnetic disturbances for different geomagnetic activity indices exhibit distinct characteristics for the period of 1970-2009. In this paper, the semiannual variation of geomagnetic activity is significant in the low-latitudinal Dst index showing the magnitude of the ring current, less significant in the midlatitude of Ap and Kp indices. There is no evidence of semiannual variation in the auroral electrojet AE index but clearly observed in AL index which are measure of global geomagnetic activity in the auroral zone, also responds to convection electrojets and substorms electrojet. The correlation coefficient was used to determine the reliability of the variation, which ranges between 0.595-0.988.

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SEMI-ANNUAL VARIATION OF GEOMAGNETIC INDICES FOR THE PERIOD OF 1970-2009

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Semi-Annual Variation of Geomagnetic Indices for the Period of 1970-2009

Falayi E.O [α], Rabiu A.B [σ] & Beloff N [ρ]

Abstract - Semiannual variations of the geomagnetic disturbances for different geomagnetic activity indices exhibit distinct characteristics for the period of 1970-2009. In this paper, the semiannual variation of geomagnetic activity is significant in the low-latitudinal Dst index showing the magnitude of the ring current, less significant in the midlatitude of Ap and Kp indices. There is no evidence of semiannual variation in the auroral electrojet AE index but clearly observed in AL index which are measure of global geomagnetic activity in the auroral zone, also responds to convection electrojets and substorms electrojet. The correlation coefficient was used to determine the reliability of the variation, which ranges between 0.595-0.988.

I. Introduction

The use geomagnetic activity indices (AE, AL, AU, AO, Dst, Kp, aa, ap) and solar activities (Sunspot number and Solar flux 10.7) plays an important role in the study of geomagnetic disturbance variation. The geomagnetic activity indices are used for measuring the level of geomagnetic activity. These indices are computed from measurements of geomagnetic disturbances. Semiannual variation of geomagnetic disturbance has been studied using different indices, the aa, Ap, and Am midlatitude indices (for example, McIntosh, 1959; Russell and McPherron, 1973; Bertelier, 1976; Mayaud, 1980; Orlando et al., 1993; Cliver et al., 2000, 2002), low-latitude Dst index (Cliver et al., 2000; Chen 2004; Falayi and Beloff, 2009) and auroral electrojet AE, AL, AU, and AO indices (Bertelier, 1976; Hajkowicz, 1998; Ahn et al., 2000; Cliver et al., 2000; Lyatsky et al., 2001; Benkevitch et al., 2002).

Traditionally, these variations have been attributed to three external effects: Changes in the heliographic latitude of the Earth during the year (Cortie, 1912); variations of the solar wind flow direction with respect to the Earth's magnetic dipole axis (Bartels, 1925; McIntosh, 1959); and variation of the angle between the geocentric solar magnetospheric (GSM) equatorial plane and the solar equatorial plane (Russell and McPherron, 1973). The Earth reaches extreme heliographic latitudes near equinoxes which lead to enhanced geomagnetic activity during those periods, as the Earth is then better connected to the fast solar wind streams from the low-latitude coronal holes. Annual variation is also known in solar wind (SW) speed, temperature and density (Bolton, 1990 and Paularena et al., 1995). Szabo et al. (1995) established that annual variation in speed is strongest around solar minima.

The general tendency for magnetic disturbances to be stormier at equinoxes than at solstices has been recognised for more than 150 years (Sabine, 1856) and the cause of the semi-annual variation has been studied by many researchers (Lyatsky and Hamza, 2001; Lyatsky and Tan, 2003; Byung-Ho and Ga-Hee, 2003; Clua de Gozalez et al., 2001) and its cause remain under discussion in the scientific community. Statistical studies by Ahn et al. (2000), and Lyatsky et al. (2001), demonstrated strong differences in the seasonal variations for various geomagnetic activity indices and the strong dependence of these variations with latitude. Regression analysis shows that the majority of seasonal variability is attributed to a generalized equinoctial effect, the geomagnetic activity correlates well with the angle between the Earth's dipole axis and the Earth-Sun line (Orlando et al, 1995; Cliver et al., 2000). Because the Earth's magnetic dipole axis is offset from the spin axis, the angle the dipole makes with the solar wind varies over the course of a day. Crooker and Siscoe (1986) explained the semiannual variation in which the Bz coupling efficiency between the solar wind and magnetosphere can be modulated by the tilt angle of Earth dipole. Falayi and Beloff (2009), found a statistically significant in October-November peak in geomagnetic activity for Northern Hemisphere, which is sufficiently larger (by 50%) than March-April peak.

In this paper, we study the long-term evolution of the semiannual variation using early geomagnetic activity. Here we use this correlation to study the annual mean variation of geomagnetic activity. Dst (Disturbance Storm Time), Kp, Ap, AL, AE indices, solar flux and sunspots are key features in the forecast of geomagnetic activity.

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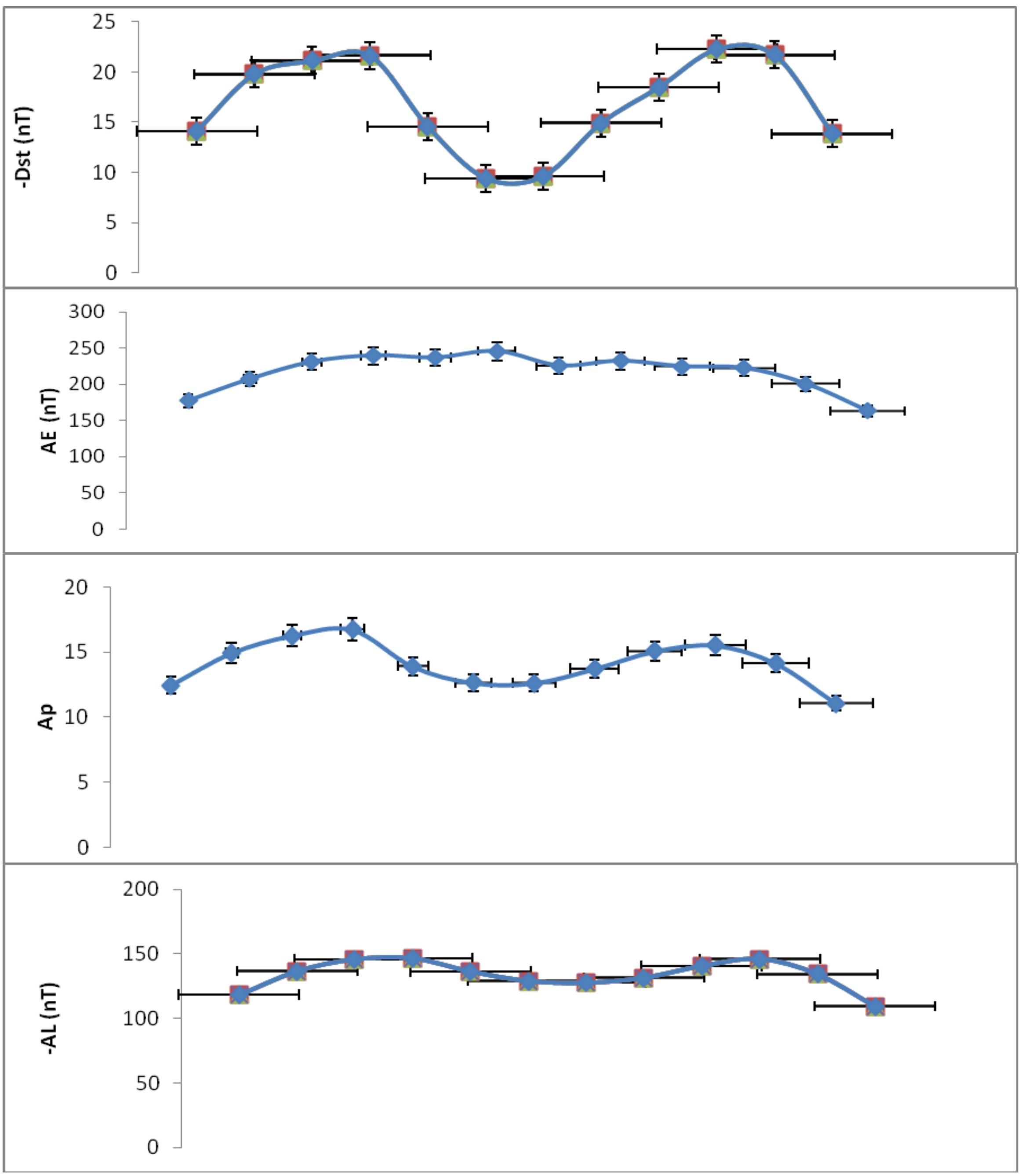
II. Data Analysis

a) *Annual Variation For Geomagnetic Activity Indices*

Figure 1 demonstrated the semi-annual variation in the monthly mean of the low latitudinal Dst index, two midlatitude Ap and Kp indices and AL (negative component of the auroral electrojet) for the period of 40 years from 1970-2009. We took the data from (http://omniweb.gsfc.nasa.gov). Since the Dst index is commonly negative, for better comparison with other indices the absolute values of the Dst index are shown. We computed monthly average of the indices for periods shown in Figure 1. It also demonstrated the semiannual variation of geomagnetic activity is significant in the low-latitudinal Dst index showing the magnitude of the ring current. The AL index, which is the negative component of the auroral electrojet index AE, is utilized to study the universal time seasonal variations of northern hemisphere auroral zone magnetic activity in the midnight sector on quiet days. There is no evidence of semiannual variation in the auroral electrojet AE index which is a measure of global geomagnetic activity in the auroral zone, also responds to convection electrojets and substorms electrojet. It less significant in the midlatitude of Ap and Kp indices, which show magnetic disturbances at middle latitudes propagating there predominantly from higher latitudes.



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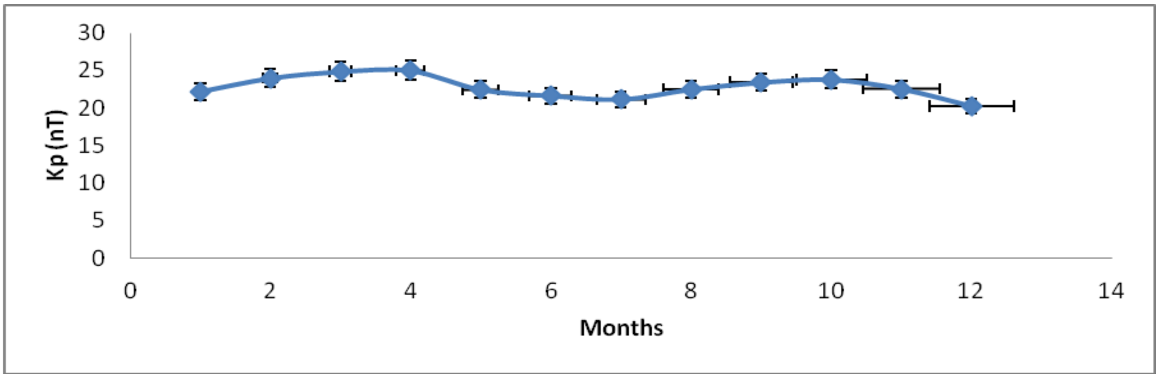


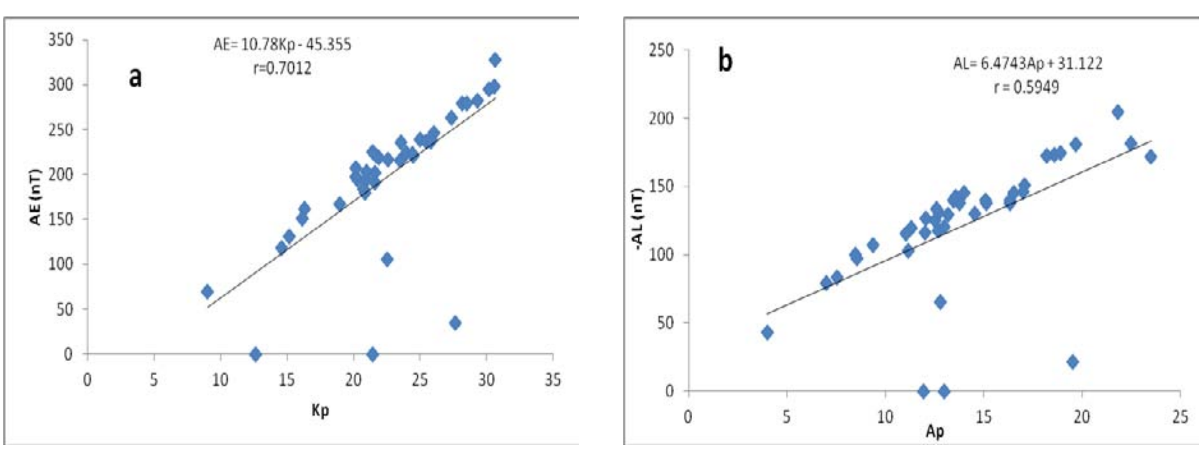
Figure 1. Monthly average variations of Dst, AL, AE, Kp and Ap indices from 1990-2009.

b) Annual Correlations

In order to make evident of the annual trend of the geomagnetic activity, averaging together corresponding monthly values of Dst, AL, AE, Kp, Ap, Rz and Solar flux 10.7 over the whole period considered (1970- 2009). The method to determine the reliability of the obtained variations is the correlation coefficient (r). From Figure 2 we show the values of the indices and the straight lines of best fit given by the linear regressions which shows a strong correlation was established between annual mean of AL versus Ap and AE versus Kp (see Figure 2 a and b). The correlation coefficient between annual mean of AL versus Ap and AE versus Kp ranges between 0.595 and 0.701 respectively. Correlation over the entire period is strong but not as strong as for an individual storm. However, the correlation for AE versus Kp is high, as they monitor similar ionospheric currents and have their geomagnetic stations fairly close.

The good correlation is a validation of the idea that sunspot number is a good proxy for solar flux 10.7. There is a strong positive correlation (correlation coefficient 0.988) between the two quantities (Figure 2c). Also Figure 2 (d-f) shows Dst versus Ap, sunspot number and solar flux with correlation coefficient of 0.783, 0.643 and 0.651 respectively. Dst index shows a state level of geomagnetic activity and is basically connected to the geomagnetic field near the equator and to the condition of the ring current, and it describes the development of global large scale of geomagnetic disturbances. The result indicated that Ap and Dst indices are potentially useful in prediction of storm time enhancements of ring current intensity.

Feynmann (1982) had noted that as the sunspot number increases the base level of geomagnetic activity increases as well, this determine the level of geomagnetic activity which is proportional to the sunspot number. Sunspot number R_z is commonly considered an appropriate and reliable index of solar variability. Variations of solar activity and prediction of its change on both a short- and long-term basis is becoming increasingly relevant because of our improving knowledge of the Sun-Earth relationships and the influence of solar activity on geomagnetic variations.



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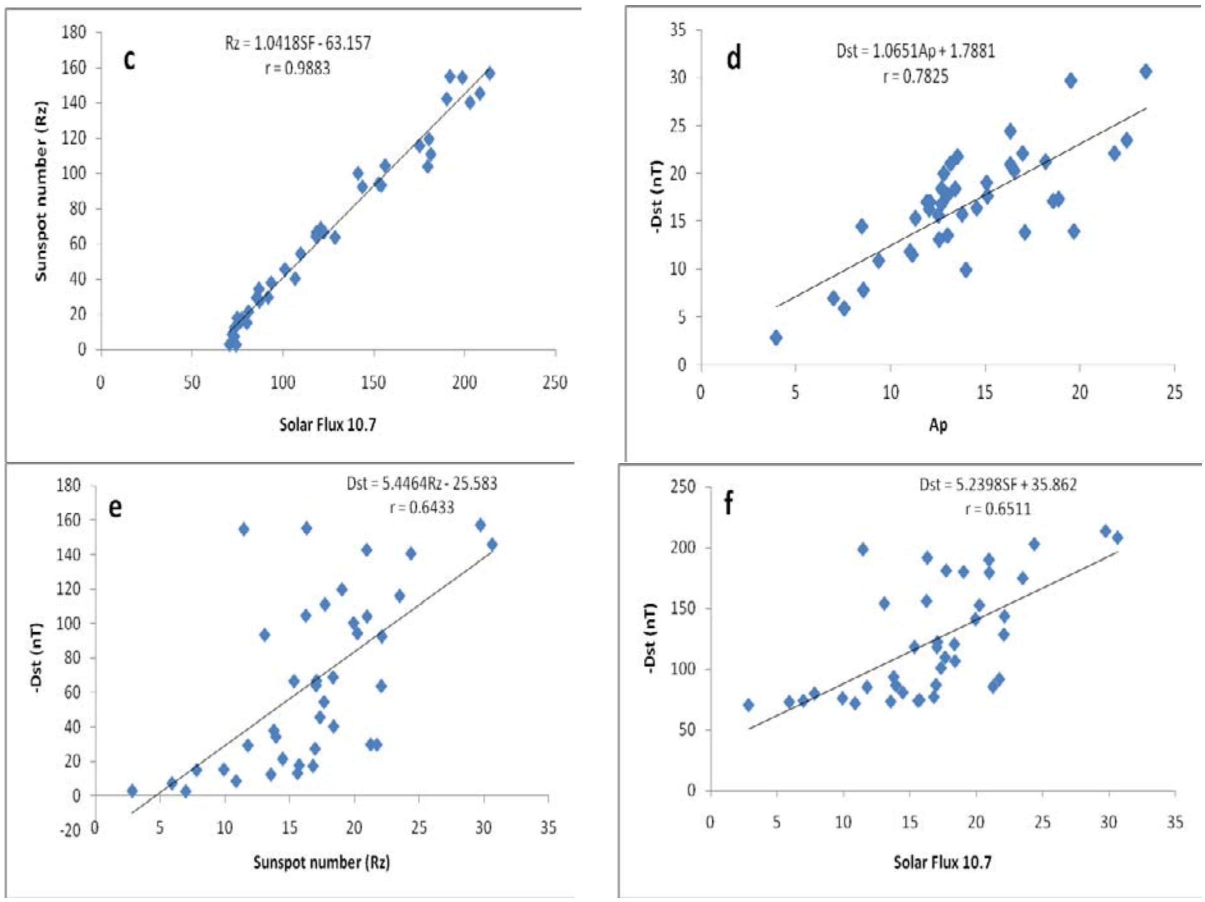

Figure 2. Correlation plots for annual mean AE, AL, Dst, Kp, Ap, Sunspot number and Solar flux.

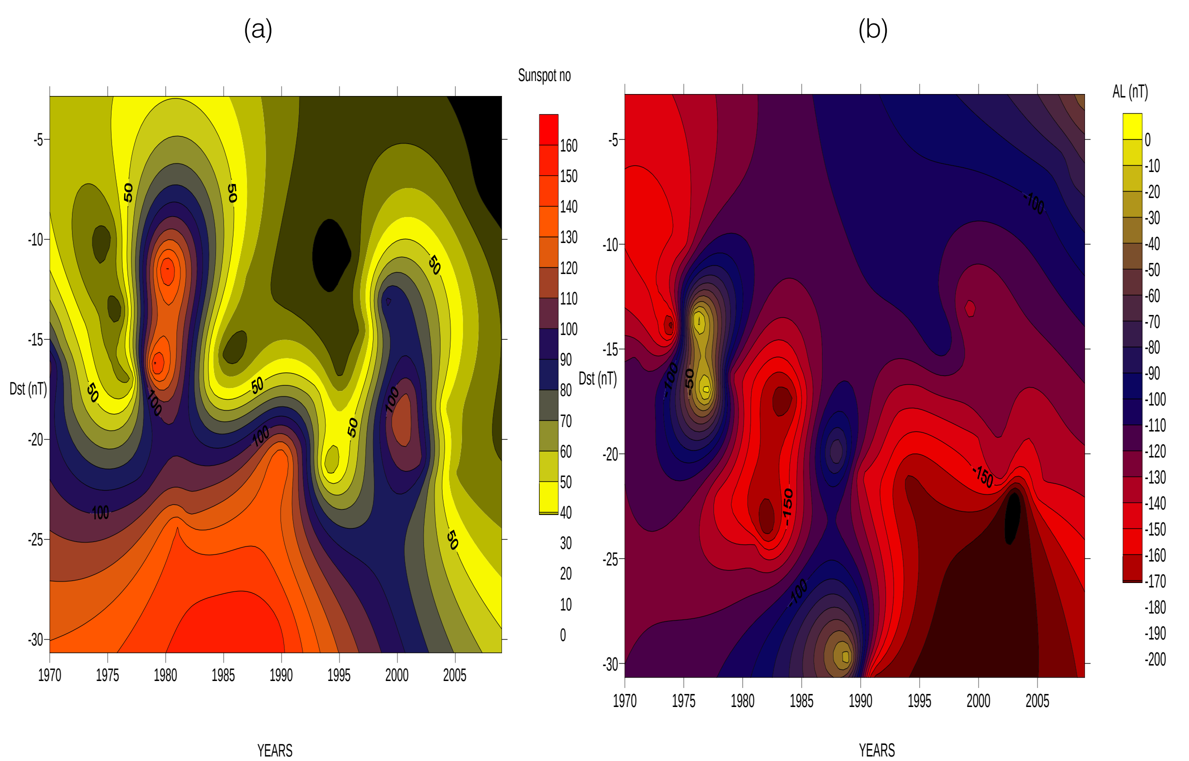

Figure 3. Annual variation of geomagnetic activity predicted from a) Dst and Sunspot number b) Dst and AL.

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Figure 3 show the contour plot of annual variation of Dst index, Sunspot number and AL index, It was noticed that each of the effects produces distinct annual variability patterns and hence their contribution could be identifiable from the data. The contribution to the annual variations from the ring current at low latitude appears statistically comparable with the contribution from sunspot number and substorm westward electrojet at high latitudes. The annual variation was observed between the years of 1970-2009, may be caused by unsymmetrical geomagnetic disturbances between hemispheres. The annual variations may be as results of the high speed of solar winds are transported inward to the ring current region during magnetic storms. This accumulated energy is indicated by westward electrojets, which contribute to AL, making it more responsive to the reconnection in put on the time scales considered (Figure 3b). This produces a diamagnetic decrease in the Earth's magnetic field measured at near-equatorial stations, and is the cause of the main phase of the magnetic storms (Lyatsky and Tan, 2003).

III. Results And Discussion

The result reported here gives support to Russell and McPherron model. From Figure 1 we observed the greatest occurrence of geomagnetic activities during the period of the April and October. This is an evident that the interplanetary magnetic field (IMF) is a significant factor for geomagnetic activity. The south component *Bz* of the interplanetary magnetic field is always associated with the progress of the magnetic field reconnection at the magnetopause. However, the energy of the solar wind is input into the magnetosphere, driving drastic geomagnetic disturbances such as geomagnetic storm and substorm. The geomagnetic activity has long been known to be highly variable in time. One of the earliest variations distinguished in the geomagnetic activity were its semiannual variation. The asymmetry variation of geomagnetic activity implies that there is an increase in the energy input in the magnetosphere due to the solar wind –magnetosphere interaction.

The semiannual variation is clearly observed in the AL index showing substorm activity while the AE index shows no semiannual variation in the study. The analysis has shown that when corrections are made for the solar zenith angle variation with month, the seasonal variation of electrojet current maximises during equinoctial months. This result may testify the important role of conjugate auroral zone conductivity in substorm generation, which has a clear semiannual variation as discussed by Lyatsky et al. (2001), Benkevitch et al. (2002) and Newell et al. (2002). The observed features of the semiannual variations may be caused by two main sources of geomagnetic activity, increases in the ring current and substorm westward electrojet during enhanced geomagnetic activity around equinoctial months (Figure 1).

Semiannual variation of geomagnetic activity to be very strong in the low-latitudinal Dst index showing the magnitude of the ring current. Such variation with a lesser amplitude is also seen in the midlatitude Ap and Kp indices, which show magnetic disturbances at middle latitudes propagating there predominantly from higher latitudes. The seasonal variations in geomagnetic activity indices showed that the study of auroral electrojet AE and AL indices showed that the semiannual variation is evident in AL index but not observed in AE index.

In this study, we investigated linkage between the geomagnetic indices and solar activities, the correlation coefficient for the relation tested; these had values ranging from 0.594-0.988 for correlation coefficient (Figure 2). From our analysis, the result confirms that sunspot activity is one of the main sources of geomagnetic activity. This variation may be strongly influenced by the strength and direction of the interplanetary magnetic field and by the solar-wind velocity, density, temperature and kinetic energy. The surface signature of the solar wind magnetosphere interaction manifests itself differently in the auroral zones, mid and low latitudes. Observing the correlation between solar activity (sunspot number and solar flux 10.7) and the geomagnetic activity index (Dst), we found a decrease in the correlation between the two parameters in the current in Figure 2 (e and f). The variability in geomagnetic activity may be as a result of solar wind emanating from polar coronal holes.

Despite the observational support, the way the equinoctial mechanism works has remained unknown (Cliver et al., 2000). Boller and Stolov (1970) suggested a theoretical explanation of the equinoctial effect in terms of the Kelvin-Helmholtz's instability. They proposed that annual and diurnal variations of the Earth's dipole to the solar wind cause modulations of the conditions favourable for the development of Kelvin-Helmholtz's instability at the flanks of the magnetosphere. Campbell (1982) reported that the annual and semiannual variation changes that are observed in the Earth's heating and ionization during the yearly path around the Sun may be the causes of semiannual variation.

We found that AL shows semiannual variation pattern, suggesting that the electric field is the main modulator of the semiannual magnetic variation. Also AL currents have a more rapid response to the IMF direction than the AU currents (Nowada et al., 2009). The Dst index was found to show more prominent seasonal variation than the AE indices, therefore variation of the Dst index is noticeable during the main phase of a magnetic storm.

IV. Conclusion

In this paper, we analysed monthly means for the period 1970 to 2010 in order to highlight the annual

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and semi-annual variations. The mechanisms causing these variations are complicated and still an open issue. The semi-annual peak is clearly better detected DST and AL; this is related to Russell-McPherron effect (Russell and McPherron, 1973). The semiannual variation of geomagnetic activity implies that there is an increase in the energy input in the magnetosphere due to the solar wind-magnetosphere interaction. The dayside reconnection process between the interplanetary magnetic field and geomagnetic field may cause asymmetric variation in geomagnetic activity. In this study we also showed annual variation of geomagnetic indices.

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Behaviour of Tensile Testing of X-120M Steel from Plate to Line Pipe Due to Bauschinger Effect

By Jai Dev Chandel & Nand Lal Singh
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Abstract - The X-120M 'V-Nb-Ti-B' micro alloyed steel of bainitic microstructure used in the experiment having high dislocation density. High dislocation density was due to the nature of Thermo Mechanical Controlled Processing and Accelerated Cooled rolling to achieve the strength level of X- 120 ksi. During the cold forming and mechanical expansion, the deformation occurred which reversed the strain. The reversal of strain leads to increase in yield strength to ultimate tensile strength ratio in transverse direction. The tensile test has been performed for steel plate as well as on line pipe formed in longitudinal and transverse of rolling of the plate and longitudinal and transverse direction of the line pipe axis before and after the mechanical expansion of the line pipe. The yield strength and ratio of yield strength to ultimate tensile strength in transverse direction is more after mechanical expansion of the line pipe as compared before expansion transverse yield strength because of the bauschinger effect. In longitudinal direction the results remains the same because the hoops stresses developed in transverse direction with respect to the axis of the line pipe.

Keywords : Bauschinger Effect, Thermo Mechanical Controlled Processing and Accelerated Cooled rolling, Yield Strength and Ultimate Tensile Strength.

GJSFR-A Classification: FOR Code: 020304, 020399

BEHAVIOUR OF TENSILE TESTING OF X-120M STEEL FROM PLATE TO LINE PIPE DUE TO BAUSCHINGER EFFECT

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Abstract - The X-120M 'V-Nb-Ti-B' micro alloyed steel of bainitic microstructure used in the experiment having high dislocation density. High dislocation density was due to the nature of Thermo Mechanical Controlled Processing and Accelerated Cooled rolling to achieve the strength level of X-120 ksi. During the cold forming and mechanical expansion, the deformation occurred which reversed the strain. The reversal of strain leads to increase in yield strength to ultimate tensile strength ratio in transverse direction. The tensile test has been performed for steel plate as well as on line pipe formed in longitudinal and transverse of rolling of the plate and longitudinal and transverse direction of the line pipe axis before and after the mechanical expansion of the line pipe. The yield strength and ratio of yield strength to ultimate tensile strength in transverse direction is more after mechanical expansion of the line pipe as compared before expansion transverse yield strength because of the bauschinger effect. In longitudinal direction the results remains the same because the hoops stresses developed in transverse direction with respect to the axis of the line pipe.

Keywords : Bauschinger Effect, Thermo Mechanical Controlled Processing and Accelerated Cooled rolling, Yield Strength and Ultimate Tensile Strength.

I. Introduction

Tensile properties of line pipe are one of the governing parameter as far as design of line pipe is concerned. The strength of line pipe steel is achieved by the lean and clean microalloying plus thermomechanical controlled processing and accelerated cooling (TMCP and AC) of steel plates. The line pipe manufacturing is involving the cold forming processes in whole cycle. During the cold forming of X-120M steel plate in first J-C-O process, strain energy stored in plates in terms of dislocations start releasing by movement, piling up against the barrier in the microstructure and cancellation of dislocations. The movement or cancellation of dislocations is known as bauschinger effect. The Bauschinger effect [1] refers to a property of materials where the material's stress/strain characteristics changed as a result of the microscopic stress distribution of the material. The Bauschinger effect is normally associated with conditions where the yield strength of a metal decreases when the direction of strain is changed. The basic mechanism for the Bauschinger effect is related to the dislocation structure in the cold worked metal. As deformation occurs, the dislocations will accumulate at barriers and produced dislocation pile-ups and tangles. It is fundamental that the bending [2] provides a heterogeneous deformation in section that determines the presence of high residual stresses. The wall thickness to diameter ratio t/D and strain hardening rate during cold expansion has the influence on the effect value. The general tendency is the softening growth in new higher strength steels that is stipulated by higher value of residual stresses. Nevertheless the value of the effect at equal strength is determined as well by the type of microstructure (specific value of each of the strengthening mechanisms resulted in strain hardening behaviour). The Bauschinger effect in TMCP steels has been previously studied [3] with respect to line pipe production by the UOE forming. The Bauschinger effect influences line pipe properties in two ways: during line pipe testing where tensile coupons of transverse direction to the line pipe axis need to be flattened prior to testing when comparing the line pipe and plate tensile properties. According to the API 5L standard, line pipe testing can be carried out by flattening of a line pipe wall-piece and tensile testing of the flattened part or by hydraulic expansion [4, 5] of a line pipe ring. During flattening the inner side of the line pipe wall is subjected to tension and outer side to compression, hence flattening adds a half cycle [6, 2] to the reverse deformation sequence already experienced by the line pipe material of high strength steel. Consequently a large difference in line pipe mechanical properties can be observed due to the method of testing (20% difference in the yield stress between flattened specimens and ring expansion. The difference in the test data also depends on steel chemistry. Recent investigations of TMCP steels have found that the Bauschinger effect depends on chemistry even for the same method of testing. At the moment, the Bauschinger effect dependence on the dislocation structure and microalloy particle distributions (related to a steel chemistry and processing parameters) is only known qualitatively and only a limited amount of data are available. With an increase in pre-strain the drop in yield strength of TMCP steels on reverse loading increases, due to an increase in dislocation density and

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consequent increase in number density of dislocation-particle interaction sites.

II. Materials And Experimental Methods

The experimental steel is a low carbon and low Pcm 'V-Nb-Ti-B' micro alloyed steel for studying the bauschinger effect on the tensile properties of line pipe steel. The chemical composition of experimental TMCP and ACC steel plate of grade API-5L, X-120M shown in table # 01. The parameters Pcm and CEQ are calculated as per formulae given as $Pcm = C + Ni / 60 + Si / 30 + (Mn + Cu + Cr) / 20 + Mo/15 + V / 10 + 5B$ and $CEQ = C + Mn/6 + (Cr+Mo+V)/5 + (Ni + Cu)/15$.

Table 1 : Weight Percentage of Elements of X-120M Steel Plates

Element	**C**	**Si**	**Mn**	**P**	**S**	**Cr**	**Ni**	**Mo**	**Al**	**Cu**
Wt. (%)	0.065	0.290	1.950	0.012	0.005	0.170	0.040	0.130	0.042	0.021
Element	**Ti**	**V**	**Nb**	**Ca**	**N**	**B**	**Al/N**	**Nb+V+Ti**	**Pcm**	**CE**
Wt. (%)	0.012	0.001	0.042	0.001	0.002	0.004	21	0.055	0.211	0.454

The TMCP and AC X-120M steel plate has been converted into line pipe through J-C-O-E technique [7] as shown in the figure # 01. The complete detail of J-C-O-E line pipe manufacturing/forming has been given in the reference number [7] by the authors titled "Formation of X-120M line pipe through J-C-O-E Technique, J D Chandel, and N L Singh. Journal of Scientific Research Publication, Engineering, USA, Volume # 03, No. 04 April-2011, Page # 400-410" and the tensile test samples has been cut as per API-5L at every stage of the formation. Tensile test has been performed on the experimental plate in the longitudinal as well as in the transverse direction to the rolling direction. Similarly the tensile test has also been performed on the experimental formed line pipe of above steel to longitudinal as well as in transverse direction to the axis of the line pipe.

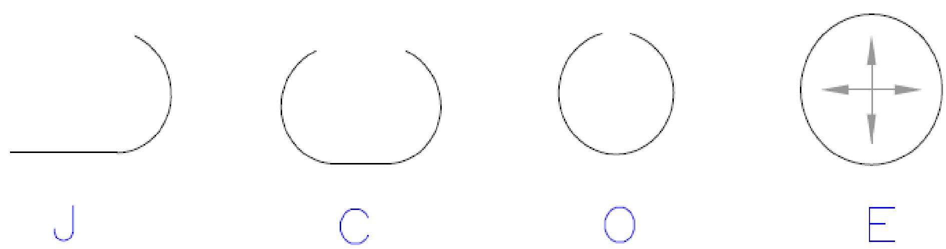

Figure 1 : Schematic of J-C-O-E Process.

III. Results And Discussions

The experimental TMCP and AC steel having lath-type and bainitic-type ferrite with high dislocation density as shown in figure # 02 in TEM microstructure and the line pipe formed from the experimental steel plate shown as in figure # 03.

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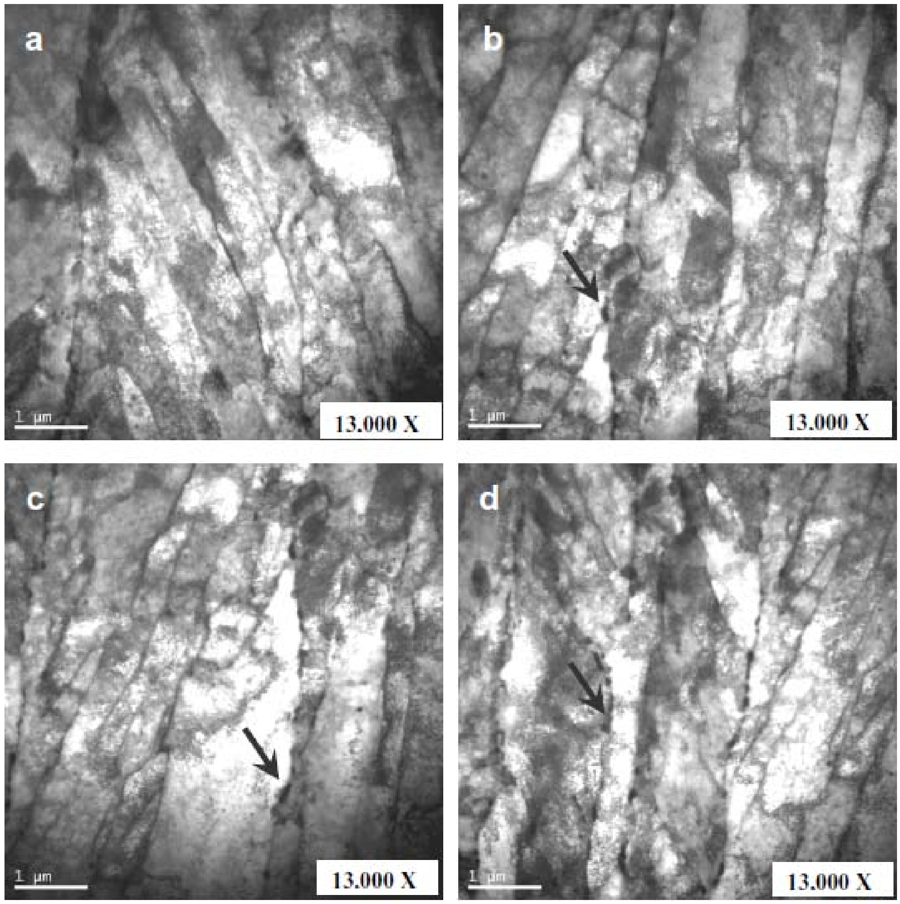

Figure 2 : Bright field TEM micrographs showing lath-type and bainitic-type ferrite with high dislocation density. Inter-lath carbides are indicated with arrows.

Figure 3 : Experimental X-120M Plate and Mechanically Expanded Line Pipe

The tensile testing has been carried out on experimental steel plate and line pipe for UTS, YS and YS/UTS ratio. The samples have been cut for above parameters as per API-5L at various stages of line pipe manufacturing namely before forming (from plate), before mechanical expansion (after line pipe forming) and after mechanical expansion during the line pipe manufacturing cycle. The results of above parameters are shown in figures # 04-09.

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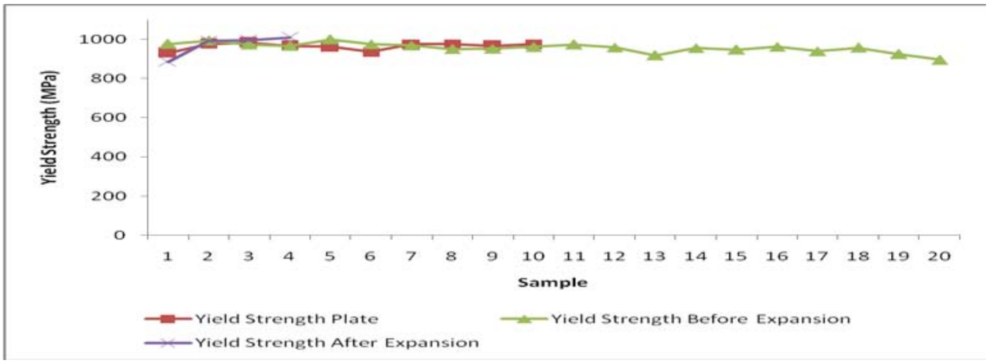

Figure 4 : Yield Strength in Longitudinal Direction of X-120M

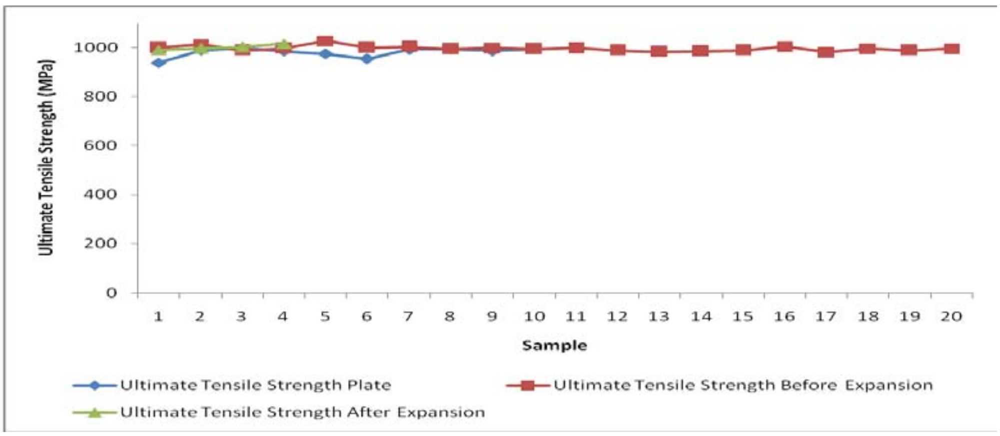

Figure 5 : Ultimate Tensile Properties in Longitudinal Direction of X-120M

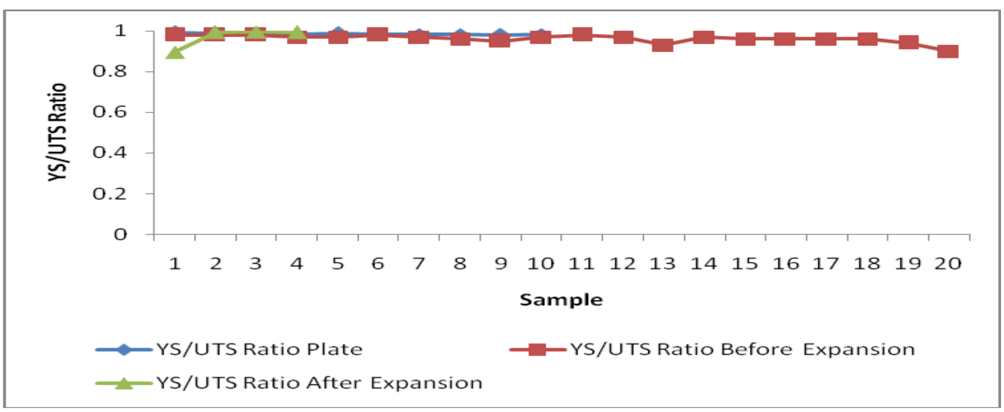

Figure 6 : YS/UTS Ratio in Longitudinal Direction of X-120M

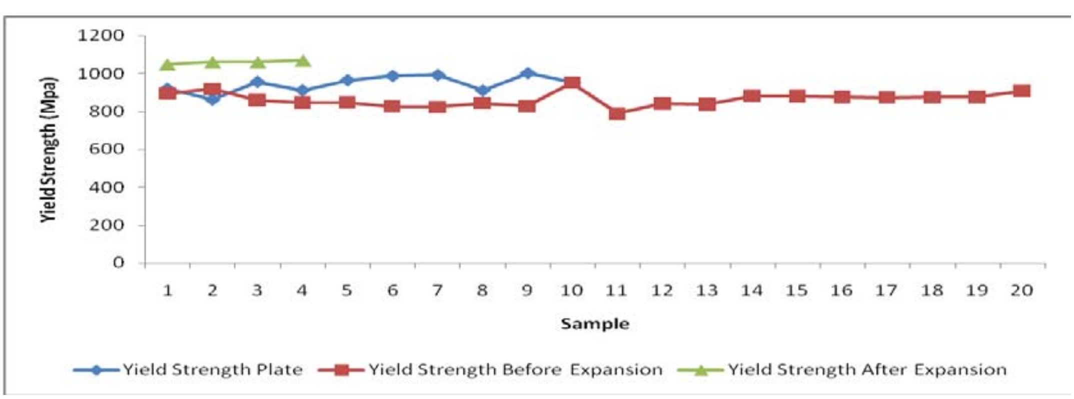

Figure 7 : Yield Strength in Transverse Direction of X-120M

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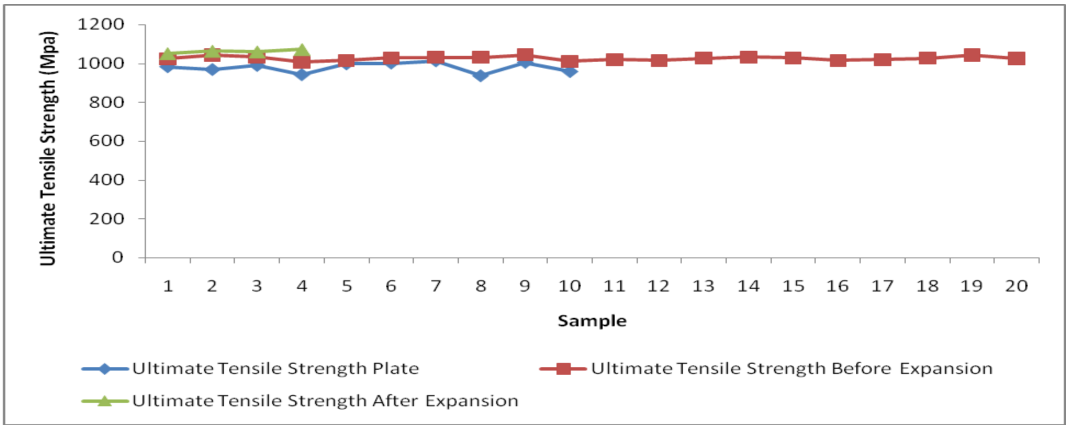

Figure 8 : Ultimate Tensile Properties in Transverse Direction of X-120M

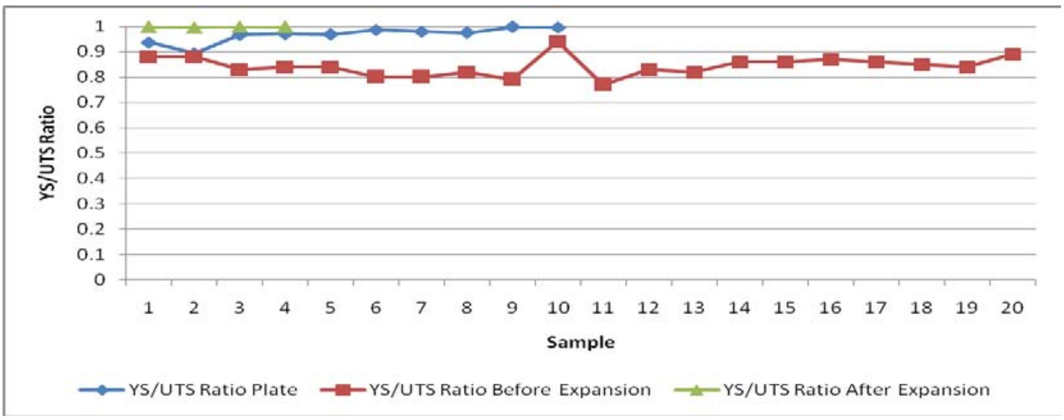

Figure 9 : YS/UTS Ratio in Transverse Direction of X-120M

Recent studies of plate to line pipe tensile properties changes have shown an increase in both YS and UTS from plate to line pipe due to work-hardening. In longitudinal direction the reverse deformation as a source of work-softening is considered less prominent form plate to line pipe. In transverse direction a decrease in the YS and YS/UTS ratio from plate to line pipe forming and increase in YS and YS/UTS ratio after mechanical expansion was observed. The YS, UTS and YS/UTS ratio remain almost same from plate to final cold expanded line pipe along the rolling direction as shown in figure # 04-06. In case of transverse to the rolling direction the yield strength after cold J-C-O-E formation decreases as compared to the plate. After cold mechanical expansion the yield strength increases as compared the plate as shown in figure # 07. The strength is achieved mainly by TMCP and AC process. During TMCP and AC process dislocations are generated and the desired microstructure has been obtained by accelerated cooling which ultimately leads to the required strength level. During the first cold forming operation the dislocations start moving and as a result generation of opposite sign dislocations, this leads to drop in yield strength. In figure # 08 the ultimate tensile strength increases marginally after both the cold forming operations. In figure # 09 the YS/UTS ratio follow the same pattern as of YS as YS/UTS ratio parameter depends on YS. On the basis of these data and some earlier work [2, 8] for line pipe X-70M and X-65M respectively, it is possible to conclude, that, during line pipe forming, two competitive processes take place in the line pipe material at the same time, work hardening due to the unidirectional straining and work softening due to the reverse cold deformation (the Bauschinger effect). During plate to line pipe cold forming the strain levels and deformation direction add to the dislocation structure formation.

IV. Conclusion

Following conclusion can be drawn from the present experimental study.

1. The values of the parameters of YS and YS/UTS drops after forming in transverse to the rolling direction of the TMCP and AC plate with respect to the values of the parameters of before forming stage and in longitudinal direction the values of the above parameters more or less remain the same.
2. The values of the parameters of YS and YS/UTS increases after mechanical expansion in transverse to the rolling direction of the TMCP and AC plate and in longitudinal direction the values of the above parameters more or less remain the same.

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The Effect of Variation of Meteorological Parameters on the Tropospheric Radio Refractivity for Minna

By O. N. Okoro & G. A. Agbo
Ebonyi State University, Abakaliki, Nigeria

Abstract - This paper investigates the effect of diurnal variations meteorological parameters on the troposheric radio refractivity during dry and rainy seasons for Minna in 2008. The hourly averages of radio refractivity during dry (February) and rainy (August) seasons were calculated from the data obtained from the Center for Basic Space Science (CBSS) through Omini web. This data used for the computation of radio refractivity is a five minutes interval of the variations of meteorological parameters for each day in the troposphere for Minna. The results indicated that the hourly averages of radio refractivity during rainy season (August) are greater than the results in dry season (February). This is as a result of variations in meteorological parameters such as humidity and temperature in the lower troposphere which causes the radio refractivity to vary at different time of the day.

Keywords : *Meteorological parameters, Troposphere, Radio refractivity.*

GJSFR-A Classification: *FOR Code: 040107*

THE EFFECT OF VARIATION OF METEOROLOGICAL PARAMETERS ON THE TROPOSPHERIC RADIO REFRACTIVITY FOR MINNA

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Keywords : Meteorological parameters, Troposphere, Radio refractivity.

I. Introduction

The propagation of radio wave signal in the troposphere is affected by many processes which include the variations of meteorological parameters such as temperature, pressure and humidity. These are associated with the change in weather in different seasons of the year. These variations in meteorological parameters have resulted in refractivity changes. According to Grabner and Kvicera (2008), multipath effects also occur as a result of large scale variations in atmospheric radio refractive index, such as different horizontal layers having different refractivity. This effect occurs most often, when the same radio wave signals follow different paths thereby having different time of arrivals to its targeted point. This may result to interference of the radio wave signals with each other during propagation through the troposphere. The consequence of this large scale variation in the atmospheric refractive index is that radio waves propagating through the atmosphere become progressively curved towards the earth. Thus, the range of the radio waves is determined by the height dependence of the refractivity. Thus, the refractivity of the atmosphere will not only vary as the height changes but also affect radio signal.

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The quality of radio wave signal reception and probability of the failure in radio wave propagations are largely governed by radio refractivity index gradient which is a function of meteorological parameters changing in lower atmosphere such as temperature, pressure and humidity (Sarkar 1978; Judd 1985).

Radio waves travel through vacuum with a speed equal to the speed of light. In material medium, the speed of the radio waves is approximately c/n where c is the speed of light in vacuum and n is the radio refractive index of the medium. The value of radio refractive index (n) for dry air is almost the same for radio waves and the light waves. But the value of radio refractive index (n) for water vapor, which is always present in some quantity in the lower troposphere, is different for the light waves and radio waves. This arises from the fact that water vapor molecule has a permanent dipole moment which has different responses to the electric forces of different radio wave frequencies propagated within the atmosphere.

Radio–wave propagation is determined by changes in the refractive index of air in the troposphere (Aediji A. T., Ajewole M. O., 2008). Changes in the value of the troposphere radio refractive index can curve the path of the propagating radio wave. At standard atmosphere conditions near the Earth's surface, the radio refractive index is equal to approximately 1.0003 (Freeman .L., 2007). Since the value of refractive index is very close to unity, then the refractive index of air in the troposphere is often measured by a quantity called the radio-refractivity N, which is related to refractive index, n as:

$$N = (n-1) \times 10^{6} \qquad (1)$$

As the conditions of propagation in the atmosphere vary, the interference of radio-wave propagation is observed. Such interferences are incident with some meteorological parameters (inversion of temperature, high evaporation and humidity, passing of the cold air over the warm surface and conversely), (Valma., *et al*, 2010).

The atmospheric radio refractive index depends on air temperature, humidity, atmospheric pressure and water vapour pressure. Subsequently, meteorological parameters depend on the height at a point above the

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ground surface. Variation in any of these meteorological parameters can make a significant variation on radio-wave propagation, because radio signals can be refracted over whole signal path (Priestley and Hill, 1985). In the atmosphere, pressure, temperature and humidity decrease exponentially as height *h* increases (Falodun and Ajewole, 2006).

According to Willoughby, (2002), atmosphere has an important feature:- the vertical gradient of the refractive index, *G*. The vertical gradient of the refractive index is responsible for bending of propagation direction of the electromagnetic wave. If the value G is negative, the signal bends downward (Guanjun and Shukai, 2000). The characterization of the seasonal variation in fading and its dependence on meteorological parameters provides the way to improve transmission performance by better tailoring of performance equipment design and usage to the amount of fading expected at a given location and time of the year.

This work is, therefore, aimed at finding out the diurnal variation of meteorological parameters with the tropospheric radio refractivity in dry and rainy seasons at Minna for the year 2008.

II. Methodology

The meteorological parameters (pressure, temperature relative humidity) used to calculate radio refractivity for Minna were provided by Center for Basic Space center (CBSS).

The analysis were done in all the months of the year 2008, but the months of February and August results were chosen to represent the dry and rainy season in Nigeria.

The hourly variations of meteorological parameters for each day for five minute (5min) interval for each day were recorded for dry and rainy seasons in Minna. The average variation of each hour per day was calculated from the recorded data .The partial pressure of water e was determined from the equation as follow:

$$e = e_s \mathrm{H} \qquad (2)$$

where H is the relative humidity, and e_s is the saturation vapour pressure determined by Clausius-Clapeyron equation given as:

$$e_s = 6.11 exp[17.26(T - 273.16)/(T - 35.87)] \qquad (3)$$

In relation with the measured meteorological parameters such as the temperature, pressure and relative humidity radio refractivity was calculated using;

$$N = 77.6\frac{P}{T} + 3.37\ x\ 10^5 e/T^2 \qquad (4)$$

where

P = atmospheric pressure (hPa)

e = water vapour pressure (hPa)

t = absolute temperature (K)

Equation (4) may be employed for the propagation of radio frequencies up to 100GHz (Willoughby, *et al*, 2002).

The error associated with the application of the above formula is less than 0.5% (ITU-R, 2003).

III. Results and Discussion

Averages of hourly variations of meteorological parameters for each day were obtained, from the data collected for dry and rainy seasons in 2008, for Minna.

The results were used to calculate radio refractivity.

The plots of diurnal variations of radio refractivity for both dry and rainy seasons are shown in fig 1, 2 and 3 below.

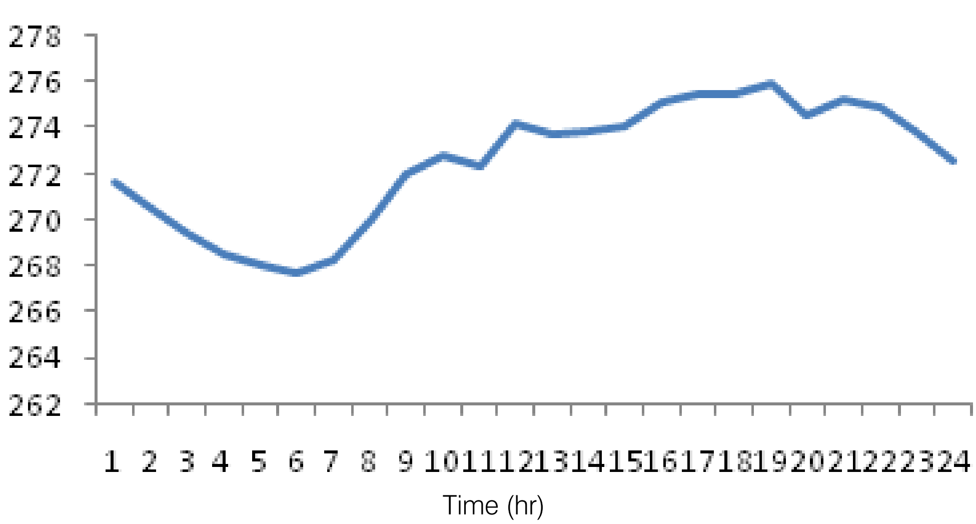

Fig 1 : Diurnal variations of radio refractivity for Day one for dry season (February)

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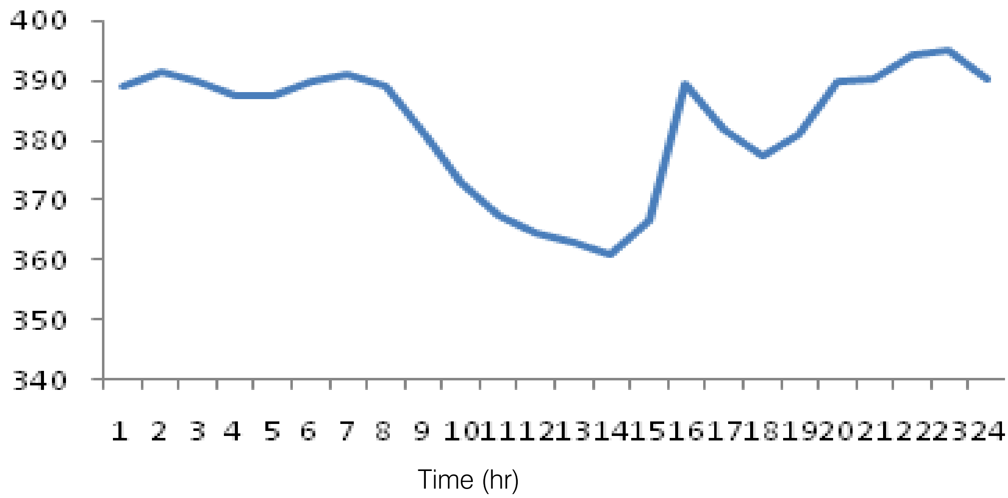

Fig 1 : Diurnal variations of radio refractivity for Day one for rainy season (August)

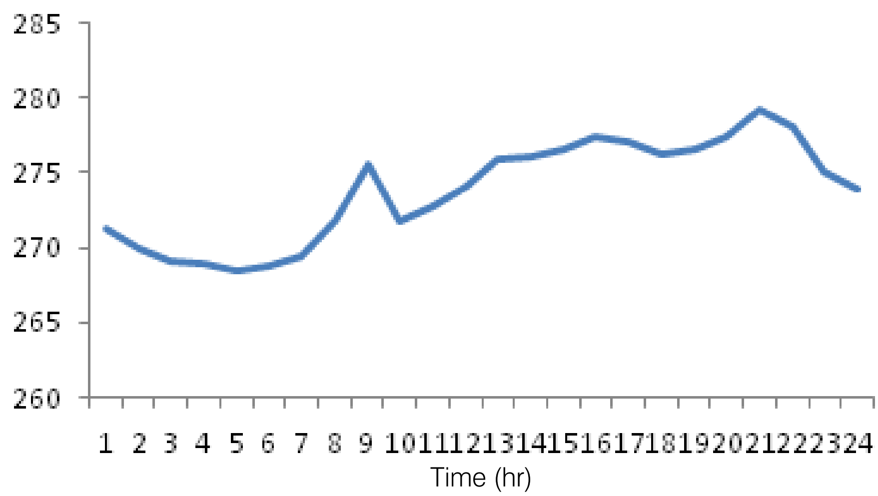

Fig 2 : Diurnal variations of radio refractivity for Day two for dry season (February)

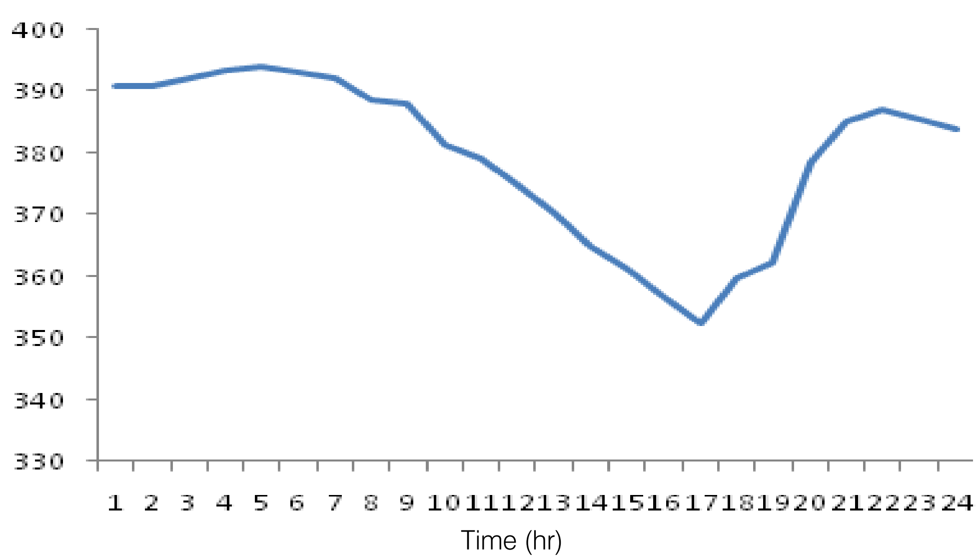

Fig 2 : Diurnal variations of radio refractivity for Day two for rainy season (August)

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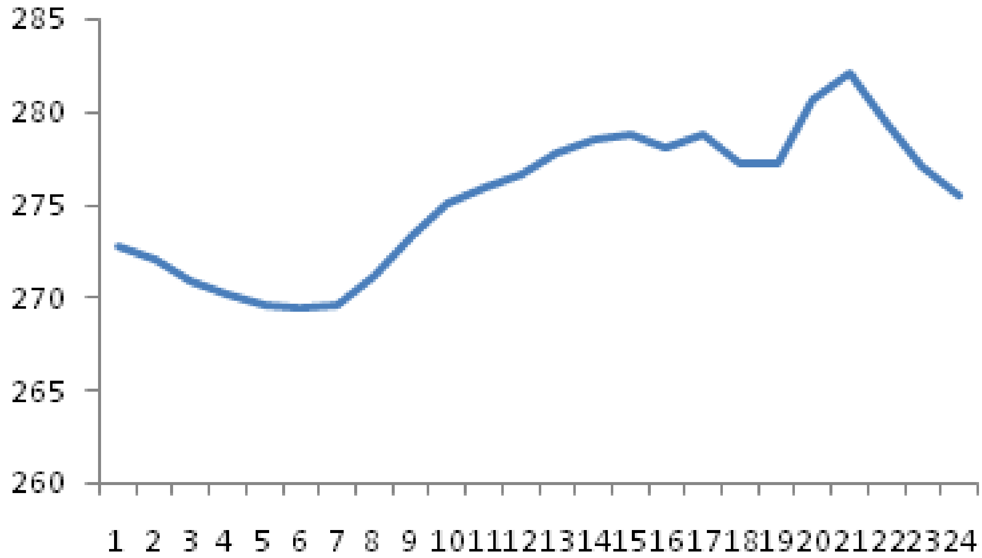

Fig 3 : Diurnal variations of radio refractivity for Day three for dry season (August)

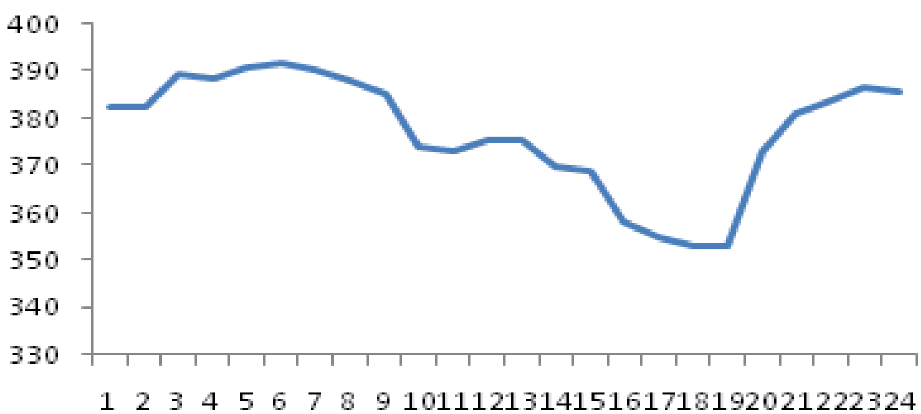

Fig 3 : Diurnal variations of radio refractivity for Day three for rainy season (August)

Minna, Niger State is located on Latitude 9° 36' 50" N and Longitude 6° 33' 24" E and is dominated by dry season within the year. The measured relative humidity was converted to water vapour pressure by applying equation (2) for both dry and rainy seasons.

The result contains both dry air and water vapor. Dry air has no significant variations in composition with altitude, (Smith and Weintrant, 1953). The amount of water vapor, on the other hand, varies widely, both spatially and temporally. Water can also exist in the troposphere in liquid phase (fog, clouds, rain) and solid form (snow, hail, ice) and the most important effect in relation to weather activities, not only presence of rain- and snowfall but also because large amount of energy are released in condensation process.

From the figures (1, 2, and 3), the hourly average values of radio refractivity plotted at 1-hour interval were observed to posses similar characteristics in dry season and also a different similar characteristics for rainy season. In fig 1, 2 and 3 of day one, day two and day of dry season, radio refractivity were observe to fall from the midnight hours (between 1:00-7:00hrs) owing to the decrease in humidity within that period of the day. Between 8:00- 21:00hrs, radio refractivity were observed to almost increase at a constant rate because of the presence of fog noticed in the early hours of the day during the period which causes humidity to vary resulting also to change in radio refractivity . At about 20:00hr, radio refractivity was found to increase to a peak value and between 22:00-24:00hrs it decreased again to a lower value resulting fall in refractivity.

In fig 1, 2 and 3, representing rainy season, radio refractivity is found to have the peak values during early hours of the day and rate hours of the night corresponding to the time that the atmosphere is mostly dominated by moisture content of water vapour which eventually increases humidity in the atmosphere. At the rate hours of the day, a decrease in radio refractivity was observed corresponding to the period when there is sun shine.

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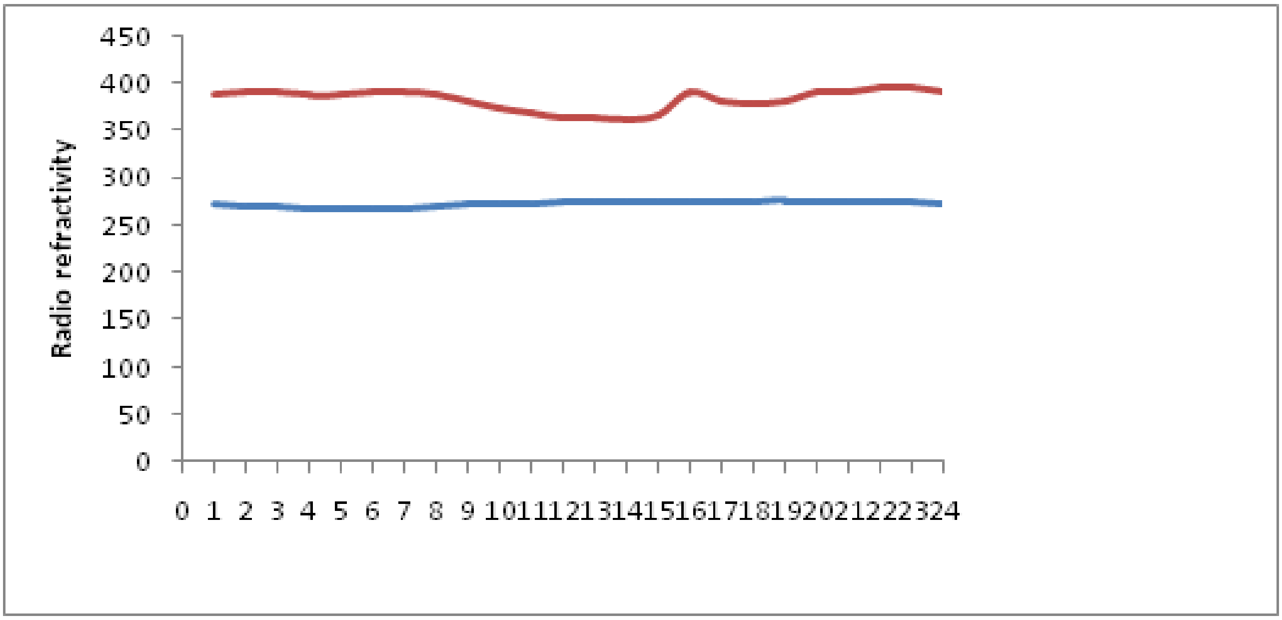

Fig 4 : Comparison of Diurnal variation of radio refractivity with time in February and August

Fig 4 shows the comparison of diurnal variation of radio refractivity with time in February and October. In figure 4, there are high variations of radio refractivity due to the changes in weather in the lower troposphere during rainy season than in the dry season which almost varies linearly with time. This may have resulted in the changes in atmospheric weather condition corresponding to this period which is accompanied by high moisture contents in the troposphere. This high moisture content resulted in the changes of radio refractivity.

IV. Conclusion

The work has shown that the effect of meteorological parameters on the tropospheric radio refractivity in Minna has being attributed to seasonal variations in weather in the troposphere most especially at the lower part (below sea level). This variation in weather was observed to be more significant during the rainy season than the dry season in Minna owing to the increase in the tropospheric temperature and humidity, and it therefore resulted to very high radio refractivity within that period.

V. Acknowledgement

The authors wish to express their profound gratitude to the Center for Basic Space Science, University of Nigeria, Nsukka for their services.

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Geo-electric probe for Groundwater in Giri, Nigeria

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Abstract - This project report focuses on the relevance of electrical resistivity method in ground water investigations; past research works on the use of this method are mentioned. Geology and hydrogeology of the study area are investigated, an adapted version of the national verification form for provision of potable water, schematic of the Federal Capital Territory (FCT), maps of the drainage pattern, hydro geology, geology of the study area and other relevant maps are presented. ABEM terameter 300c and other geophysical equipments are employed in measuring resistivity readings over a region of 900 000m2 within the university of Abuja permanent site. This region is characterised by rock outcrops of various sizes, predominantly granites and quartz. Wener array is employed in this survey; it is well established from past research work (Leoflinch, 2001) that depth of fractured rock was 24.5m-VES 1. Current dipoles separation must be three times this depth i.e. 75m; hence electrode separation of 25m is adopted. Ten parallel traverses, each of length 1000m, separated from each other by 100m are marked out, over which readings are taken at intervals of 25m. From field data, apparent resistivity maps are drawn by employing 3d field software; low resistivity zones of well fractured rocks—which delineated the productive from the unproductive zones—are observed as potential harbours for ground water.

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GEO-ELECTRIC PROBE FOR GROUNDWATER IN GIRI, NIGERIA

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Introduction, Materials and methods, Results, discussion, Acknowledgements, References

I. Introduction

a) General introduction

The final relocation of government from Lagos to Abuja in 1991 brought about a massive influx of people into the Gwagwalada area council of which Giri is a part. The population grew from 150 000 to 500 000 between 1991 and 2004 (Uzodinma, 2004). There are 63 boreholes which supplies potable water to 29 communities in Gwagwalada (Table 1). The facility often breaks down causing shortage in water Supply; they are reticulated. Within Giri, there is an intake structure at river Wuye with a package treatment plant which draws water at 50m^3/h. There are two bore holes and pumps. Due to the increasing population in this region and inadequate supply of water in Gwagwalada, there is the need to seek for other source of water to meet the people's demand. It is in this light that the research work was conducted within the University of Abuja permanent site in Gwagwalada. The main objective is to delineate locations within the survey which have potential for groundwater. The region of interest is located within basement complex with fractures and faults. This complex is composed of enclosed aquifers within the weathered overburden and structures like faults, joints and features (Enslin, 1961)

The use of electrical resistivity method dates back to 1970 in mineral and ground water exploration. Reputed for its success ((Emenike, 2001; Okwueze and Ezeanyim, 1991; Okwueze, 1996), this method was employed for ground water investigation in Barkumbo valley, Gudun hill area and Tambari valley, very close to Bauchi state, from which highly weathered basement materials were revealed, leading to the suggestion that parts of the Barkumbo valley are best suited for a borehole programme (Shemang et al, 1994). Resistivity measurements of upper aquifer was conducted around Lake Alau area in Maiduguri; Results of this study showed that water table of upper aquifer system is the source for ground water being tapped from hand dug wells in the region (Alkali, 1995). Geoelectric investigations of ground water resources were conducted at Onibode area, near Abeokuta, south western Nigeria; delineated aquifer units, observed beneath the weathered layer and beneath the fractured basement rocks were identified as probable drilling zones of water supply boreholes. This method was utilized to determine the possibility of sinking a mechanised borehole in Gwagwalada area council secretariat (Leoflinch, 2001)

The outcome of Geo-electric investigation of groundwater resources by Oyedele, (2000) in which two aquifer units were delineated and conclusion by Olayinka, (1990)-cited by the former-that resistivity range of 10Ωm to 200Ωm harbours weathered zones, are favourably pertinent to this research; thereupon, impact–wise, ambiguities and enigmas normally associated with geophysical data, are reasonably improved, meaning conferred reliability on result of this survey is enhanced. The main objective of this investigation is to delineate locations within the survey area which have potential for groundwater. The outcome of this result will hopefully address the water supply problem of the University's permanent site; this research will also assist ground water development in the region.

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S/N	Name of Community	Number of boreholes	Number of hand pumps	Number of taps	Remarks
1	Tungan Maje	1	2		
2	Paikon Kore	4	3		
3	Dobi	6	3	10	
4	Zuba	6	4	10	
4a	Zuba Market	1		40	
5	Pmasso	3	2	20	
6	Anagada	2	2	30	
7	Machada	2	2	10	
8	Pagnada	2	2		
9	Dukwa	3	3		
10	Wuna	2	2		
11	Chitumu	1	1		
12	Gurfata	2	2		
13	Kutunku	2	2		
14	Dadabiri	2	2		
15	Pabeyi	1	1		
16	Yimi	1	1		
17	Giri	2	2		
18	Tungan Gayan	1	1		
19	Ungwan Dodo	1	1		
20	Rafin Zurfi	1	1		
21	Gwako	2	2		
22	Tsauni	2	2		
23	Shenagu	1	1		
24	Ikwa	2	2		
25	Ibwa	2	2		
26	Gwoi	1	1		
27	Kutun Sarki	3	3		
28	Kaida	2	2		
29	Dagiri	2			ongoing project

Table 1 : National data verification form for provision of potable water in Gwagwalada

b) Location of survey site

The survey site is located within the University of Abuja permanent site, 1200m from Giri junction and 150m from Giri Airport road. It is located within longitude 7009’54’’E and 7010’38”E and latitudes 8059’13”N and 8059’49”N (Figure 1).

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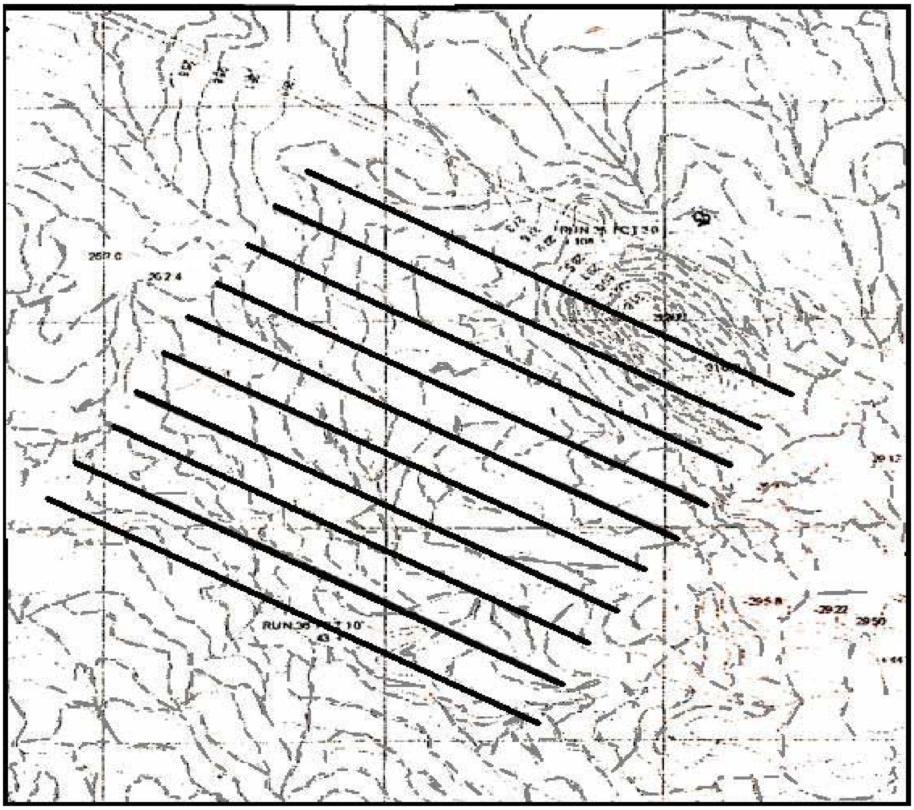

Figure 1 : Location map of the surveyed area

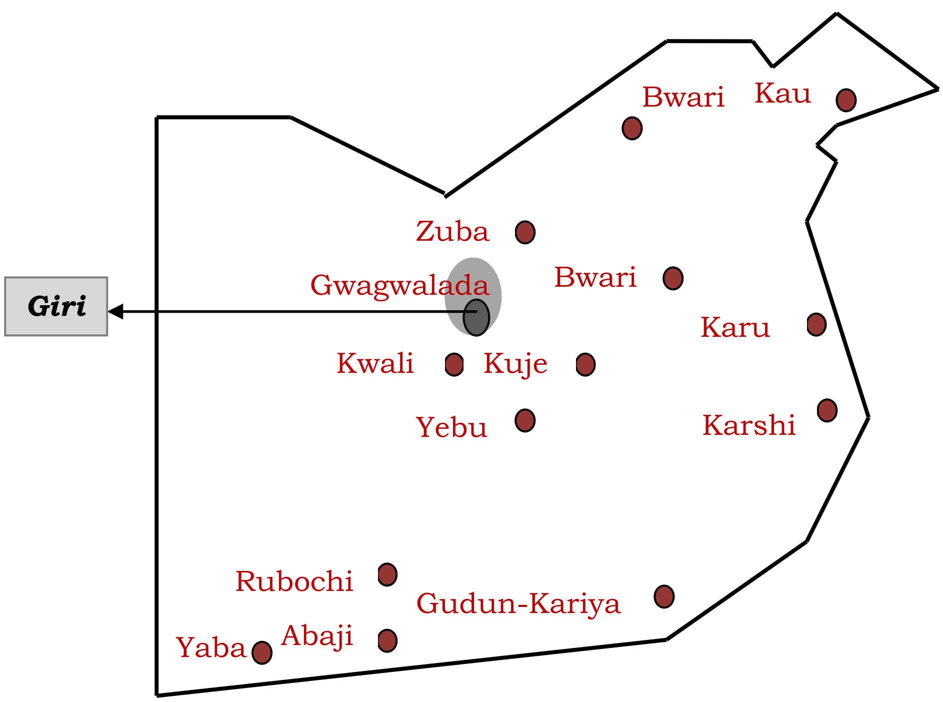

Figure 2 : A schematic of the FCT map

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c) Geology

Abuja, the Federal Capital Territory (FCT), lies within the longitude 6027’00’’E and 7023’24’’E and the latitude 8015’00’’N and 9012’00’’N (Ideh and Sanni, 1998). It covers 8000km2 area, more than twice the area of Lagos state. Underlying the FCT, almost predominantly are, high grade metamorphic and igneous rocks of the Precambrian age (Mamman and Oyebanji, 2000). Generally the North North East (NNE) and South South West (SSW) of the FCT are made of gneiss, migmatites and granites which characterize the Northern Nigeria. The out crop of schist belt is found along the Eastern margin of the area. This belt broadens as one moves south wards and maximum size is found to the South Eastern region of the FCT.

The geology of the FCT is same as that of Gwagwalada and Giri. The area like most Northern Nigerian region is underlain by basement complex.

The rocks found in Gwagwalada consist of granite, gneiss, diorites, horn blende schist, mica schist, feldspathic quartz schist and migmatites (Figure 2).

While some rock outcrops are found in various places around, some are concealed by a thin weathered layer.

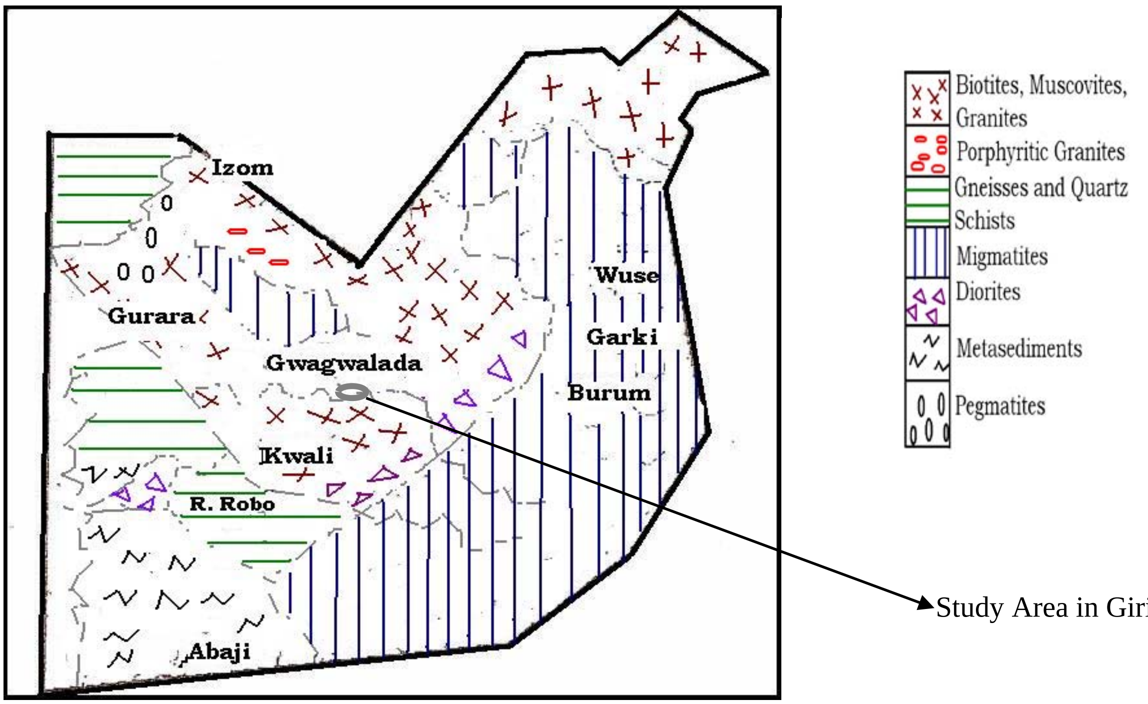

Figure 2 : The Geologic map of the Federal Capital Territory

The granites vary from medium to coarse-grained types. They are grey coloured, massive and homogeneous. The survey site reveals various rock outcrops, consisting of grey coloured granites, scattered and isolated in some regions and also appearing as bands in some other regions.

These granite outcrops are most numerous within streams and rivers.

There are also small fragments of quartz rock spread around the region as well as granites, which are compacted into the soil. They are noticed around high vegetation zone. The shrub savannah occurs extensively in rough terrain close to hills and ridges. The hills are in clusters or long range, with the Wuna range located North of Gwagwalada. There are also small fragments of quartz rock spread around the region as well as granites, which are compacted into the soil. They are noticed around high vegetation zone.

d) Hydrogeology

Water bearing rocks compose of aquifers and they consist either of unconsolidated deposits or consolidated rocks.

Consolidated rocks are made of rocks and mineral particles of various sizes and shapes welded together by heat and pressure or chemical reaction into a rock mass (Gunn and Childress, 1998);

Aquifers made of consolidated rocks-granite as an example- are found in the Gwagwalada regions; water flows through these rocks through fractures, gas pores and other openings in them.

Most unconsolidated deposits consist of material gotten from the disintegration of consolidated rocks. Some or all of the following materials in various combinations are examples of unconsolidated deposits. They are soil-like materials, gravel sand, silt clay and fragments of shell of marine organisms.

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Worth mentioning is the fact that physical properties of aquifer materials and aquifer themselves, that is thickness and depth are important in determining how quickly ground water will move and what channel it will take as it moves through the aquifer. This is because the thicker and deeper the aquifer the less porous the aquifer is and it will take some time for groundwater to move and assume the direction where pores and fractures are located. This knowledge helps in deciding how best to get water out of the ground for drinking. In the basement complex, ground water is highly localised and aquifers develop from the secondary weathering, usually induced by fracturing and other tectonic activities (Offodile, 1988). The greatest amount of water flows through joints.

e) Rivers and drainage pattern

In Giri, there is an intake structure at River Wuye with a package treatment plant which draws water at 50m3/h.

River Wuye is one major river in the Giri region which is surrounded by tributaries. It flows into River Usuma. River Usuma is a tributary of River Gurara (Figure 3); the river is 8000m from the survey region. Rivers are good surface water resources. Ground water within this region of interest is recharged by surface precipitation-lateral flow from the above-mentioned rivers and tributaries.

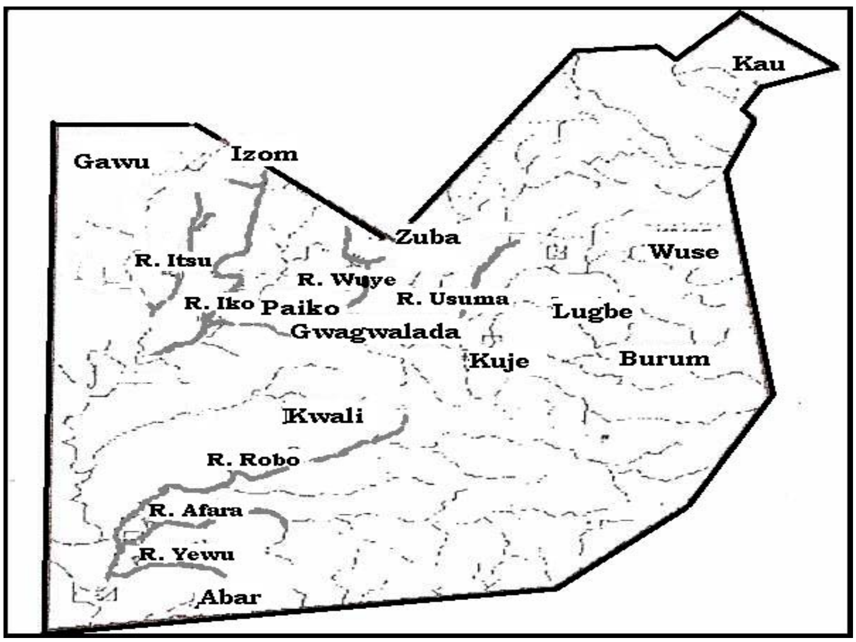

Figure 3 : River /drainage pattern of the Federal Capital Territory

f) Rainfall

In Gwagwalada, there are two prevalent seasons namely, the rainy and dry seasons. The rainy season falls within the period of April and October; the dry season falls within November and March (Physical setting, 2003). The temperature drops from 950F (350C) during the dry season to 770F (250C) during rainy season due to dense cloud cover. The relative humidity rises in the afternoon to 50%. The annual range of rainfall for the federal capital territory is in the order of 1100mm to 1600mm.

Gwagwalada enjoys higher rainfall total than the more southerly regions of the FCT. The FCT experiences heavy rainfall occurrence during the months of July, August and September. These three months contribute about 60% of the total rainfall in the region (Dawam, 2000)

One of the past works is the report of geophysical investigation of Leoflinch house at phase 1, behind university of Abuja male hostel. The result showed overburden thickness of between 10m to 12m (Leoflinch 2001).

The lithology of formation is given as:

Top soil (0.77m thick), ferrogenised sandstone (3.3m), highly weathered rock (21.5m), and fractured rock (24.5m)-VES 1

Top soil (0.83m), ferrogenised sand stone (2.8m), sand stone formation (3.0m) and weathered/fractured rock (23m)-VES 2

Four distinct strata were identified within the subsurface; these were the overburden, weathered, fractured and bed rock.

Deep-rooted fracture zone is envisaged between 36 to 50m which will further enhance the bore yield. Total depth of borehole is 50 to 55m (Leoflinch 2001).

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II. Materials and Method

a) Electrical resistivity method

The electrical resistivity method was employed in this survey for ground water. It measures the apparent resistivity of soils and rocks as a function of depth or position (Geovision, 2000). Resistivity of soil is function of porosity, permeability, ionic content of pore fluids and clay mineralisation. Current flow is always perpendicular to equipotential lines when the ground is uniform; however when inhomogeneity is present, resistivity changes with electrode configuration and the value derived is "apparent resistivity ". Wener array was employed in this survey.

Current density and voltage

For current I, flowing into ground via current dipoles over some hemispherical shell, we have, Current density:

$$J = \frac{I}{2\pi r^2} \quad (1)$$

Where current density, J decreases as distance r, increases during dissipation of current I. Voltage change across a hemispherical sphere of radius r and thickness δr is expressed as:

$$\delta v = -\rho \delta r I \frac{\rho \delta r I}{2\pi r^2} = -\rho J \delta r \quad (2)$$

Voltage at an arbitrary point r is given by:

$$V_r = -\int dv = -\int \rho J \delta r = -\int \rho \frac{\rho I}{2\pi r^2} dr \quad (3)$$

The above expression leads on, to the expression for the apparent resistivity for wener array (Figure 5):

$$\rho_a = 2\pi a R = RG \quad (4)$$

where G—referred to as geometric factor, for wener array—is given by $2\pi a$;

The most probable single but important factor controlling resistivity of rocks –sedimentary rocks- is the resistivity of pore fluid as explained by Archie's law. In 1942, Archie expressed the effective resistivity, ρ, of rocks as:

$$\rho = a\emptyset^{-m} S^{-n} \rho_w \quad (5)$$

$$F = \frac{\rho}{\rho_w} \quad (6)$$

Where a, m and n are empirically determined constants in which we take $0.5<a<2.5$, $1.3<m<2.5$ and $n\approx 2$; Ø is the porosity, S is the volume fraction of pores with water and ρw is the resistivity of the solution in the pores—electrolyte or water--of the rock.

In his review, Slater (2007), expounded the permeability equation defined by

$$k = \frac{\emptyset (r^2)}{aT} \quad (7)$$

$$k = \frac{c l_c^2}{F} \quad (8)$$

The four parameter Cole-Cole model was also considered, given by

$$\sigma^*(\omega) = \sigma_0 [1 + m_g (\frac{(i\omega\tau)^c}{1+(i\omega\tau)^c (1-m_g)})] \quad (9)$$

All stated parameters in 5, 6, 7, 8 and 9 are pertinent to resistivity values of earth sample—they control these values.

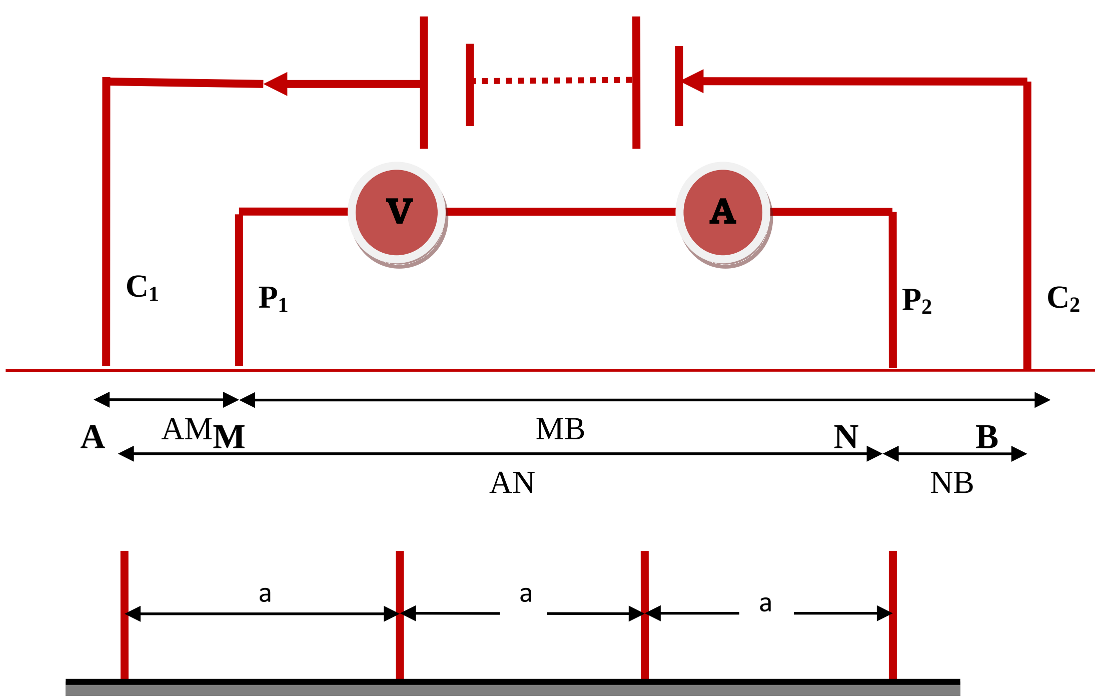

Figure 5 : Wener array electrode configuration

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Where ω is frequency, σ_0 is the dc conductivity, $\sigma^*(\omega)$ is the frequency dependent electrical response of soils—or complex electrical conductivity, m_g is global changeability given by $m_g = 1 - \sigma_0/\sigma_\infty$, where σ_∞ is the conductivity at high frequency, time constant τ, l_c is the percolation threshold length—scale controlling fluid flow, ρ_a is the ground apparent resistivity, ρ is the effective resistivity of rocks, k is the permeability, μ is the fluid dynamic viscosity,$\emptyset$ is the porosity, g is gravitational acceleration, $i = \sqrt{-1}$, F is the cementation factor and c=1/226

b) Instrumentation

The ABEM terameter SAS 300C was employed during the survey to measure resistance values; these values were displayed on the visual display unit. Multiple values showed up initially but a single value was retained with time; this electronic device measures ground resistivity in mΩ, Ω or kΩ. The product of every single resistance value and an appropriate geometric factor gave values of apparent resistivity. A specially built battery supplied some voltage to the terameter.

c) Field procedure

The survey conducted, stretched through an area of 900 000m^2. Grasses and shrubs along the profile were mowed with the cutlass. Thereafter, the field was divided into ten traverses or profiles; each profile was 1000m long and inter-profile spacing was 100m. 41 holes, separated by 25m, one from the other, were dug along each traverse; 41 wooden pegs were driven into them with the mattock hammer.

Four electrodes were co linearly planted in the ground alongside each peg. The first and last electrodes were the current electrodes and the second and third electrodes were the potential electrodes. With the aid of banana plugs and sockets of 4mm, crocodile clips and a pair of cables of black and red coloured insulation, all four electrodes were connected to the terameter. Current was injected through current electrodes into the subsurface, once the terameter was switched on; following this potential difference between the second and third electrodes was measured through potential electrodes. 41 ground resistance values were measured per profile and 410 values were recorded for the entire survey. To derive apparent resistivity values, each ground resistance value was multiplied by geometric factor of 157.1m (wener array).

d) Electrode separation

Electrode separation of 25m was adopted based on past geophysical report (Leoflinch, 2001); the result showed overburden thickness of 10m to 12m. The lithology of formation showed thicknesses of top soil (0.77m), ferrogenised sandstone (3.3m), weathered rock and fractured rocks (46m). The target depth for wener array equals electrode separation. Only 30% of current flow beneath this depth, therefore to energise a target, electrode separation typically needs to be 2 to 3 times its depth, hence current dipole separation of 75m was adopted which implied electrode separation of 25m.

III. Conclusion

a) Data acquisition

Table 2 is a collection of resistance values for profile 1 to 10 for 41 probe points with inter-probe separation of 25m. Table 3 is a collection of corresponding apparent resistivity values for profiles 1 to 10 with inter-probe separation of 25m meters. These apparent resistivity values were derived by multiplying each resistance value by geometric factor 'G'=2πa=157.1m.

b) Data analysis, interpretation and results

Table 2 : Resistance values in ohms for profiles 1 to 10

Point probe	Distance in meters	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	0	3.19	3.96	3.46	2.52	3.07	3.93	3.47	3.54	2.69	2.34
2	25	3.51	5.89	1.39	2.61	4.57	5.84	1.39	5.27	2.96	2.42
3	50	3.70	4.37	3.37	3.33	3.39	4.33	3.38	3.91	3.12	2.16
4	75	4.47	3.38	3.45	2.68	2.62	3.35	3.46	3.02	3.77	2.48
5	100	5.23	0.21	3.28	2.44	0.16	0.21	3.29	0.18	4.41	2.26
6	125	4.72	3.82	3.23	2.25	2.96	3.79	3.24	3.41	3.98	2.55
7	150	5.41	3.17	5.00	3.49	2.46	3.14	5.02	2.84	4.57	3.23
8	175	5.79	2.64	7.82	3.16	2.05	2.62	7.85	2.36	4.89	2.93
9	200	6.95	2.67	2.64	3.94	2.07	2.65	2.65	2.39	5.86	3.65
10	225	10.63	0.14	2.8	2.60	0.12	0.14	2.18	0.14	8.97	2.41

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11	250	7.66	1.78	2.82	5.54	1.38	1.76	2.83	1.59	6.46	5.13
12	275	8.43	0.16	4.49	2.49	0.13	0.16	4.51	0.15	7.11	2.31
13	300	7.26	2.90	3.99	1.97	2.25	2.88	4.00	2.6	6.13	1.82
14	325	6.29	3.50	5.86	2.35	2.71	3.47	5.88	3.13	5.31	2.18
15	350	5.87	3.66	5.93	2.96	2.85	3.65	5.95	3.29	4.95	2.74
16	375	4.89	2.99	6.41	3.27	2.26	2.89	6.43	2.61	4.13	3.03
17	400	4.98	3.22	6.90	3.03	2.50	3.19	6.92	2.88	4.2	2.81
18	425	5.58	3.68	7.03	2.55	2.85	3.65	7.05	3.29	4.71	2.36
19	450	6.03	3.40	8.14	4.52	2.64	2.50	4.48	3.04	5.02	4.22
20	475	9.50	3.67	6.54	4.55	1.34	3.64	10.54	1.55	8.02	4.22
21	500	2.36	2.38	6.23	5.24	1.41	3.16	6.21	1.62	1.99	4.86
22	525	3.76	2.87	4.94	6.76	1.32	2.85	4.96	1.52	4.46	6.26
23	550	4.74	2.04	4.37	5.97	1.46	3.08	4.38	3.48	4.00	7.00
24	575	6.33	2.88	4.12	7.77	3.26	2.86	4.13	3.76	3.68	7.20
25	600	6.73	2.58	4.40	8.44	2.00	2.56	4.41	3.75	5.54	7.82
26	625	7.06	5.19	3.83	3.15	2.50	5.15	3.84	2.88	8.35	2.92
27	650	8.25	5.09	3.32	16.5	2.14	5.05	3.38	2.85	10.37	15.29
28	675	7.92	5.41	4.80	5.29	4.01	5.37	4.82	4.63	9.39	4.90
29	700	8.42	13.85	3.93	9.27	2.28	13.7	3.94	2.63	9.98	8.59
30	725	10.93	7.74	3.27	8.25	5.65	7.68	3.28	6.52	12.95	8.11
31	750	9.73	18.27	5.31	6.32	10.3	13.2	5.33	11.9	11.53	5.86
32	775	16.93	7.58	2.78	8.72	5.95	7.62	2.79	6.86	20.06	8.08
33	800	4.72	6.84	3.73	1.15	5.30	6.78	8.74	6.11	5.59	1.06
34	825	8.76	4.92	3.74	4.97	3.81	4.88	3.75	4.39	10.38	4.61
35	850	11.91	5.68	5.35	4.18	4.4	5.63	5.37	5.07	10.05	3.87
36	875	6.26	3.09	4.12	3.03	3.81	3.06	4.13	4.39	5.28	2.81
37	900	9.23	0.38	4.59	1.74	0.30	0.38	4.60	0.35	7.79	1.61
38	925	9.45	4.93	5.26	2.79	3.82	4.89	5.28	4.41	7.97	2.59
39	950	5.44	5.51	3.98	2.37	4.27	5.46	3.99	4.92	4.59	2.20
40	975	5.29	4.53	4.78	2.81	3.51	4.49	4.80	4.05	4.46	2.60
41	1000	3.80	4.19	3.98	11.79	3.25	4.16	3.91	3.75	3.21	10.93

Table 3 : Apparent resistivity values for profiles 1 to 10

Probe point	Distance in meters	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	0	501	622	544	396	482	617	545	556	423	360
2	25	551	925	218	410	718	917	218	828	465	380
3	50	581	686	529	366	533	680	531	614	490	336
4	75	702	531	542	421	412	526	544	474	592	392
5	100	822	33	515	383	25	33	517	28	693	333
6	125	741	600	597	432	465	595	509	536	625	400
7	150	850	498	785	548	386	493	789	446	718	500
8	175	909	415	1228	496	322	412	1233	371	768	460
9	200	1092	419	415	619	325	416	416	375	920	570
10	225	1670	22	440	408	19	22	441	22	1409	378

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11	250	1280	279	443	870	217	276	445	250	1015	800
12	275	1324	26	705	391	20	25	798	24	1117	30
13	300	1140	456	627	309	393	452	628	408	963	286
14	325	988	550	920	169	426	545	924	492	834	342
15	350	922	578	931	465	448	573	935	517	778	430
16	375	768	457	1007	514	355	354	1010	410	649	470
17	400	782	506	1084	476	393	501	1081	452	660	44
18	425	877	578	1104	401	448	573	1107	512	714	371
19	450	947	534	1279	710	415	393	704	478	800	658
20	475	1490	576	1027	715	211	573	1651	243	1260	663
21	500	371	374	979	823	221	497	975	254	313	763
22	525	591	451	776	1062	207	448	779	239	701	983
23	550	745	320	686	281	230	484	688	547	628	1100
24	575	994	452	647	1221	512	449	649	590	578	1131
25	600	1057	405	691	1326	314	402	693	589	870	1228
26	625	1109	815	602	495	393	809	603	452	1315	459
27	650	1296	800	529	2592	379	793	531	448	162	2402
28	675	1244	850	754	831	630	843	757	727	1475	770
29	700	1323	2176	617	1456	358	2158	619	413	1568	1349
30	725	1717	1216	514	1304	888	1206	515	1024	2034	1274
31	750	1928	2084	834	993	1616	2067	837	1865	1811	920
32	775	2659	1206	437	1320	935	1197	438	1078	3151	1269
33	800	741	1074	586	180	833	1065	587	960	878	167
34	825	1376	773	581	781	598	767	889	686	1530	724
35	850	1872	882	840	652	691	884	844	796	1529	608
36	875	983	485	647	476	592	481	649	690	829	441
37	900	945	60	764	271	47	60	723	55	1224	253
38	925	1484	774	826	438	600	768	829	693	1252	402
39	950	855	866	625	372	671	858	627	773	721	346
40	975	831	712	751	441	551	705	754	636	701	408
41	1000	597	658	625	1852	511	653	614	589	504	1717

Interpretation is qualitative; apparent resistivity values versus distance are plotted on profile maps and drawn as contours. As cited by Wyatt et al, ward (1990) suggests that wenner method is effective in terms of: high signal to noise ratio with good resolution of horizontal layers, moderate rating for the resolution of steeply dipping structures and moderate sensitivity to surface inhomogeneity; based on these, it is well established (Leoflinch, 2001; Telford, 1990) that the sharp drop in resistivity values which is indicative of some sort of discontinuity within two zones 550m and 850m respectively from the Giri-Airport road, may suggest the presence of faults or fault zones—zones having potential for ground water. Contour map was generated using 3D field software. The raw field data was first smoothened, before contours were drawn. Areas of interest are those situated within low resistivity zones.

IV. Discussion of Results

Resistivity values on profile maps (Figure 6) generally undulates west wards and rises steeply eastwards; peak values are observed between 600 and 800 Ωm for most profiles. Information on profile maps have been translated to apparent resistivity contour map (Figure 7).

At 625m from the east end, three zones of resistivity range of 1200 Ωm to 2000 Ωm are observed, according to figure 2. These zones are observed as peak points of the wiggles drawn on the profile maps in figure 1. The first zone is located within longitudes of 7^{0}10’21’’E and 7^{0}10’38”E; and latitudes of 8^{0}59’31”N and 8^{0}59’35”N respectively. The second zone is located within longitudes 7^{0}10’21”E and 7^{0}10’38”E; and latitudes 8^{0}59’28”N and 8^{0}59’29”N. The third zone is located within longitudes 7^{0}10’21”E and 7^{0}10’38”E; and latitudes

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8059’13”N and 8059’19”N. These zones are rich in massively bedded rocks as well as fresh crystalline rocks. Between these three zones are two isolated spots having resistivity values peaking at 800 Ωm; there are possibilities of granite and quartz.

Two isolated zones each of 200 Ωm peak resistivity value are spotted between the 5^{th} and 6^{th} profile; and 8^{th} and 9^{th} profile; these two regions marked as productive, are delineated away from the unproductive region, defined by resistivity values acquired during investigation. The first and second zones are 550m and 850m respectively, away from the Giri-Airport highway. The first zone is located within longitudes $7^0$10’00”E and $7^0$10’11”E and latitudes $8^0$59’29”N and $8^0$59’33”N. The second zone is located within longitudes $7^0$09’57”E and $7^0$10’16”E and latitudes $8^0$59’41”N and $8^0$5945”N. These zones are granitic fault zones, with presence of weathered granite, weathered and fractured rock.

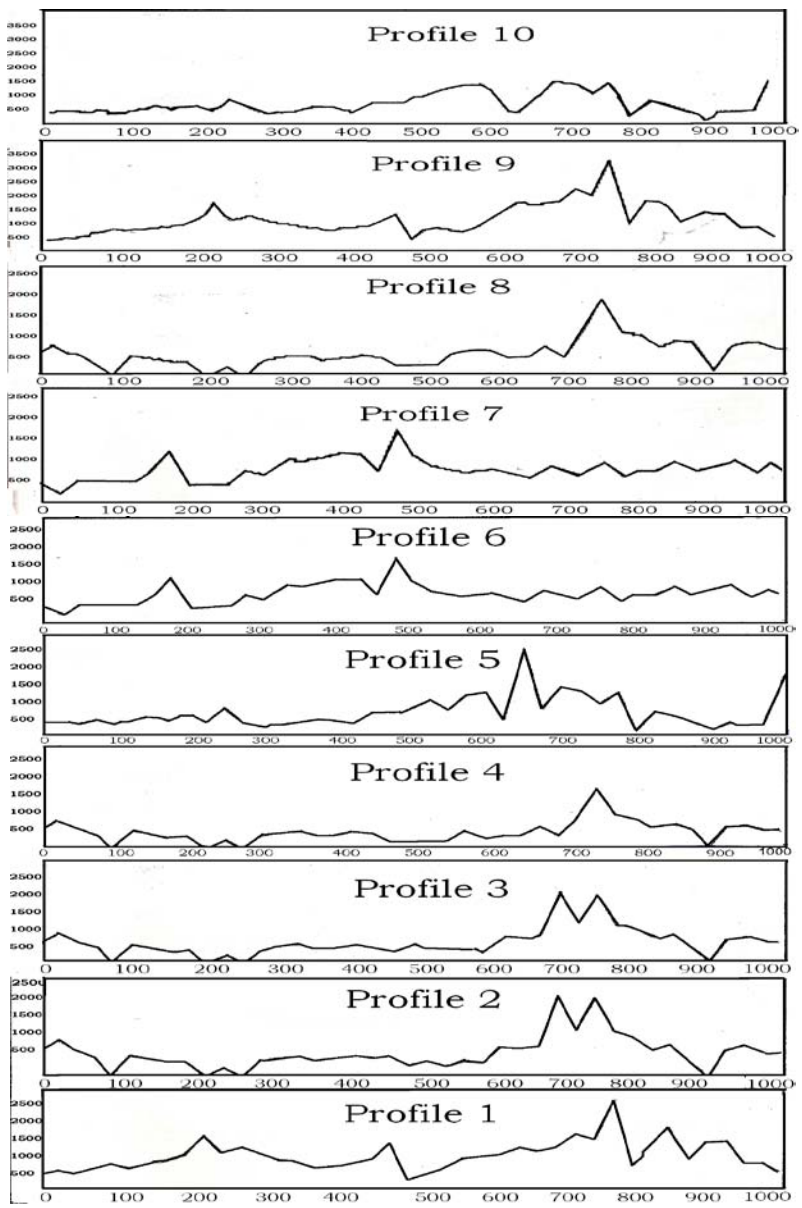

Figure 6 : Resistivity Profile map, showing profiles 1 to 10; it indicates resistivity versus distance

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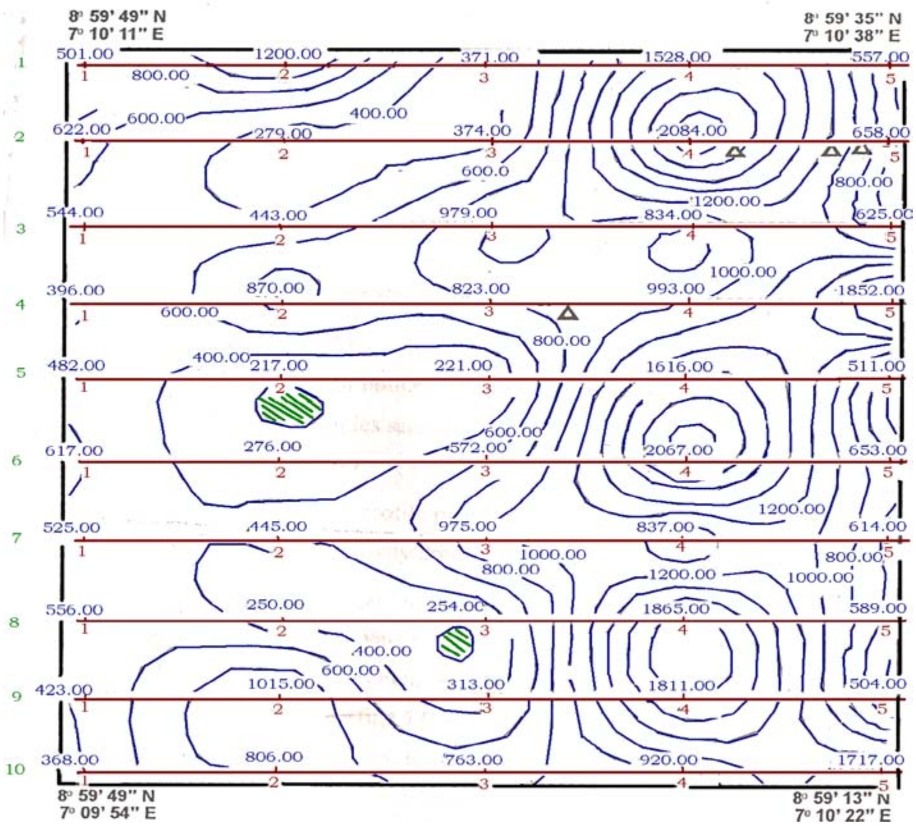

Figure 7 : Apparent resistivity map of the area under survey

a) Conclusion

Past investigations which employed electrical resistivity method have been mentioned, data of ongoing potable water projects for Gwagwalada have been presented and with the aid of a geologic map, the geology of the study area have been described; hydrogeology of this region have also been explained; additionally, field procedure have been described and a suitable electrode separation of 25m have been adopted. Ground resistance and apparent resistivity data of the study area have been acquired; data have also been analysed.

Two isolated zones 550m and 850m respectively from the Giri-Airport highway are identified as having potential for ground water, based on resistivity values of present report with peak value as 200 Ωm and past geophysical report by Leoflinch.

These zones are identified to harbour faults, fractured zones and weathered rocks. The first zone is located within longitudes $7^0 10'00''$E and $7^0 10'11''$E and latitudes $8^0 59'29''$N and $8^0 59'33''$N. The second zone is located within longitudes $7^0 10'16''$E and $7^0 09'57''$E and latitudes $8^0 59'41''$N and $8^0 59'45''$N.

Further work must be directed at employing multiple geophysical techniques such as Magnetic, Seismic and Microgravity techniques for enhanced precision in the acquired results; it is expected that the use of multiple techniques will infer that faults will be well mapped and the geometry of the zone of interest will be well delineated.

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It is vital, that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

Format

Language: The language of publication is UK English. Authors, for whom English is a second language, must have their manuscript efficiently edited by an English-speaking person before submission to make sure that, the English is of high excellence. It is preferable, that manuscripts should be professionally edited.

Standard Usage, Abbreviations, and Units: Spelling and hyphenation should be conventional to The Concise Oxford English Dictionary. Statistics and measurements should at all times be given in figures, e.g. 16 min, except for when the number begins a sentence. When the number does not refer to a unit of measurement it should be spelt in full unless, it is 160 or greater.

Abbreviations supposed to be used carefully. The abbreviated name or expression is supposed to be cited in full at first usage, followed by the conventional abbreviation in parentheses.

Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

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All manuscripts submitted to Global Journals Inc. (US), ought to include:

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Abstract, used in Original Papers and Reviews:

Optimizing Abstract for Search Engines

Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

The Editorial Board and Global Journals Inc. (US) recommend the use of a tool such as Reference Manager for reference management and formatting.

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Figures: Figures are supposed to be submitted as separate files. Always take in a citation in the text for each figure using Arabic numbers, e.g. Fig. 4. Artwork must be submitted online in electronic form by e-mailing them.

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21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

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27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. **Think technically:** Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

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33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

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Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

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· Adhere to recommended page limits

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- Separating a table/chart or figure - impound each figure/table to a single page
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· Keep on paying attention on the research topic of the paper

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- Fundamental goal
- To the point depiction of the research
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- Significant conclusions or questions that track from the research(es)

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- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
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- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
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Approach:

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- Resources and methods are not a set of information.
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- Leave out information that is immaterial to a third party.

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The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

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- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
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- Present a background, such as by describing the question that was addressed by creation an exacting study.
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Approach

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	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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