STM JOURNALS

Journal of
Water Pollution &
Purification Research

ISSN: 2394-7306
Volume 12, Issue 2, 2025
May–August
DOI (Journal): 10.37591/JoWPPR

https://journals.stmjournals.com/jowppr

Review JoWPPR

The Effects of Physiochemical Parameters and Microbial Counts on Metal Coupons Corrosions in Freshwater Environment at Different Water Depths

Ejoku George[1,*], C.P. Ukpaka[2], E.N. Wami[3], E.O. Ehiri[4]

Abstract

The effect of water quality on metal coupon corrosion was investigated at the New Calabar River in Choba. The study examined metal corrosion rates at five different depths: 30 cm, 60 cm, 90 cm, 120 cm, and 150 cm in a freshwater environment. Water samples were collected at each depth and analyzed for physicochemical and microbial parameters to understand their impact on metal degradation. Key parameters measured included pH, Electrical Conductivity, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Chemical Oxygen Demand (COD), Total Hardness, Turbidity, Nitrate, Phosphate, and heavy metals such as Lead (Pb), Cadmium (Cd), Sulphate (SO_4^{2-}), Chromium (Cr), Nickel (Ni), and Copper (Cu). Additionally, microbial analyses were conducted to assess the role of biological activity in corrosion. Results indicated that physicochemical properties of freshwater varied with depth, influencing corrosion rates of the submerged metal coupons. Variations in parameters such as dissolved oxygen, turbidity, and heavy metal concentrations contributed to differences in corrosion rates and weight loss. Although Total Coliform levels remained consistent across depths, biofilm formation was observed, significantly enhancing corrosion. Furthermore, Escherichia coli (E. coli) and Salmonella species increased with depth, contributing to biofilm development and accelerating corrosion. The deeper the metal coupons were submerged, the more pronounced the biofilm formation, leading to greater metal deterioration. This study highlights the impact of depth-dependent water quality variations on corrosion processes. Understanding these influences is crucial for industries utilizing submerged metal structures to mitigate corrosion risks and ensure the longevity of materials in freshwater environments.

Keywords: Corrosion, environmental pollution, metal coupon, microbial-count, physicochemical

***Author for Correspondence**
Ejoku George
E-mail: bookings.bestino@gmail.com

[1]Reserch Scholar, Department of Chemical/Petrochemical Engineering, Rivers State University, Port Harcourt, Rivers State, Nigeria
[2,3,4]Professors, Department of Chemical/Petrochemical Engineering, Rivers State University, Port Harcourt, Rivers State, Nigeria

Received Date: March 04, 2025
Accepted Date: April 01, 2025
Published Date: April 09, 2025

Citation: Ejoku George, C.P. Ukpaka, E.N. Wami, E.O. Ehiri. The Effects of Physiochemical Parameters and Microbial Counts on Metal Coupons Corrosions in Freshwater Environment at Different Water Depths. Journal of Water Pollution & Purification Research. 2025; 12(2): 31–51p.

INTRODUCTION

Background of the Study

Metal surface get iodized by atoms most times, thereby harmed the entire surface of the metal that is what is call corrosion. Metals are prone to iodization, which occurs when they lose electrons to oxygen and other substances in the air or water.

It gains an electron and reduces its oxygen. Metals form oxides when exposed to numerous factors that contribute to the complex mechanism of corrosion. Stainless steel, Mild steel, Carbon steel, and Copper steel coupons in aquatic environments were assessed and evaluate Some of these factors are known to cause corrosion of metals associated

with aquatic environments, which occurs as a result of the physiochemical interaction of the metal with its environment [1].

The process that reduces a refined metal to its original ore is known as electrochemical deterioration, and it happens when metals and their surroundings interact [2]. In addition to reducing the metal's strength, the process may also lessen its usefulness. Both biotic and abiotic microorganisms, both living and nonliving, have an influence on how much the corrosion process is influenced. Not only can metals dissolve in water with very little dissolved salt content, but they also naturally corrode when they react with oxygen to form metal oxides. This process is known as water-borne ion dissolution. Plumbing materials dissolve gradually as a result of this process [3].

A chemical reaction between metal and its surroundings causes deterioration of the metal, which is known as corrosion. Life on a daily basis involves it. An analogy for the process would be iron rust. The process wherein a metal reacts with oxygen to form iron oxide compounds can be applied to metals or structures like bridges. Since most metals prefer to transition from an unstable, high-energy state to a stable, low-energy state, they are generally more stable in compounds than in pure metal form. Any metal can corrode, but the rate at which it does so varies. For example, stainless steel that contains iron corrodes more slowly than pure iron [4].

Since corrosion affects the water, air quality, soil, and industrial operations in the Niger Delta region of Nigeria, it has garnered significant attention in science and engineering. Since there is more oil and gas being extracted, explored, and used, the corrosion problem has actually gotten worse. Chemical engineers are at risk of metal corrosion, which is the gradual degradation of materials through chemical reactions with their surroundings. Metals can become unstable forms such as oxide, hydroxide, and sulphite formation due to materials and processes used in industrial operations on natural water as well as the environment [5].

BASIC CORROSION THEORY

It is challenging to comprehend and interpret metal corrosion without a solid understanding of corrosion theory. The fundamental ideas of corrosion theory were reviewed, including the fact that iron causes a reaction when it is submerged in water along with airborne oxygen, which leads to corrosion [6].

$$4Fe + 2H_2O + 3O_2 \longrightarrow 4FeO(OH) \quad (1)$$

This is a typical instance of iron corrosion, or rust. Upon closer inspection, it is usually discovered that this reaction is comprised of multiple distinct reactions that are taking place at various locations on the metal surface. These reactions are known as anodic reactions because they occur in anodic areas.

$$Fe \longrightarrow Fe^{2+} + 2e^- \quad (2)$$

Here Fe^{2+} ion are being produced by oxidation of the iron metal and electrons are entering the metal. In some reaction oxygen will be reduce by accepting electrons from the metal $O_2 + 2H_2O + 4e^- 4OH^-$, which is known as cathodic area to maintain charges neutrality in the metal material both the anodic and cathodic reaction must occur at the same rate, the electron produce and consumed per unit time be equal, this may not be possible due to some region of the metal material that may have high electricity resistance between the anodic and cathodic area that will retard the movement of electrons.

In order for the solution to remain neutral, diffusion cations to the cathodic area and anions to the anodic area are required. During the corrosion process, positive ions are generated at the anodic region and negative ions at the cathodic region. In a solution with a high ionic conductivity, such as seawater, diffusion happens easily. This explains why seawater corroded more quickly than freshwater. Compared to freshwater, seawater has a higher ion conductivity. The importance of corrosion is evident in

everyday life; it can lead to industrial accidents, waste money on homes and highways, and it cost industrialized nations up to 5% of their annual gross domestic product. With a basic understanding of electrochemistry, material science, and the application of science and art to prevent or control corrosion damage in a safe and cost-effective manner is known as corrosion engineering. The corrosion engineer uses experimental research to accomplish this, as the majority of corrosion engineering's key components are empirical in nature. Although there is theory that can be very helpful in solving corrosion problems, empirical test results are the basis for final analysis [7].

Reasons for conducting corrosion tests are:

- To establish corrosion mechanisms
- Defining corrosion resistance of materials and to develop new corrosion resistant alloys
- Developing corrosion protection processes
- To determine service life of equipment
- Define the critical potential values for materials in various environments.

The assessment of metal corrosion is a critical task in the oil and gas sectors. Predicting metal corrosion at varying depths in aquatic environments requires a solid understanding of the corrosion process. For the purpose of this project, the corrosion of a chosen metal in a freshwater environment will be evaluated and assessed using finite element analysis at various depths.

The sole concern of this work is to further investigate and study the cause(s) of frequent failures of metal materials such as pipelines found within fresh water environments, considering the depths of water environment and flowing condition. For the purpose of this project, the corrosion of a chosen metal in a freshwater environment will be evaluated and assessed using finite element analysis at various depths

The influence of the physiochemical parameters and other environmental factors need to be studied [8-10]. Corrosion is a problem that has been studied in science and engineering, particularly in the Niger Delta region of Nigeria where pipeline and engineering structure failures that occur in an aquatic environment are common. Evaluations of metals (selected) corrosion in fresh water environments using finite element techniques were required. And contribute to the wealth of knowledge. The impact of corrosion is an issue in plumbing systems, residential water supplies and water consumption.

Corrosion, cause the following

- Deep pits appear on a pipe and can penetrate pipe or tank walls
- Metal surface thins and red stains appear in plumbing systems
- Metals can oxide in a process or rusting take place

In order to identify the causes and create a system to lessen it, it is necessary to assess and analyze the natural process of corrosion, which happens when metals react with oxygen to form metal oxides. It is necessary to investigate the effects of the physiochemical parameters and other environmental factors. In the Niger Delta region, the number of pipeline failures due to corrosion in the marshy and aquatic environment is rising. This work's only goal is to learn more about the cause(s) of the materials' frequent failures in freshwater environments. As the current study takes into consideration, corrosion investigation in the Niger Delta necessitates more thorough and critical analysis. The Nigerian Niger Delta region will be the site of the inquiry [8-11]. The goal of the research is to lessen the corrosion issue in our plumbing, process plant, and equipment. The study will look at the effects of water characteristics on corrosion. We will watch how conductivity, pH, and temperature affect the rate at which different metals corrode in a water environment.

The aim of this thesis is to examine the effect of fresh water depths on corrosion of different metals using finite element techniques.

The overall goal of this article can be achieved through the following objective:

- Determine the physiochemical properties of the fresh water environment at various depths
- Examine the parameters that influence metal corrosion in fresh water environment
- Compare physiochemical parameters and how it affects corrosion rate of each metal at different water depth.

This work is important because it will add to the growing body of knowledge about the physiochemical parameters that affect the rate at which metals corrode. This work focuses primarily on the corrosion process in natural environments. The finite element method is used to investigate the mechanism of metal corrosion as it relates to the rate of corrosion and weight loss in water media. Psychochemical parameters play a critical role in metal corrosion, and their interactions with one another affect the metal's weight loss in any given environment. The work will focused on comparisons of the effect of physiochemical parameters of fresh water at different depths of water environment on corrosion process and activities.

Metal Corrosion

The entire surface of metal structure is faced with corrosion attacks; the attacks are caused by chemical or electrochemical reactions and they can cause metals to fail. Corrosion attack can be possibly plan and for and managed. Most common types of corrosion are localized corrosion [11].

Localized Corrosions

Are corrosion that attacks only portions of a metal. There are three categories of localized corrosion:

- Pitting corrosion – this corrosion creation of small holes in the surface of a metal.
- Crevice corrosion – are corrosion that occurs in stagnant locations.
- Filiform corrosion - corrosion that occurs when water gets under a coating such as paint.

This type of corrosions occurs when two different metals are located together in a liquid electrolyte, such as salt water, one metal's molecules are drawn toward the other metal, leading to corrosion in one of the two metals.

Structural Cracking

When environmental conditions are stressful enough, some metal can begin to crack, fatigue, or become brittle and weakened.

In managing water systems, internal corrosion is the main focus. Cooling tower pipework and internals, closed system pipework and heat exchangers and steam boilers are all susceptible to corrosion. And if the corrosion process is not controlled, the results can be devastating to the system. The bases of corrosions, checking from fundamental chemical reaction to the types of environments in which corrosion can occur. As corrosion occurs in aqueous environments, there are different types of degradation metals can experience in such conditions [12].

Uniform Corrosion

This is the most prevalent kind of corrosion and is regarded as an attack across a material's surface. It is also the least harmful because it is relatively easy to determine the extent of the attack and to assess the impact it will have on material performance because the phenomenon can be reliably reproduced and tested. Generally, a material's surface corrodes over comparatively large areas [12].

Pitting Corrosion

Corrosion pitting one of the most damaging forms of corrosion, pitting can be challenging to identify, predict, and characterize. This type of corrosion is confined to a specific area, where a localized anodic point or, more frequently, a cathode point forms a small corrosion cell with the surrounding normal surface. After starting, a pit develops into a "hole" or "cavity" that can take on many different forms.

Generally speaking, pits pierce vertically downward from the surface. Non-uniformities in the metal structure itself can also lead to pitting corrosion, as can localized breaks or damage to protective coatings or oxide films. Pitting is risky because it can result in a structure failure with a comparatively small total metal loss.

Crevice Corrosion

Is another type of localized corrosion that usually arises from a stagnant microenvironment where two areas of a metal have different ion concentrations. In shielded areas where oxygen is restricted, such as under washers, bolt heads, gaskets, etc., crevice corrosion occurs. These smaller gaps permit the entry of a corrosive agent but do not permit sufficient circulation to reduce the oxygen content, preventing re-passivation [13].

The pH moves away from neutral as a stagnant solution accumulates. An increasing disparity between the external surface (bulk environment) and the crevice (micro environment) leads to higher corrosion rates. In comparison to pitting, crevice corrosion frequently happens at lower temperatures. Crevice corrosion can be reduced with proper joint design.

Depletion or enrichment of an alloying element at the grain boundaries, as well as the presence of impurities, can lead to interganular corrosion. Interganular corrosion, which happens along or next to these grains, significantly impairs the metal's mechanical qualities while the majority of the metal is still intact. Carbonate precipitation is one type of Interganular corrosion that can happen to metals when they are exposed to extremely high temperatures or concentrated hot work, like welding [14].

Stress Corrosion Cracking (SCC)

Tensile stress combined with a corrosive environment—often at high temperatures—is the cause. This could be the consequence of rapid temperature changes or actual tensile loads on the metal causing expansion or contraction. It could also be the consequence of residual stress applied during the manufacturing process, from grinding, machining, welding, cold forming, and so on. Most of the surface usually stays intact in stress corrosion, but tiny cracks start to show in the microstructure, making the corrosion difficult to see. Usually appearing brittle, the cracks form and spread perpendicular to the stress location.

Galvanic Corrosion

When two electrochemically dissimilar metals come into contact electrically in an electrolytic environment, such as when copper comes into contact with steel in a saltwater environment, the resultant degradation of one metal near a joint is known as galvanic corrosion. Even with these three requirements met, there are still a lot of other variables, like temperature and metal surface polish, that can impact the likelihood and severity of corrosion. Galvanic corrosion can occur in some engineered systems that use a variety of metals in their construction, including different kinds and materials of fasteners.

Mechanism of corrosion Process

Corrosion mostly happens electrochemically when metal is exposed to electrolytes such as water or moisture, or Fe(s) and O_2, which stand for solid iron atoms and oxygen molecules. Corrosion is the naturally occurring process that changes a recovered metal into a more stable form, such as oxide, hydroxide, or sulfide. It is the gradual deterioration of materials, primarily metals, caused by external variables and electrochemical or chemical processes [14, 15].

MATERIALS AND METHOD

Materials

The materials needed used were Carbon Steel, Stainless Steel, Copper Steel, Mild Steel, boat, life vest, distilled water, conical flask beaker, analytical balance, brush or sponge, reagents, fresh water environment at different depths (30cm, 60cm, 90cm, 120cm and 150cm).

Determination of Water Physiochemical Parameters

For this article the parameters for investigation are pH, electrical conductivity, total suspended solids, total dissolve solid, chemical oxygen demand, biochemical oxygen demand, dissolve oxygen, turbidity, alkalinity, total hardness, Nitrate, phosphate, sulphate, Copper, Lead, cadmium chromium, Nickel, Total coliform, *E. coli* and *Salmonella*. These parameters can one way or the other impacts on water environment for corrosion of metal coupons. The parameters are good contributors, and they differ at various water depths of water

Methodology

The experimental work was to study the effect of physiochemical parameters of fresh water environment at different water depths on metals corrosion, four different metals were selected (Carbon Steel, Stainless Steel, Mild Steel and Copper Steel). The experiment was carried out at normal room temperature (28 ± 0.5). Based on the understanding of the research work, precautions were carefully observed during the process of carrying out the field and laboratory experiment. Metal coupons were careful lowed into the fresh water at different depths, and allowed for duration of three months. The change in weight as result of corrosion were taken and recorded. The metal coupon were cleaned off the oxide, and put back in the water. The laboratory analysis of physiochemical parameters were carried out with Proper personnel protective equipment. To avoid hazards, like Life vest, goggles. Lab coats and hand glove, the reading was properly taken in good condition. All the apparatus will be washed before and after use. The fresh water samples were collected at the New Calabar River, Choba in Rivers State, with the coordinate of 4.8121192; 6.8452748, for analysis of physicochemical parameters and microbial count, which were carried out at the Department of chemical/petrochemical engineering laboratory of Rivers State University and Austino Research and Analysis Laboratory Nig. Ltd. The depths considered for this experiment were 30cm, 60cm, 90cm, 120cm and 150cm, the experiment was done in favorable condition. Metals coupons were introduced into the fresh water with the support of rope as to suspend it for immersion and removal. The metal coupons were brought out and check for weight loss with a weight balance and the reading were recorded for every three (3) interval for 18 months. The work was successful with the help of local divers around fresh water environment under the Choba Bridge.

Degree of accuracy was employed which help to monitor the weight of various samples before and after immersed into the different water depths. The initial and final weight losses of the metal coupons were recorded.

The initial mass, volume and densities of the selected metal coupons were recorded, the selected were, Carbon Steel CBS-D, Stainless Steel SST-C, Mail Steel MS-B and Copper Steel CPS-A.

The following parameters were observed and analyzed:

- Metals weight loss: the change in weight of metal at the time observed. Model was used to predict the corrosion rate.
- Rate of corrosion

$$C_R = \frac{534\Delta W}{\rho \mathrm{At}} \tag{3}$$

Where:

C_R = Corrosion rate (mm/day)
W_O = Initial weight of material (gm)
W_t= Instantaneous weight of material (gm)
ρ= Density of material (gm/mm^3)
A = Cross sectional area of materials (mm^3)
t = Time

Theoretical Approach Using Base Model

Metal corrosion assessment under the influence of the environmental factors and interaction with the environment can be developed from mass transfer or transport of physiochemical parameters the physiochemical parameters are transported from a region to another. There is creation of uniformity in the concentration in the interaction of metal and environment.

This can be express as

$$\frac{\partial c}{\partial t} = Dx\ \frac{\partial^2 CR}{\partial x^2} - U\frac{\partial C}{\partial t} \tag{4}$$

From the equation 4, the differential equation is control by the dimension of mass transfer parameters that influence the corrosion of metal in the system.

Equation 4 can be expressed as

$$\frac{\partial C_R}{\partial t} = Dx\ \frac{\partial^2 cR}{\partial x^2} - U\frac{\partial C_R}{\partial t} \tag{5}$$

Metal Weight Loss with Time

The weight lost was measure in terms of change in weight of metals per unit time of three (3) months interval, which is also known as velocity i.e

$$W_L = \frac{change\ in\ metal\ weight}{time\ (period\ of\ exposure} \tag{6}$$

Microbial and Corrosion Rate Interaction Model

The effect of-microbial activities on each metal in *the water* environment can be expressed as follows:

For Carbon Steel (CBS-A)

$$CR = X_1 N_d + C_1 \tag{7}$$

Where CR is corrosion rate in (Mpy), N_d is number of months and C = constant, X is biomass (cfu/ml) or microbial growth.

From equation (10) making N_d the subject of the formula, we have

$$N_d = \frac{\mathrm{CR}-\mathrm{C}_1}{\mathrm{X}_1} \tag{8}$$

For Stainless Steel (SST-C)

The mathematical expression for microbial and corrosion rate correlation is given:

$$CR = X_2 N_d + C_2 \tag{9}$$

Therefore making N_d the subject of the formula from equation (12) we have

$$N_d = \frac{\mathrm{CR}-\mathrm{C}_2}{\mathrm{X}_2} \tag{10}$$

For Mild Steel $(MS - B)$

The equation of the relationship between the microbial and corrosion of the mild steel is given as:

$$CR = X_3 N_d + C_3 \quad (11)$$

Making subject of formula, we have

$$N_d = \frac{\mathrm{CR} - \mathrm{C_3}}{\mathrm{X_3}} \quad (12)$$

For Copper Steel CPS-A

The microbial and corrosion rate of CPS-A can be written as

$$CR = X_4 N_d + C_4 \quad (13)$$

Therefore making N_d the subject of the formula, we have

$$N_d = \frac{\mathrm{CR} - \mathrm{C_1}}{\mathrm{X_4}} \quad (14)$$

Substituting equation (16) into equation (17), we have

$$\mathrm{CR} = \mathrm{X_1}\frac{(\mathrm{CR} - \mathrm{C_2})}{\mathrm{X_2}} + \mathrm{C_1} \quad (15)$$

$$\mathrm{CR} = \frac{\mathrm{X_1}}{\mathrm{X_2}}(\mathrm{CR} - \mathrm{C_2}) + \mathrm{C_1}$$

Substituting equation (14) into equation (15), we have

$$\mathrm{CR} = \frac{\mathrm{X_2}}{\mathrm{X_3}}(\mathrm{CR} - \mathrm{C_3}) + \mathrm{C_2} \quad (16)$$

Substituting equation (19) into equation (20), we have

$$\mathrm{CR} = \frac{\mathrm{X_3}}{\mathrm{X_4}}(\mathrm{CR} - \mathrm{C_4}) + \mathrm{C_3} \quad (17)$$

Corrosion Model for Metal Interaction with Physiochemical Properties

The corrosion of the various metals in the water environment can be attributed to the physicochemical properties of the resultant effects of the functional parameters such as the pH, electrical conductivity, DO, TSS, TDS, Heavy metals and organic matter etc.

Empirical model techniques can be used in terms of least square method to determine the effects of the functional parameters (physicochemical properties or parameters) in the process system. Mathematically, we can define corrosion rate of metals in the various depths of fresh water environment as a function of the physicochemical parameters or properties.

$$CR = f(\text{pH, electrical conductivity, density, organic matter, etc.}) \quad (18)$$

Considering each of the functional parameter by denoting with the latter pH = P, electrical conductivity = E, density = D and organic matter = O

Substituting these letters into equation *(18*) we have

$$\mathrm{CR} = \mathrm{f(P, E, M, D, 0)} \quad (19)$$

Therefore the mathematical expression of equation (19) can be expressed using the approach in equation 20

$$CR = f(aP + bE + cM + dD + eO) \quad (20)$$

For corrosion rate (CR) is the dependent variable in the equation (23), whereas a, b, c, d and e are the functional coefficient (constants). The independent variables of the process for the desired corrosion rate are P, E, M, D and O, whereas the functional coefficient (constants) a, b, c, d and e are to be determine in the process.

RESULTS AND DISCUSSIONS

The analysis of physiochemical parameters was carried out to examine the impacts on the corrosions rate for various metals sample in fresh water environment at different depths, many parameters were considered for this research work but Temperature was not analysis due to its effect on corrosion rate, temperature fervors the growth of biology organism in the fresh water environment, in the absence of biological effects, corrosion can said to increase for every 10^{0c} rise in temperature but the increase growth rate of biological organisms in warmer water has the opposite effect, because it produce a protective concretion on the metal surface. Fresh water temperature is optimal if measured on site and for this research work fresh water temperature was considered because different depths were involve. The illustrations of the result of analysis are shown below.

Figure 1 describes the pH analysis of fresh water at different depths. At 30 cm depth the pH value was 6.45, and it increased as the depth increased to 60cm it was 6.65, it still increase to 6.75 at the depth 90cm. The value of the pH at 30cm, 60cm, and 90cm were respectively 6.45, 6.65 and 6.75. However, the pH dropped between the depth of 100 and 120. There was little increase in pH value between the depth of 120cm and 150cm. This can attributed to activities of sulphate reducing bacteria and concretion of surrounding activities. If air flow into the aquarium, it removes the carbon dioxide $C0_2$ present and therefore lower the concentration of pH in the fresh water, the activities of fish in the water also produce carbon dioxide ($C0_2$) this explained why pH can vary at various depths. The normal freshwater pH range 7.5 and 8.2 but can vary from 6,5 to 8.5 for stagnant water and sediments beneath the seabed, however some changes may occur caused by actions of sulphate reducing bacteria, the concretion and surrounding activities and vary the pH of water column and can cause change in pH. Metals corrosions in fresh water can catalyze by local circumstances. To obtain a better understanding of corrosion in fresh water the site (fresh water environment) pH should be measure not just the fresh water but also at interval down the sediment. In natural processes the pH is constantly affected by carbon dioxide and nitrates, calcium rich rock and gravel also dissolve into water and raise the pH

Dissolve Oxygen and Biochemical Oxygen demand

Metal exposed to surface water usually face with Oxygen reduction, which is *cathodic* reactions. Corrosion rate is most times controlled by availability of dissolved Oxygen at the *cathodic*.

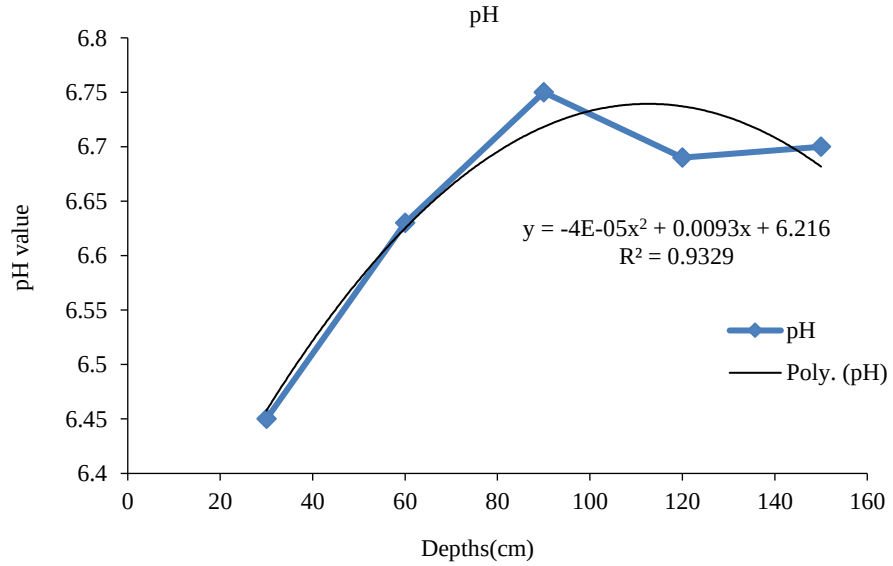

Figure 1. Analysis Result for pH of fresh water at different depths.

Surface water get saturated with oxygen from the atmosphere the amount of dissolved oxygen in surface water depends on temperature. Between the depths used for this research work, oxygen content

depends on the biological activity and the rate of mixing with surface layers. Polluted water often has low dissolved oxygen level due high oxygen uptake by micro-organism, which results in control of corrosion rate by sulphate reducing bacteria.

Figure 2 illustrates the rise in Dissolve oxygen and biochemical oxygen demand, at 30cm depth the rise was slow and uniform till its get to 60 cm depth were the increase in biochemical oxygen demand rise rapidly, dissolve increase gradually, as the depth increase its indicate that the parameters were also increased. Between the depths 60cm to 150cm the rate of biochemical oxygen demand increased to 25mg/l while dissolved oxygen increase to 20mg/l as shown in the graph below.

Figure 2 describes the actions of total hardness and alkalinity, on metals coupon submerge at different depths. Total hardness is a measurement of the minerals content in a water sample that is irreversible by boiling. From the graph below at the depth of 30cm the total hardness was 240.48 mg/l, as the increased ii was indicate that total hardness increased. Total hardness can result to abnormal cloudiness and the formation of scale, and low hardness makes the water corrosive and aggressive. Water that contain calcium or magnesium salt (Hard water) is less corrosive. The increased can be attributed to the concentration of multivalent cations in water. However, levels of hardness that are too low could make the water corrosive and more aggressive. Total hardness is mostly caused by the dissolved mineral compounds.

Figures 3 and 4 illustrate the curve of electrical conductivity, it is the water ability to conduct electricity, the curve shows the electrolyte in the fresh water, the total concentration, mobility concentration of ions, and how it influence the rate of corrosion. From the graph the water electrical conductivity at 30cm depth was 695.5 µs/cm and at the depth of 150cm it is 858.4µs/cm, except at the depth of 90cm where it decreased to 487.2 µs/cm, the range indicate that it is suitable as fresh water for all species. Therefor the rate of corrosion is influence considerably by the electrical conductivity of the electrolyte

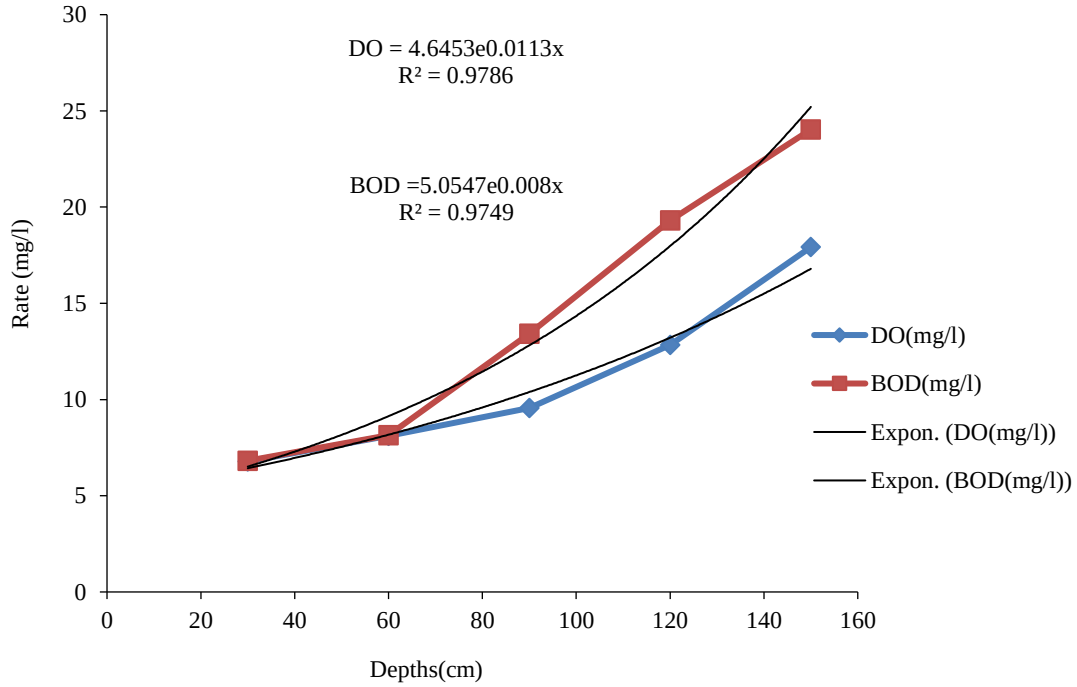

Figure 2. Analysis result of dissolve oxygen (DO) and biochemical oxygen demand (BOD) of fresh water at different depths.

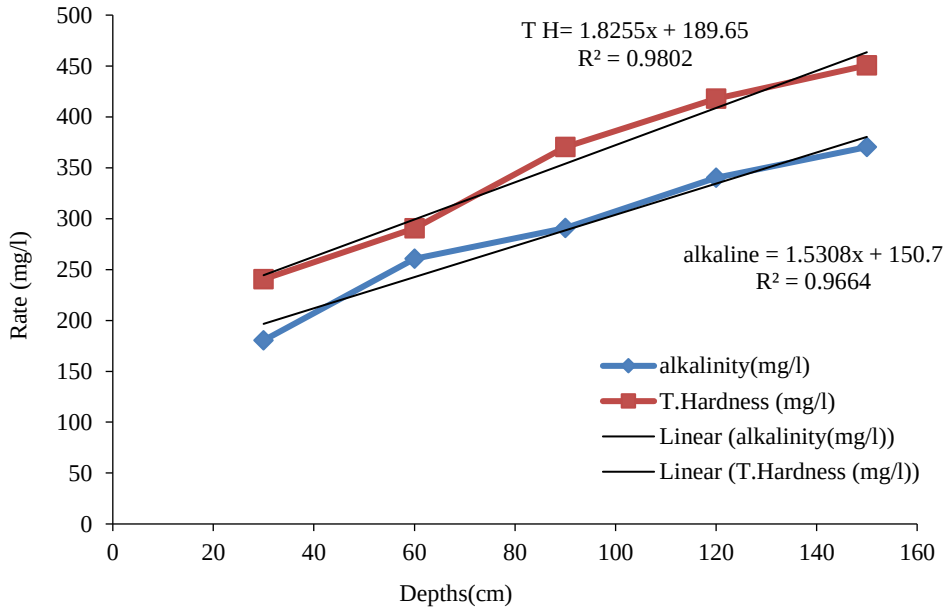

Figure 3. Analysis result of alkalinity and total hardness of fresh water at different depths.

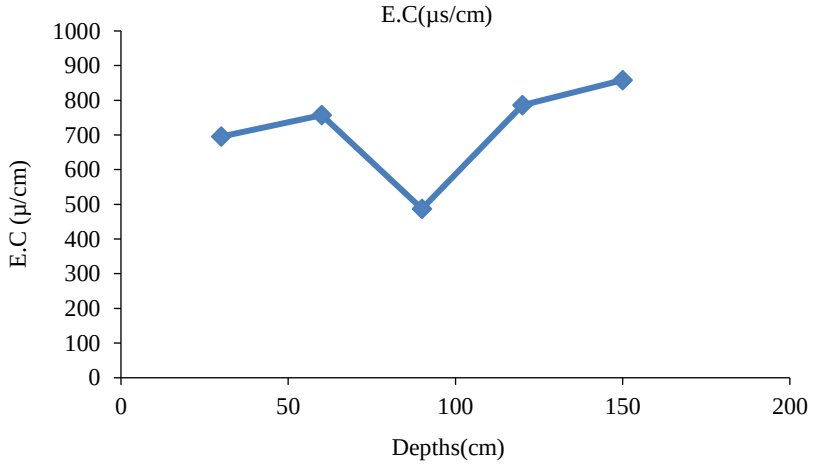

Figure 4. Analysis result of electrical conductivity for fresh water at different depths.

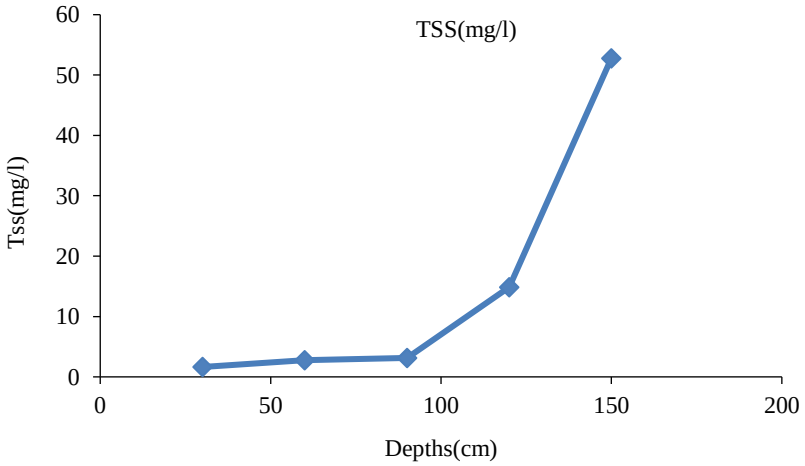

Figure 5. Analysis result for total suspended solid in fresh water at different depths.

Figure 5 illustrate the Patten of curve showed in the graph which indicate total suspended solid increase at 30cm depth TSS was 1.64 which was not much as the depth increased to 60cm and 90cm, there was also slight increased at the rate of TSS, at the depth of 120cm the increase in TSS were rapidly and it recorded 14.85mg/l , at the depth of 150cm, TSS recorded 52.8mg/l, from the result it indicate that TSS were more at deeper than outer surface.

Total suspended solid at the surface fresh water were low and contribute to corrosion of metal, the presence of chlorine in water as gas which is reacted with moisture in the air to produce hydrochloric and hypochlorous acid that corrode some metal elevated TSS indicates the following. The concentration of dissolved ions may cause the water to be corrosive with a salty or a brackish taste as we as result in scale formation.

Figure 5 describes the curve below of total dissolved solid as it is directly associated with the water quality and purity, at the depth of 30cm the total dissolved solid was recorded 417.48(mg/l), as the depth increased the total dissolved solid increase, however the result indicate that at 90cm the total dissolved solid dropped to 292.32(mg/l) and it increase as the depth get further. The particular in water purification system may be suspended inform such as molecular, ionized and micro-granular, the levels of total dissolved solid in water affect all that lives in fresh water, it also contribute to corrosion build up. Its activities was attributed to increase in corrosion rate.

Turbidity

This is the haziness or cloudiness of fluid as a result of separate particles like dissolved solid or total dissolve solids. These particles are not visible to the naked eyes, it can cause growth of microorganism such as phytoplankton. High turbidity, suspended particles absorb more heat making the water warmer with lower oxygen concentration

Figures 6 and 7 show the levels of turbidity in the freshwater environment, at 30cm depth turbidity level was low about 0.63 (NTU). As the depth increased the level of turbidity increased, high increase turbidity will increase the rate corrosion. This attribute the reason why corrosion rate were away higher in this research work, it noted the rate of corrosion ere higher from the depth of 90cm because factors like turbidity and others contribute more to favor corrosion rate. Turbidity range 0.5 to 10 NTU in fresh water, the deeper down has increase turbidity.

Figure 8 illustrates the graph and the pattern of increase, at the depth of 30cm, the COD was 120 (mg/l) as the depth increased the chemical oxygen demand increase, the highest recorded chemical oxygen demand was recorded at the highest depth used for the research work. The effect of COD on microbial activities, contribute to metal corrosion and is considered as carbon source for microbial growth and metabolism, which promotes the growth of microbes into colonies or biofilms, and affect the corrosion of metals, often attaching to the surface of the metal.

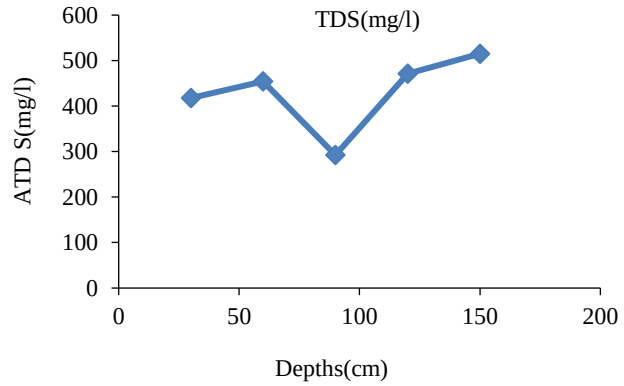

Figure 6. Analysis result of total dissolved solid in fresh water at different depths.

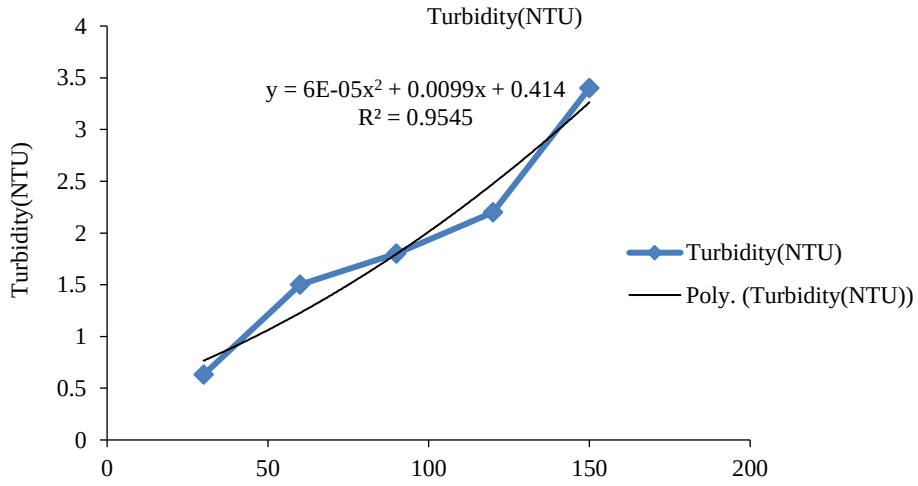

Figure 7. Analysis result of turbidity in fresh water at different depths.

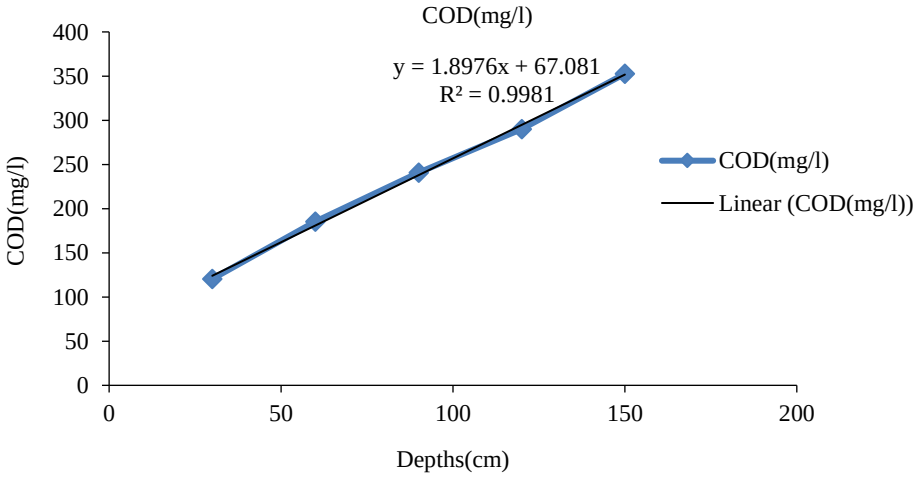

Figure 8. Analysis result chemical oxygen demand in fresh water at different depths.

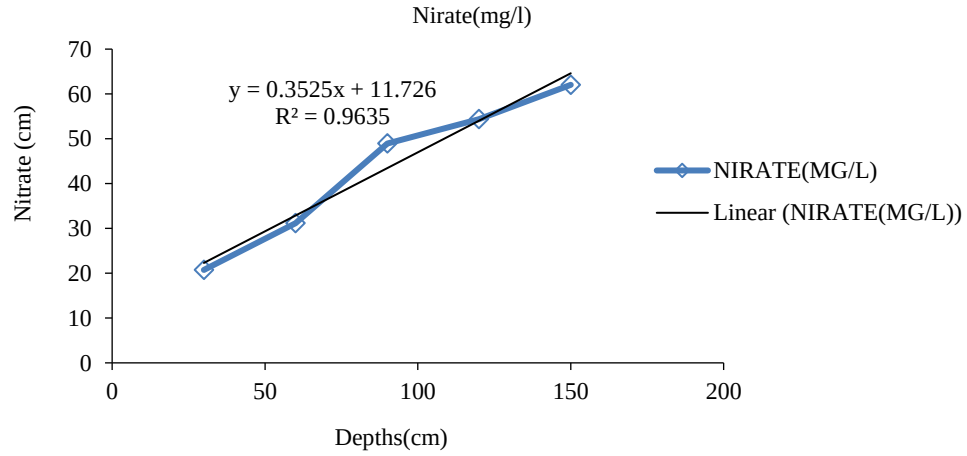

Figure 9. Analysis result of nitrate in fresh water at different depths.

Figure 9 describes the relationship of nitrate in freshwater environment with corrosion of metal, the result obtained from analysis showed that at 30cm depth level of nitrate was 20.74 mg/l, but as the depth of fresh water increased it revealed the presence of nitrate increased. The effect of nitrate on corrosion

depends on it state, dilute concentration of nitrate can deleterious effect on corrosion behavior, it was recorded that dilute concentration of nitrate acid can increase corrosion rate of metal rather than reduced it, high level of nitrate makes the unsuitable as drinking water. In fresh water environment, lakes, Rivers, nitrogen and other nutrients like phosphorus, stimulate the growth of algae, which serves as food for organism. Sodium Nitrate is anodic inhibitor and as the name implies, anodic process (metal dissolution) and reduces the corrosion rate by suppressing the anodic reaction, through the formation or maintenance of a passive film on metal surface.

Figure 10 describes the role and relationship, of Phosphate and Lead (Pb), there contributions in fresh water corrosion rate of metal. Phosphate and Lead, seen to have the same significant role, at the depth of 30cm there were similar rise of 0.462 and 0.39173 mg/l, respectively as the depth increased 60cm, there were also like increase of close range, at 90cm depth we observed that Lead increased to 0.61184 mg/l while phosphate increase to 0.874 mg/l, at the depth of 120cm there were close range as observed from the graph of 1.04827 and 1.162 mg/l, but at the depth of 150cm from the analysis result it observed that phosphate and Lead presence were almost the same 1.394 and 1.37505 mg/l. it revealed that phosphate and lead contribute to corrosion of metal in fresh water. Phosphate ions adsorbed onto the metal rebar surface and reduce corrosion in certain metals. It can act as anodic and cathodic as well as mixed inhibitor, while lead in fresh water that contained dissolved oxygen and carbon dioxide, the severity of the corrosion rate will mainly depend on the carbon dioxide concentration. In environment, lead is cathodic to steel, aluminum, zinc, cadmium and magnesium and therefore will accelerate the corrosion of these metals.

Figure 11 illustrates the relationship of cadmium Cd in fresh water and how it contributes to corrosion rate of metal. As at 30cm depth the result revealed that the presence of cadmium is insignificant it was 0.00461 mg/l which is low, from the depth of 90cm it get 0.01272 mg/l, how there was rapid increase from the depth of 90cm to the depth of 150cm, Cadmium element form is a very soft blush- grey metal, it is water insoluble and is not flammable.

Figure 12 illustrates the actions of sulphate in fresh water. The curve indicates that as the depths increased the presence of sulphate increased, at the depth of 30cm sulphate was 120.54 mg/l, but the increased sulphate was noted to increase as at the depth of 150cm, the sulphate increased to 320.17 mg/l. From the result as seen in the graph it revealed that sulphate contribute in the increase of corrosion rate, it accelerate corrosion of metal

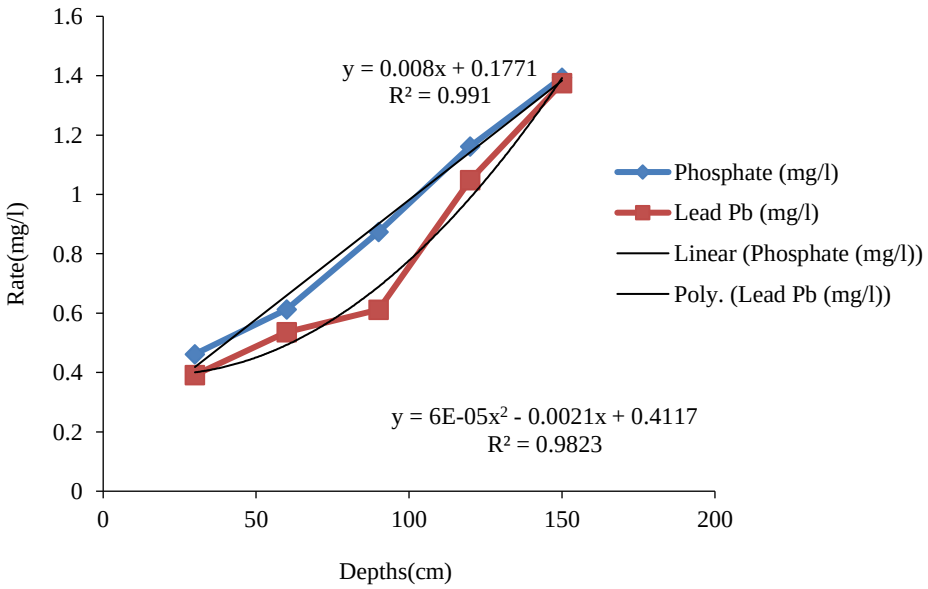

Figure 10. Analysis result of phosphate and lead in fresh water at different depths.

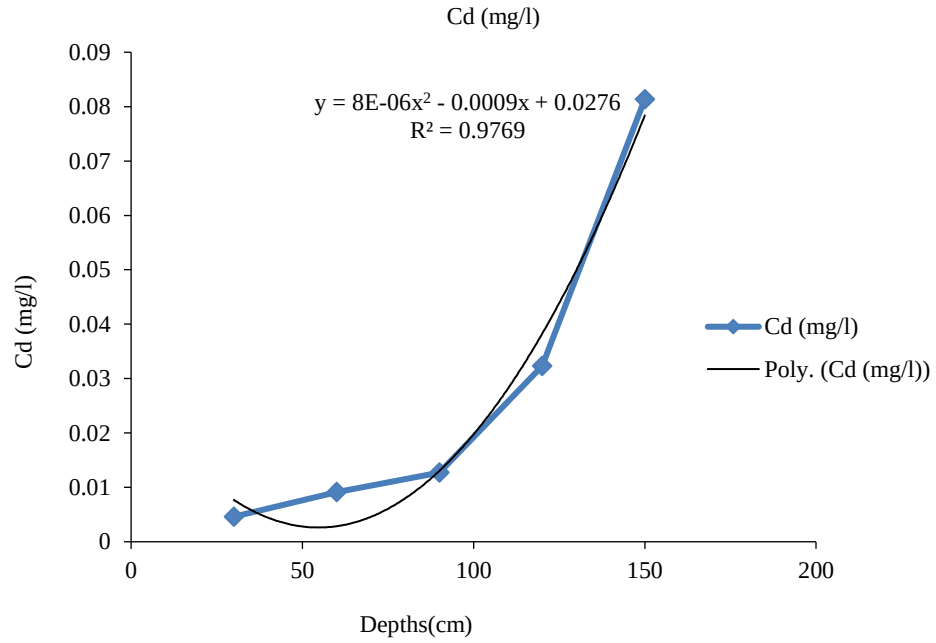

Figure 11. Analysis result of cadmium in fresh water at different depths.

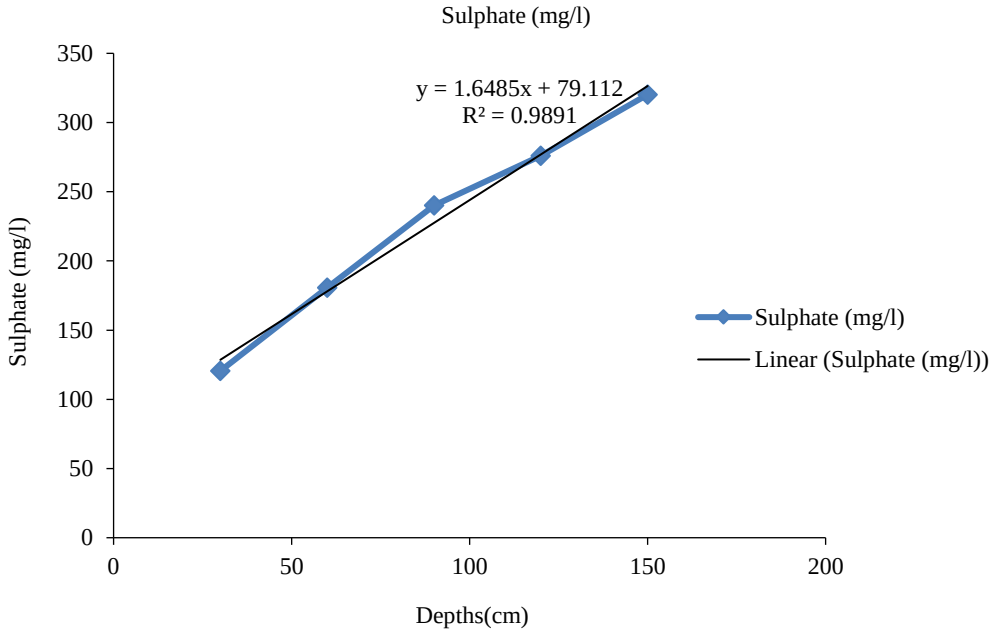

Figure 12. Analysis result of sulphate in fresh water at different depths.

Figure 13 shows the relationship and the contribution of chromium in freshwater corrosion rate, at the depth of 30cm, it was observed that chromium present was 1.63904 mg/l, as the depth increased from the analysis it observed chromium increased. The result revealed that increased in the depth, the also increased in the amount of chromium. More chromium will increase the flow accelerated corrosion.

Figure 14 illustrates the role of nickel in fresh water. The graph above indicates that an increase in the depth of water there will be increased the presence of nickel, at depth of 30cm, nickel was 0.15821 mg/l, as the depth were increased the amount of nickel present were also increased. Nickel appears to be more sensitive to cathodic hydrogen embrittlement due to absorption of hydrogen. The behavior of nickel in electrolyte is detrimental effect to oxygen in general and can cause corrosion,

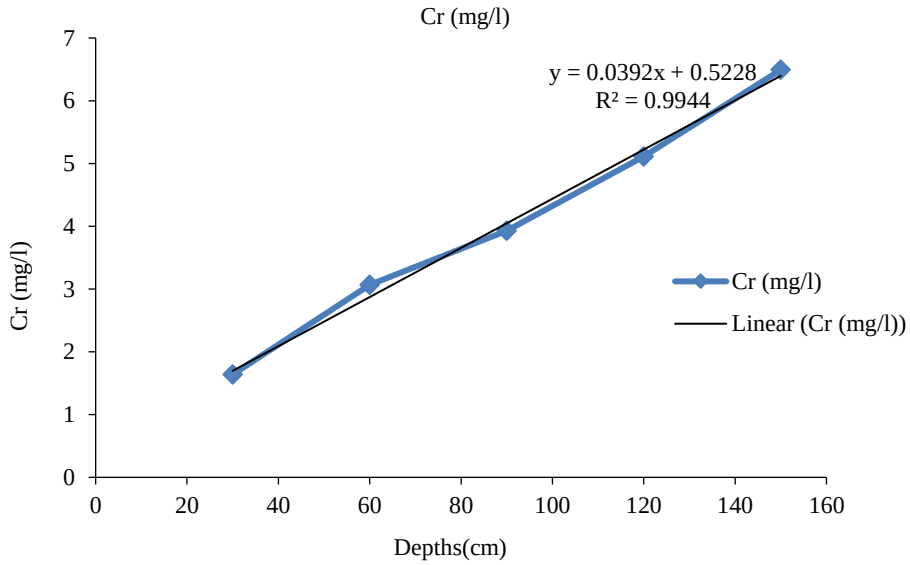

Figure 13. Analysis result of chromium in fresh water at different depths.

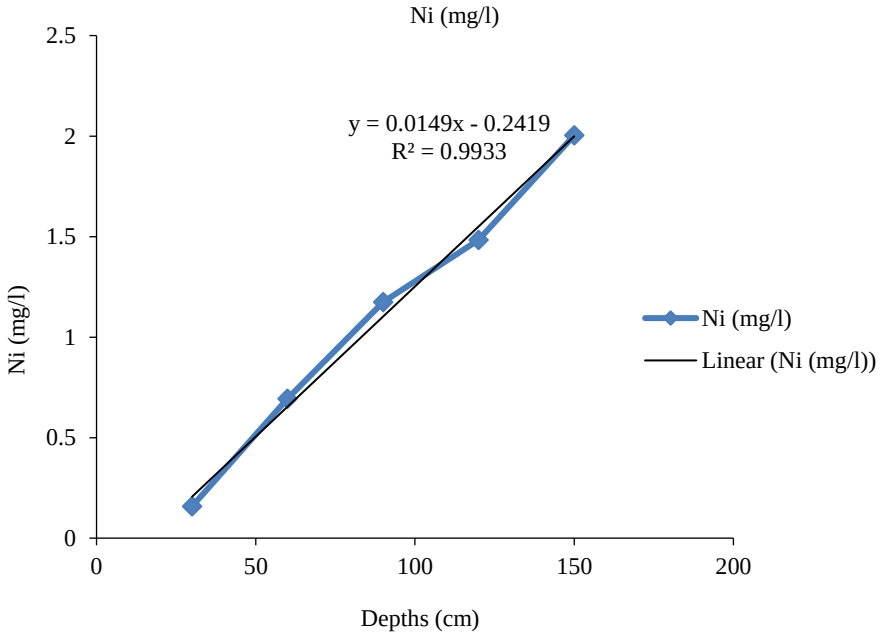

Figure 14. Analysis result of nickel in fresh water at different depths.

Figure 15 illustrates the actions of copper in the freshwater environment. At the depth of 30cm, the result showed that copper was about 4.82403, this indicate presence of copper in fresh water environment at a shallow depth, as the depth increased the presence of copper increased. Copper in freshwater system has a scale character and behavior towards corrosions of metal, the scale product were CuO_2 and $CaCO_2$ respectively. Copper in fresh water environment upon immersion the presence of makes the water surrounding the metal to turn milky and developed bacteria colonization. Bacteria colonies that appeared after immersion contribute to accelerate corrosion of metal.

Microbial Analysis Result of Fresh Water Collected at Different Depths

Microbial actions catalyzed corrosion rate of metal in a substantial economic concern. Aerobic microbes enhance iron oxidation through indirect mechanism and their impact appears to be limited compared to anaerobic microbes.

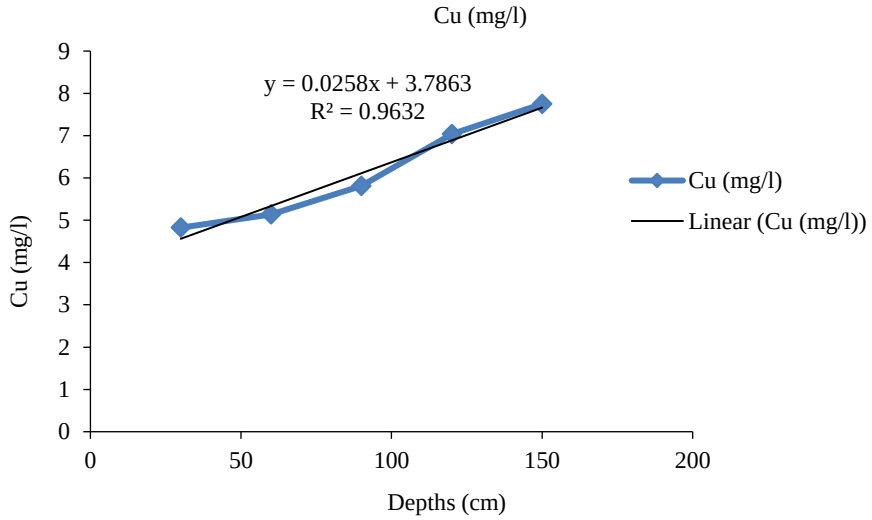

Figure 15. Analysis result of copper in fresh water at different depths.

Microbiology activities induced corrosion causing organism are sulphate reducing bacteria (*Desulphovibrio*, *Desulphotomaculum* and *Desulphomones*), iron reducing bacteria, and acid producing bacteria. Microbial inducing corrosion has a potential impact on fresh water environment, it is not itself a form of corrosion, but rather a process that influence and even initiate corrosion, it can accelerate most form of corrosion including uniform corrosion, pitting corrosion, crevice corrosion etc. microbial activities act as a driving force for biocorrosion, microorganism are ubiquitous in nature and grow at vary rapid rate in fresh water environment. Microorganisms play an important role in the initiation, propagation and inhibition of corrosion in different ways by their different energy driving pathways. Microbial organism or microbial communities in water environment developed what is refers as biofilms on a submerged surface. The biofilms influence the physic-chemical interaction between the metal and water environment frequently enhance corrosion.

Figure 15 shows the total coliform (cfu/ml) illustration in the fresh water at different depths, the presence of Total coliform in the water enhances the development of biofilms and it contribute to corrosion rate, but the depths of the water do not necessary change the presence. As the depth were increase it didn't showed any significant change in total coliform present in the fresh water medium, as seen in graph. The result revealed that the total coliform present play active role in metal corrosion in fresh at any depths.

Figures 16 and 17 illustrate the growth of *Escherichia Coli* (*E. Coli*), at the depth of 30cm the amount of *E. coli* had risen to 35 Cfu/ml, as the depth increased the presence of *E. coli* increased, at 150cm the *E. coli* has risen to 84 Cfu/ml, showed that *E. coli* increased as depth increased. The result obtained revealed that the nutrient that could activate the bacteria growth was found as the depth increased, and it enhanced the development of biofilms consequently contributing to the corrosion rate. From Figure 16 above, it revealed that depth play important role in the presence of *E. Coli*, at deeper level of the water the *E. coli* increases and play active role in metal corrosion in fresh at different depths.

Figure 18 describes the growth of *Salmonella*, at the depth of 30cm, *Salmonella* was not observed from the result, which revealed its existence was not significant, at the depth of 60cm it was recorded about 10Cfu/ml, as the depth increase the result revealed that its amount were increased at the depth of 150cm it increased to about 51Cfu/ml. It is a type of bacteria that is found in surface water, mostly through water run off or waste water and found than self in freshwater. *Salmonella* stain showed potent capacity to form biofilms with slight variation. Its activities of adherence capabilities lead to acceleration in corrosion rate of metal, most times it remind viable for about four (4) hours on metal mostly on stainless steel [15].

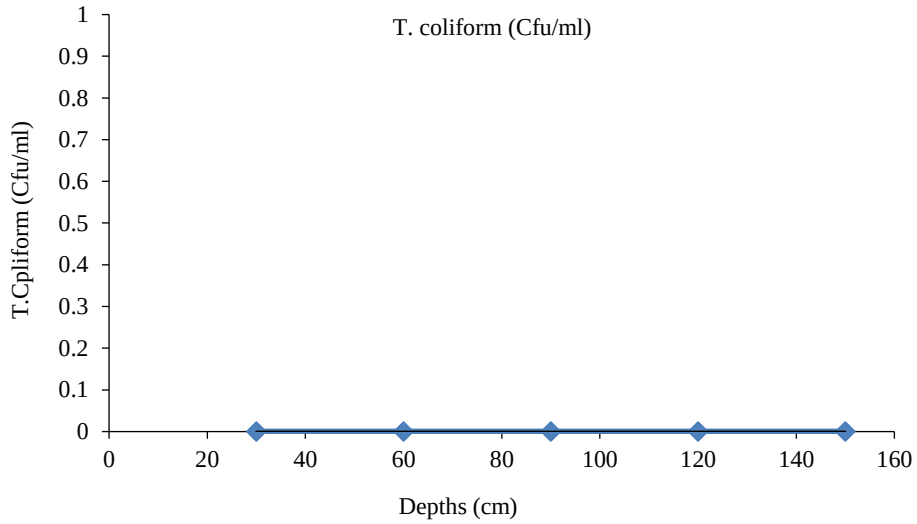

Figure 16. Microbial analysis result of total coliform in fresh water collected at different depths.

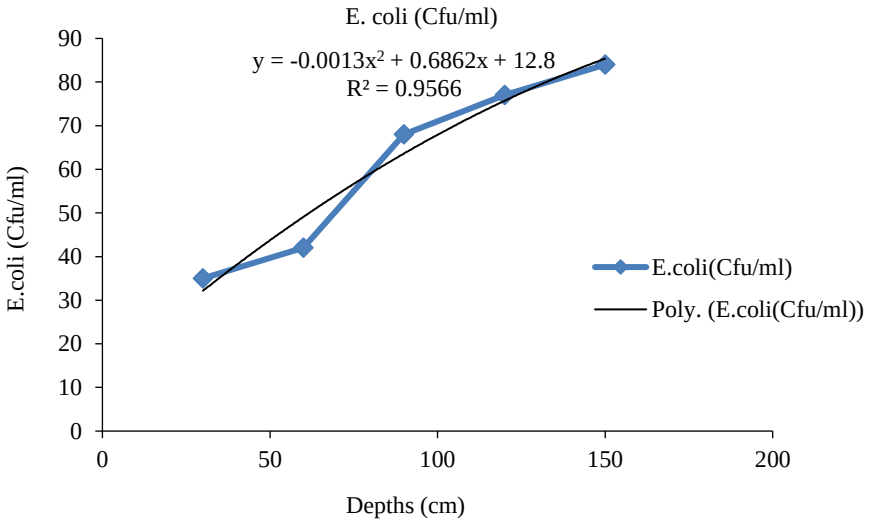

Figure 17. Microbial analysis result of *E. Coli* in fresh water collected at different depths.

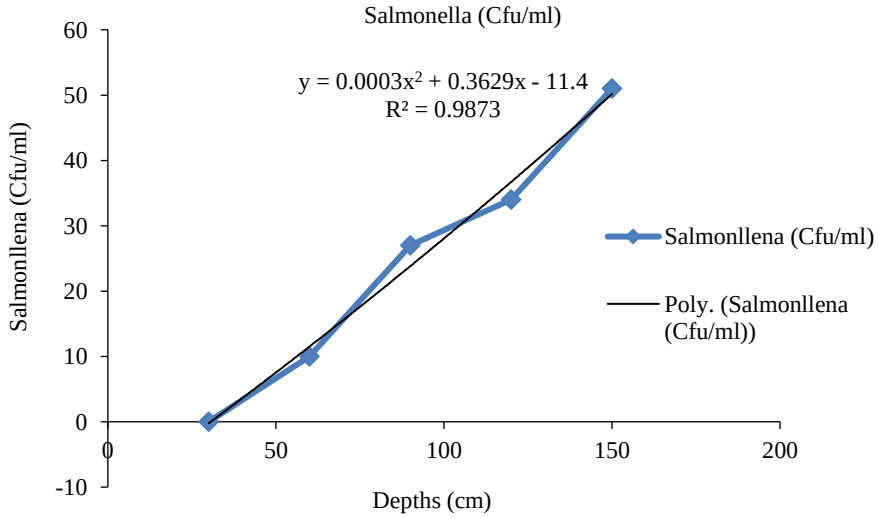

Figure 18. Microbial analysis result of *Salmonella*e in fresh water collected at different depths.

CONCLUSION

The study on effect of physiochemical parameters variations at different depths in freshwater environment on metal corrosion, was necessary because of constant failure on pipeline and metal facilities / installation in Niger Delta area of Nigeria. The research was carried out to demonstrate the significant factors that attribute to the failure of submerge facilities (pipelines) and metal installations. Determination of the effects physiochemical properties of the freshwater ,environment at various depths, noted that there are various physiochemical properties like pH, Electrical conductivity, Total Suspended Solid, Total dissolve Solid, Dissolve Oxygen, chemical Oxygen demand, Total Hardness, Turbidity, Nitrate, Phosphate Lead (Pb), Cadmium, Sulphate, Chromium, Nickel and Copper. Microbial analyses were equally conducted.

It was revealed that fresh water environment physiochemical parameters, varies at different depths. The effect on metal coupons submerge at different depths varies as well, the changes in parameters and behaviors of the fresh water contribute to variations in corrosion rate and weight loss of metal. Microbial activities in fresh water at different water depths develop biofilm on the surface of submerged facilities, or metals installations at different rate for various water depths. The biofilm influence physical – chemical interactions between the metals and water environment which enhance corrosion rate and also contribute to weight loss.

Total Coliform in fresh water at different depths do not vary, the same concentration remains the same, but it also developed biofilm and enhances corrosion of metals. *Escherichia Coli* (*E. Coli*) and *Salmonella* increased as depth was increased. Their contributions to form biofilm also increased at various depths. The dispersion in fresh water at different depths influence metal corrosion and weight loss. The diffusion of physiochemical properties in fresh water environment affects current density, and also influence electric conductivity in the system, all this contribute to corrosion rate and weight loss of metal. The formations of biofilm and activities of microorganism present at depths play a vital role in contributions to metals corrosion rate and weight loss.

REFERENCES

1. Amadi AN, Olasehinde PI, Yisa J, Okosun EA, Nwankwoala HO, Alkali YB. Geostatistical assessment of groundwater quality from coastal aquifers of Eastern Niger Delta, Nigeria.
2. Amadi SA, Ukpaka CP. Evaluation of corrosion behavior of pipeline steel structure in onshore environment. Physical Chemistry Pakistan. 2015;17(1):21-6. (IJPPE) 1, (2): 40-48, www.arcjournals.org
3. Amadi SA, Ukpaka CP. Evaluation of the metals corrosion in soi l environment of Niger Delta Area of Nigerian. Nigerian Journal of Oil and Ga s Technology. 2015;1:104-17.
4. Li Y, Xu D, Chen C, Li X, Jia R, Zhang D, Sand W, Wang F, Gu T. Anaerobic microbiologically influenced corrosion mechanisms interpreted using bioenergetics and bioelectrochemistry: a review. Journal of Materials Science & Technology. 2018 Oct 1;34(10):1713-8.
5. Angst U, Büchler M, Martin B, Schöneich HG, Haynes G, Leeds S, Kajiyama F. Cathodic protection of soil buried steel pipelines–a critical discussion of protection criteria and threshold values. Materials and Corrosion. 2016 Nov;67(11):1135-42.
6. Szabó B, Babuška I. Introduction to finite element analysis: formulation, verification and validation. John Wiley & Sons; 2011 Mar 21.
7. Hou X, Gao L, Cui Z, Yin J. Corrosion and protection of metal in the seawater desalination. InIOP conference series: earth and environmental science 2018 (Vol. 108, No. 2, p. 022037). IOP Publishing.
8. Gorjian N, Ma L, Mittinty M, Yarlagadda P, Sun Y. A review on degradation models in reliability analysis. InEngineering Asset Lifecycle Management: Proceedings of the 4th World Congress on Engineering Asset Management (WCEAM 2009), 28-30 September 2009 2010 (pp. 369-384). London: Springer London.
9. Liu C, Kelly RG. A review of the application of finite element method (FEM) to localized corrosion modeling. Corrosion. 2019 Nov 1;75(11):1285-99.

10. Scamans GM, Birbilis N, Buchheit RG. Corrosion of aluminum and its alloys. InShreir's Corrosion 2010 Dec 1 (pp. 1974-2010). Elsevier.
11. Kucera V, Mattsson E. Atmospheric corrosion. InCorrosion mechanisms 2020 Nov 25 (pp. 211-284). CRC Press.
12. Li K, Chen Z, Li J, Sun X, Xu F, Xu L. Corrosion mechanism of copper immersed in ammonium sulfate solution. Materials and Corrosion. 2018 Nov;69(11):1597-608.
13. Nwokorie RC, Nweke CO, Umeh SI, Ihenetu FC, Nlemolisa OR, Kemka UN, Obasi CC, Nnadi CI, Uzoho KH, Ejide CC. Corrosion of High Carbon Steel by Bacteria under Aerobic and Anaerobic Conditions. Materials Sciences and Applications. 2019 Mar 9;10(3):227-42.
14. Logan DL. A first course in the finite element method. Thomson; 2011.
15. North NA, MacLeod ID. Corrosion of metals. InConservation of marine archaeological objects 1987 Jan 1 (pp. 68-98). Butterworth-Heinemann.

APPENDIX

AUSTINO RESEARCH
& ANALYSIS LABORATORY NIG. LTD.
RC- 1268575
MOTTO: IMPROVING KNOWLEDGE VIA RESEARCH WORK

HEAD OFFICE:
#2 UPTH Road,
Alakahia Junction,
Opposite Alakahia Park,
Behind Jovit Restaurant,
Alakahia Uniport, PH.
Email: austinoralab@gmail.com
Tel: 07066198333;09092856207

Certificate of Analysis

NAME OF CLIENT:	Ejoku George
NO. OF SAMPLE (S):	5
SAMPLE TYPE:	Water
ANALYSIS REQUIRED:	Physicochemical
REPORTING DATE:	21/09/2023

Sample	30cm depth	60cm depth	90cm depth	120cm depth	Choba water150cm depth
pH	6.45	6.63	6.75	6.69	6.70
E.C (µS/cm)	695.8	757.4	487.2	785.7	858.4
TSS (mg/l)	1.64	2.78	3.12	14.85	52.8
TDS (mg/l)	417.48	454.44	292.32	471.42	515.04
Turbidity (NTU)	0.63	1.5	1.8	2.2	3.4
DO (mg/l)	6.78	8.12	9.56	12.83	17.92
COD (mg/l)	120.41	185.36	240.73	290.17	352.64
BOD_5 (mg/l)	6.82	8.14	13.42	19.31	24.03
Alkalinity (mg/l)	180.37	260.72	290.83	340.14	370.28
T.Hardness (mg/l)	240.48	290.53	370.21	417.89	450.62
Nitrate (mg/l)	20.74	31.18	48.96	54.36	62.03
Phosphate (mg/l)	0.462	0.613	0.874	1.162	1.394
Sulphate (mg/l)	120.54	180.64	240.11	275.94	320.17
Pb (mg/l)	0.39173	0.53628	0.61184	1.04827	1.37504
Cd (mg/l)	0.00461	0.00913	0.01272	0.03231	0.08136
Cr (mg/l)	1.63904	3.06852	3.92664	5.10978	6.49258
Ni (mg/l)	0.15821	0.69309	1.17398	1.48321	2.00364
Cu (mg/l)	4.82403	5.13654	5.81143	7.03810	7.74930
T.Coliform (Cfu/ml)	$1.13x10^2$	$1.58x10^2$	$1.73x10^2$	$1.87x10^2$	$1.93x10^2$
E.coli (Cfu/ml)	35	42	68	77	84
Salmollena (Cfu/ml)	Nil	10	27	34	51

AUSTINO RESEARCH & ANALYSIS LABORATORY
Sign..... DATE.....
Lab Analyst

CAUTION: Please disregard any result without the company seal

APPENDIX A

Weight Loss Analysis of Selected Metals Coupons due to Corrosion at different Depth of Fresh Water over Exposure is shown in Tables 1-5.

Table 1. Weight analysis result of metals in fresh water medium new calabar river (Under Choba Bridge) at the depth 30cm.

Time: (months)	0	3	6	9	12	15	Metals coupons
CPS-A	29.61	29.372	29.301	29.10	28.633	28.151	27.37
MS-B	32.47	32.411	32.406	30.315	29.825	29.224	28.892
SST-C	21.99	21.946	21.930	21.817	21.505	21.350	21.114
CBS-D	31.83	31.801	31.787	31.620	30.704	30.214	30.061

Table 2. Weight analysis result of metals in fresh water medium new calabar river (Under Choba Bridge) at the depth 60cm.

Time: (months)	0	3	6	9	12	15	Metals coupons
CPS-A	29.61	29.56	29.417	29.33	28.174	28.620	28.148
MS-B	32.47	32.44	32.39	31.17	30.69	30.18	29.06
SST-C	21.99	21.99	21.96	21.90	21.88	21.75	21.363
CBS-D	31.83	31.74	31.622	31.381	31.07	30.84	30.25

Table 3. Weight analysis result of metals in fresh water medium new calarba river (Under Choba Bridge) at the depth 90cm.

Time: (months)	0	3	6	9	12	15	Metals coupons
CPS-A	29.61	29.31	29.107	28.63	28.14	27.55	27.01
MS-B	32.47	32.36	32.18	31.59	30.27	29.15	28.36
SST-C	21.99	21.74	21.35	21.10	20.68	20.37	20.25
CBS-D	31.83	31.25	31.02	30.85	30.11	29.74	29.26

Table 4. Weight analysis result of metals in fresh water medium new calarba river (Under Choba Bridge) at the depth 120cm.

Time: (months)	0	3	6	9	12	15	Metals coupons
CPS-A	29.61	29.27	29.00	28.52	27.74	27.16	26.74
MS-B	32.47	32.15	32.03	31.26	30.48	30.18	29.39
SST-C	21.99	21.50	21.11	21.01	20.96	20.81	20.90
CBS-D	31.83	31.16	30.97	30.63	29.90	29.47	29.15

Table 5. Weight analysis result of metals in fresh water medium new calarba river (Under Choba Bridge) at the depth 150cm.

Time: (months)	0	3	6	9	12	15	Metals coupons
CPS-A	29.61	29.20	28.83	28.41	27.62	27.02	26.50
MS-B	32.47	32.07	31.91	31.00	30.29	29.63	29.11
SST-C	21.99	21.46	21.11	20.92	20.85	20.83	20.75
CBS-D	31.83	31.08	30.72	30.58	29.62	29.25	-

