PILOT ASSESSMENT OF CORROSION AND ENCRUSTATION POTENTIALS ON GROUND WATER WELL MANAGEMENT IN PARTS OF LAGOS STATE SOUTHWESTERN NIGERIA

Fakolade O. R[1], Rotimi I A[2] and Kutelu B J[3]
[1-3]Mineral and Petroleum Resources Engineering Technology
School of Engineering, The Federal Polytechnic Ado Ekiti

Email: tosofakolade@gmail.com

Abstract: Reports have shown that series of borehole had either failed, collapsed or abandoned due to casing pipe damages and poor yield in parts of Lagos state and its environs. This have possibly resulted from the poor-quality underground water quality within these areas which could either be from extraneous contaminant or source rock within the area. Consequently, the preliminary study of this underground water was conducted to ascertain possible causes and amelioration processes. To this end, fifteen borehole samples were collected for various laboratory analysis to determine their physical and chemical parameters in order to assess the level of corrosion and encrustation induced by groundwater on borehole casing and screens pipes (mild steel pipes) that is mostly used for deep boreholes within the study area by means of Corrosion and Encrustation Index Parameter (CEIP) and other cognate parameters. The results of the analysis shows that the pH value ranges from 5.2 to 6.9, Fe (0.43-2.80mg/l), Mn (0.1-1.2mg/l), TDS (86.0-392.0mg/l), DO (2.1-2.6mg/l) Chloride (Cl (6.8-53.0mg/l), temperature (25-30^{o}C) and Total hardness (22.0-226.0) respectively. Upon correlating the results with the Corrosion and Encrustation Index Parameter as well as the World Health Organization (WHO, 20O6) it was found out that the pH values, dissolved oxygen, manganese iron and temperature might have contributed to the corrosion and encrustation activities on the pipe. It is recommended that materials such as UPVC high pressured polyvinyl chloride materials, high corrosion resistant stainless pipes and corrosion resistant paints can be used as an alternative to ameliorate the problems of corrosion and encrustation for the use of the groundwater drilling operators.

Key words: Corrosion, Encrustation, collapses, total hardness and Stability Index

1. INTRODUCTION

Corrosion and encrustation have been a great challenge to borehole and water well damages in Nigeria and beyond. Despite huge amount that is being expended on water well drilling, most of these boreholes are short-lived due to negative impact corrosion and encrustation has being causing on the boreholes globally. These steadily weakened (Garg, 2005) and gradually wearing (Offodile, 2002) the material in the course of their reaction with its environment.

It slows dissolved and destroyed metals when exposed to oxygen and moisture (humidity vapour, immersion) with time. Corrosion can be fast or slow (Garg, 2005), the resultant effect is shown by the presence of rust, uniform loss of metal and perforation at some parts of the metals. The environment favorable for corrosion (Ishiaku and Ezeigbo, 2000) is mostly an artesian warm borehole as observed in Chad and Anambra basins. Fabian *et al., (*2011) also assess the rust and scale potentials of ground water in Yola area and Itakpe respectively. Encrustation (Johnson, 1975; Offodile, 2002) is expressed as the deposition of suspended and liquefied materials on slotted screen of the water well openings or blockages and void cementation of water bearing formations by materials such as calcium carbonate, iron, magnesium and manganese which are prone to precipitation. This adversely affected the rate of flow rate of water into the well (Fabian *et. al*., 2011). Encrustation occurs due to either delayed development or inappropriate of the bore hole development, wrong selection of screen slot size or wrong screen slot positioning in the groundwater well that contains high concentration of calcium carbonates, magnesium, iron and manganese. (Amah *et al*., 2008).

Lagos, a coastal city (Amah *et al*., 2008 and Offodile, 2008) with great and abundant quantity of surface and underground water resources; bays, coves, and the Atlantic Ocean has been badly hit by this menace of corrosion and encrustation on pipe damages. Due to its industrial nature, wastes and effluents are discharged into the surface water bodies (Ladipo, 1988) causing the water to be saline. The effects of corrosion and encrustation on boreholes (Ishiaku and Ezeigbo, 2000) have been accessed using Corrosion and encrustation index (CEIP) parameters. Other studies (Shomar *et. al.,* 2008; Sundaramanickam *et al.,* 2008; Daghargh, 2009; Hilles and Al-Najar,2001; and Alslaibi et al., 2011).

It has been observed that non-pathogenic bacteria grow in ground water well aquifers (Smith, 2005; Todd, 1995) has been a contributing agent of encrustation. This inadvertently may develop as sticky, dense slimes within the voids of the gravel pack and fractures in the rocks, thus reduce the flow of water flow into the hole. Also, calcite, iron and manganese and the presence of chlorides and sulphates or carbon dioxide can precipitate (Garg, 2005; Appelo and Postma, 2007) which further result to encrustation and corrosion within these fractures thus encourage the growth of bacteria.

The research works of various authors (Langelier (1936; Ryznar 1940; Carrier,1965; Johnson,1975 and Clarke, 1980) used the derived equations to determine the presence of corrosive and encrustation agent in waters. In Saudi Arabia, Alhameid and Al-Naeem (2014) applied the Langelier equation to the mapping of areas of corrosive groundwater. In Nigeria, Ozoko and Ugwu (2010) applied the Ryznar Stability Index in predicting borehole longevity in the Anambra basin. Obiefuna and Orazaluike (2011) applied Johnsons CEIP (Corrosion and Encrustation Index Parameter) to the problem of corrosion in Yola, Adamawa State while Longe et al (1987) applied CEIP to the evaluation of corrosion potentials in Lokoja, Kogi State. Most works on corrosion deal with the corrosion of metals (Mogg, 1972) but Ayers and Westcot (1994) have demonstrated that corrosion can affect not only metals but concrete as well.

In evaluating the corrosion potentials of any natural water, the evaluation of the Langelier Saturation Index is a powerful indicator used to determine the ability of natural water to corrode metal objects or to deposit metal oxides to clog the water pump assembly. According to Roberge (2007) other forms of indices that have been used include Ryznar Stability index, Pulkorius Scaling Index, Larson –Skold index, Oddo – Tomson Index. According to Ita and Effiong, (I999), the parameters that accountable for corrosion and encrustation of metals occur in specified concentrations in ground water (Johnson, 1975), these comprise; hydrogen ion concentration (pH), total dissolved solids (TDS), total iron (Fe), manganese (Mn), dissolved oxygen (DO), and hydrogen sulphides (H_2S). Others are chloride (Cl), bicarbonate (HCO_3) and total carbonate hardness, (TCH) (Raghunah, 2007). Works revealed by some researchers found out that corrosion can only advance provided PH < 7, EC > 1500µS/cm or TDS >1000, HCO > 50mg/l, CL > 500mg/l, H_2S > 2mg/l while the encrustation can be advanced by factors such as Mn> 0.1mg/l, PH > 7, TCH > 100mg/l and Fe > 0.2 mg/l.

The project assesses the level of corrosion and encrustation caused by groundwater on borehole casing pipes mostly the mild steel pipes that is mostly used for deep boreholes in the study area using Corrosion and Encrustation Index Parameter (CEIP) and other parameters. Each sample was analyzed for their indexes. The results analysed, interpreted and correlated with the Corrosion and Encrustation Index Parameter and compared to World Health Organization (WHO, 20O6) water quality standard in order to proffer solution.

2. GEOLOGICAL/ HYDROGEOLOGIC SETTINGS OF THE STUDY AREA

The geologic sequence around Lagos extends through the cretaceous Abeokuta formation (Akinmosu, 2012) that overlies unconformably on the basement complex, to the quaternary alluvial sediments. The Lagos State geology (Figure 2.1b) consists mostly the sedimentary basin made of tertiary and quaternary sediments. The tertiary sediments are made of unconsolidated sandstones, grits with mudstone laminar and sand with intercalations of clay whereas, the Quaternary deposits consist of mangrove swamps and alluvium deposits adjoining the coast. The major soil groups are juvenile, organic- hydromorphic a ferrallitic soils (Okosun,1998).

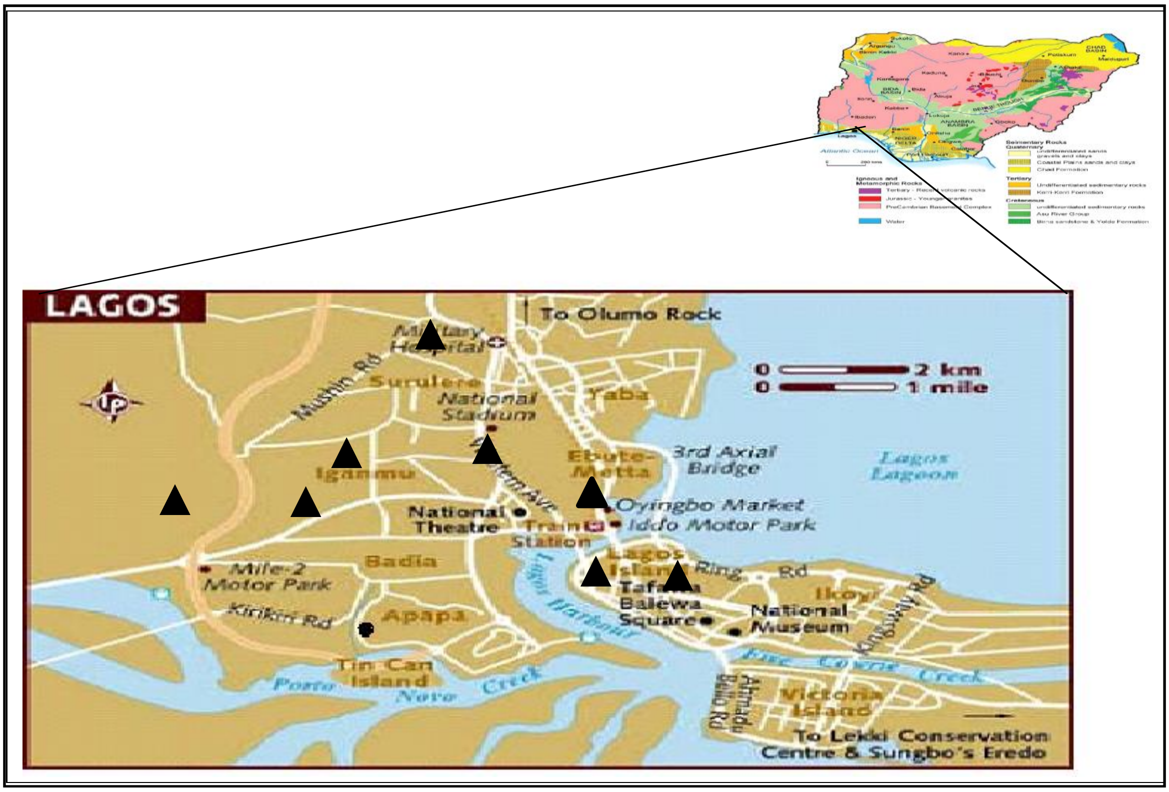


Figure 1: Generalized Geological Map of the study area (After Adelana *et al.*, 2008)

Table 1: Formation Succession in Lagos and its Environs.

Age	Formation
Quaternary	Deltaic plain
	Benin formation
Tertiary	Ilaro formation
	Oshosun formation
	Ewekoro formation
Cretaceous	Abeokuta formation
	Basement

The llaro Formation comprises fine to coarse grained sands alternating with shales and clays, This may only sustain very poor boreholes. The Ewekoro/Akimbo / Oshosun Formations, as discussed by Adegoke (1980), consist of a sequence of sandstones, shales, limestones and clays (Offodile 2002). The Ewekoro Formation consists of argillaceous rock with poor groundwater potential due to its nature. The Abeokuta Formation is made of arkosic sandstones and grits, tending to be carbonaceous towards the base. The formation has good potential for ground water except the bituminous materials associated with the sands might affect the quality of the water (Offodile 2002). All the formations are multi-aquiferous, but the relatively deep depths of the aquiferous zones witnessed in both Ewekoro and Abeokuta Formation around Lagos make them economically unattractive for groundwater prospecting. Most of the boreholes in the area depend on Akinbo Formation for water supply (Hydro 1993).

The study area (Odumosu *et al.*, 1999). is located within the southwestern coast of Nigeria with coordinate; latitudes 6^0 22'N and 6^0 52'N and longitudes 2^0 42'E and 3^0 42'E respectively (Figure 1). George (2009) in his research work asserted that Lagos is characterized by a wet equatorial climate with mean annual rainfall above 1800mm. The area experience two main seasons, namely; the rainy season and dry season, which usually last from April to October and October to March respectively. It experiences an average temperature of 27^0C. The vegetation cover is dominated by swamp forest, wetlands and tropical swamp forest comprising of fresh waters and mangrove. Water and wetlands cover over 40% of the total land area within the state and an additional 12% is subject to seasonal flooding (Iwugo *et a*l., 2003).

3.0 MATERIALS AND METHODS

Fifteen representative borehole water samples were collected within the study area in Lagos and its environs using sterilized two (2) litre volume plastic container. The plastic was thoroughly rinsed with the water from the boreholes toward ensuring no debris / impurities / particles inside it. The samples were stored in a refrigerator immediately after returning from the field to avoid unusual change in water quality before taking them to Lagos State Water Corporation Iju-Ishaga road, Lagos State for laboratory analysis. Hydrogen ion concentration (pH), Electrical conductivity (EC), Temperature (T), Dissolved oxygen (DO) were measured in during field sampling with the aid of portable Electrical conductivity probe, temperature and pH meters. This is due to unstable nature of these parameters in relationship to time factor. Chemical parameters were conducted in the laboratory using the Atomic Absorption spectrophotometer for cations and conventional titration for anions. Ions were converted from milligram per litre to milliequivalent per litre and anions balanced against cations as a control check of the reliability of the analysed results.

100ml of samples acidified with 5ml of conc. HNO_3 were measured into a 250ml conical flask, 5ml of conc. HCL were added and heated on a hot plate to about 60^0c for 15minutes. The flask was removed from heating, cooled and filtered. The filtrate from the flask was made up to 250ml in standard volumetric flask while Fe, Ca, Mg, Mn and As were analysed using Atomic Absorption Spectrometer (AAS), (Buck Scientific, Model 200A) Further calculation was conducted using Ryznar stability index parameter (Ryznar 1944) to predict the carbonate scale in water. This is an advanced equation developed to modify Langelier (1936) equation. The equation specifies that for any Ryznar index greater than six (6) indicate the likelihood of the water to form $CaCO_3$ scale, whereas when the value is less than six (6) the water will dissolve $CaCO_3$ scale. The equation is as thus:

$$RSI = 2pHs - pHa \quad \text{-------------------------} (1)$$

$$pHs = (9.3 + A + B) - (C + D) \quad \text{----------------}(2)$$

Where $A = (Log_{10}*(TDS) - 1)/10$

$B = (-13.12*Log_{10}(TEMP+273) + 34.55)$

$C = Log_{10}(CaH) - 0.4$

$D = Log_{10}(M - Alk)$

$RSI = 2pHs - pHa$

The following parameters are used in the calculation process; TDS- total dissolved solids, TEMP – temperature, M-Alk = M- alkalinity, pHs – saturation pH and pHa – actual pH respectively.

4. RESULT AND DISCUSSION

The chemical composition of any groundwater is estimated mostly by the composition of the precipitated water from the source rock area, the types of minerals present in that environment, human activities such as mining and waste disposal, climatic variability and topography of the area (Akpah and Ezeigbo *et al*., 2010).

The physical and chemical analysis results from the ground water samples are displayed in Tables 1(a & b) showing the field and laboratory analysis results and table 2 presents the ranges of the CEIP of the samples under study and their interpretation based on Johnson (1975).

Table 2: The outcomes of field and laboratory analysis of the samples from the study area

LOC	Ph	Temp	TDS (mg/l)	EC	TH (mg/l)	DO	Turbid itv	Total alkalin ity (mg/l)	Cl-	Fe	Mn	Ca
L1	5.6	28	ND	280	52	2.3	85	40	45	2.6	NIL	30
L2	5.4	28	ND	360	50	2.6	80	42	52	2.8	1.2	32
L3	5.7	28	ND	320	54	2.6	89	44	53	2.5	0.8	33
L4	5.2	27	ND	300	48	2.4	83	41	48	2.7	0.6	36
L5	6.9	25	310.5	430	220.3	2.4	11.3	274.9	6.8	0.67	ND	85.8
L6	6.9	25	392.2	430	208.1	2.5	66.3	270	10.2	2.1	ND	81
L7	6.8	25	289.1	430	226.4	2.3	14.4	267.4	6.8	0.43	ND	89
L8	6.6	25	87	140.8	28	2.2	20	30	30	0.6	0.1	10
L9	6.5	26	88	152	22	2.5	68	35	32	0.8	0.2	12
L10	6.6	26	86	140.8	26	2.2	74	28	29.5	1	0.4	0.8
L11	5.6	30	ND	136	45	2.1	83	20	17	0.7	NIL	35
L12	5.5	30	ND	216	43	2.3	65	22	20	1	1.1	33
L13	5.3	30	ND	310.5	47	2.5	10.7	24	25	0.5	0.9	31
L14	5.7	30	ND	320	41	2.1	13.6	21	27	2.2	0.7	37
L15	5.2	29	ND	300	43	2.5	72	23	31	2.5	0.6	31.6
Mz	6	27.5	250.6	284.4	76.9	2.4	55.4	96.6	28.9	1.54	0.66	38.48
RG	5.2-6.9	25-30	86.0-392.0	140.8-430.0	22.0-226.4	2.1-2.6	10.7-89.0	20.0-274.9	6.8-53.0	0.43-2.8	0.1-1.2	0.8-89.0

pH: Hydrogen ion concentration (pH), from the water analysis from the studied area ranges from 5.2 – 6.9 with an average pH value of 6.0.Ten out of the 15 samples analysed (67%) in these locations are acidic because their values are lesser than the minimum level of 6.5 when compared to World Health Organisation limit which ranges from 6.5-8.5 (WHO, 2006). The more the values reduce below the 6.5 minimum limits, the more acidic the water. The remaining 5 samples (33%) were within the acceptable range. The water samples under study shows that 67% of the samples tend to be corrosive (Johnson, 1975) while the remaining 33% is said to influence encrustation (table 2).

Electrical Conductivity (EC): This depends on the quantities of ions present in water. The electrical conductivity values of the samples under study are below 1500µS/cm (the highest permissible limit) with the highest being 430.0µS/cm (Table 2). This indicates that the electrical conductivity has not contributed to the corrosive nature of water. The CEIP standard (Raghunath, 2007) of electrical conductivity must be greater than 1500µS/cm before corrosion can take place.

Total Dissolved Solids (TDS): This parameter of the samples under study vary from 22.0 to 226.4 with the mean value of 76.9 (table 2). This suggest that the borehole water in the area under study are rich in dissolved minerals such as calcium, sulphate, silica and chloride, but with low electrical conductivity as supported by Akpah (2008) in his research work. The presence of the dissolved minerals in water increases its electrical conductivity thereby making it a god electrolyte allowing current to flow readily this enables corrosion of iron and steel to occur rapidly (Johnson, 1975).

Temperature: The temperature of the water samples is between 25˚C - 30˚C with an average value of 27.5 Corrosion occurs when the water temperature is greater than 27˚C (Amah et al., 2008).Only nine samples (60%) fall under the temperature threshold (Table 2), while the other six samples (40%) did not meet the required CEIP. When temperature is high, the activity rate of the ions in water increases thereby leading to an increase in electrical conductivity of water and corrosion rate. The electrochemical reaction responsible for corrosion requires high temperature in the presence of oxygen.

It was reported that when the groundwater temperature was high, the more destructive (Amah *et al*., 2008) the environment, which may reflect the possible borehole installation corrosion as experienced in wells bored within the study area with the mean surface temperatures values of 27°C. The temperatures variation ranging from 25 to 27.5°C (Obiefuna and Orazulike, (2010) a are capable of contributing to cause corrosion of boreholes and groundwater wells in the area.

Chloride Concentration: This varies from 6.8 mg/l to 53.0 mg/l, with a mean value of 28.9 mg/l (Table 2). About four samples (26%) analysed had Chloride concentration that is greater than 40 mg/l from the studied area which indicates that it is a saline water, while the other 74% samples have their chloride concentration level less than 40 mg/l. Although, all the samples under study fall below the minimum threshold for corrosion to take place, but the chloride concentrations coupled with TDS values fall below 1000 mg/l. They may have increasing effect in electrical conductivity and corrosion rate.

Dissolved Oxygen (DO): this is a very important among the agents that causes corrosion. The measured values of the dissolved oxygen in the study area falls between 2.1 mg/l and 2.6 mg/l. Dissolved oxygen concentration values greater than 2mg/l makes water to be corrosive (Raghunath , 2007 and Johnson, 1975).This indicate that the values of dissolved oxygen in the samples must have contributed to the corrosive nature of the well water samples. In water it acts as an oxidizing agent which oxides iron (Fe) metal, thereby oxidizing it by losing electrons I (equation 1) while oxygen is reduced by gaining electrons (equation 2). Equation 3 is a summary of the redox equation that causes corrosion (Fabian et al., 2011).

Oxidation half equation: $2Fe - 2Fe^{2+} + 4e^{-}$…………1

Reduction half reaction: $2H_2O + O_2 + 4e^{-} - 4OH$ ……….2

Redox reaction: $2Fe + 2H_2O + O_2 – 2Fe (4OH)_2$………3

$2Fe(4OH)_2$ engages in further reaction with oxygen to rust.

Dissolved oxygen occurs in higher concentration in shallow aquifers due to the increasing exposure of the water wells to atmospheric oxygen and precipitated water (Offodile, 2002).

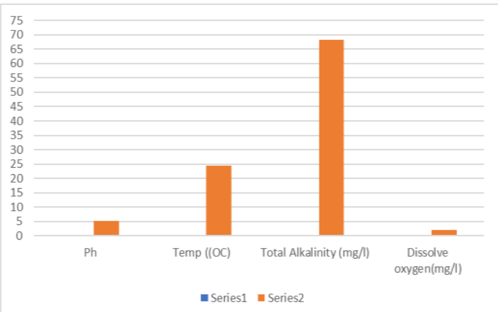
Total Alkalinity: The shallow groundwater (Schwartz and Zhang, 2003) in most cases may be rich in carbonic acid. This could possibly occur when carbon dioxide is liberated and interact

with the atmospheric precipitation causing to carbonic acid formation.
$CO_2 + H_2O \rightarrow H_2CO_3$
This acid rain may possibly permeates the groundwater thereby reducing the pH of the subsurface water and upsurge the acidity. About 4 percent of the sampled groundwater has hydrogen sulphide concentration greater than 2 mg l^{-1}. Though, other parameters such as chloride (< 28.9 mgl^{-1}) and TDS values (< 392 mg l^{-1}) are commonly lesser (Johnson, 1975) than 500 mgl^{-1} (chloride) and that of 1000 mgl^{-1} (TDS) respectively. He explained further that they contributed insignificantly to corrosion of water wells from the study area. Also, the presence of slightly increased acidity (or low pH), bicarbonate (HCO_3) coupled with the temperature of the samples may possibly contribute to deterioration of some wells from the area under study.

The presence of bicarbonate concentrations in water samples under study may possibly be from the calcite availability in the source rock through which the water is flowing. This may cause $CaCO_3$ clogs (Obiefuna and Orazulike, 2011) around the screen, thereby reduce the productivity of the well. Calcite is usually deposited in wells with methane gas presence, this will later oxidize to CO_2 by microbial oxidation. This forms a calcified slime displaying whitish spots in rock (Johnson, 1975) or casing pipe surfaces.

Table 3: Summary of the Range of measured parameters and percentage of corrosion and encrustation index parameter (CEIP) from Johnson, 1975 and WHO (2006)

Parameters	Range of CEIP	Mean	JOHNSON 1975	WHO 2006
p^H	5.2 – 6.9	6.0	Corrosive pH<7 Encrustation pH>7	Acidic Ph<7 Alkaline Ph>7
Temperature ^OC	25 – 30	27.5	Corrosive temp >27C	-
TDS (mg/l)	86.0 – 392.2	250.6	Corrosive TDS>1000 mg/l	<1000
EC (µS/cm)	140.8 – 430.0	284.4	Corrosive EC>1500 µS/cm	-
Fe (mg/l)	0.43 – 2.8	1.54	Encrusting Fe>0.3	<0.3
Mn (mg/l)	0.1 – 1.2	0.66	Encrusting Mn>0.1	<0.05
DO (mg/l)	2.1 – 2.6	2.36	Corrosive DO>2.0	-
H_2S (mg/l)	Not Determined	ND	Corrosive H_2S>2.0	-
Cl^- (mg/l)	6.8 – 53.0	28.9	Corrosive Cl^->500	200
HCO_3 (mg/l)	ND	ND	Corrosive HCO_3>50	-
Total Hardnes (mg/l)	22.0 – 226.4	76.9	Encrusting THC>100	100



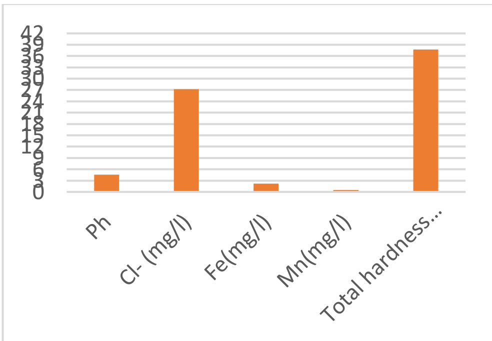


Figure 2 (a &b): Plot of histogram of percent (a) Corrosion Index Parameters (CIP) and (b) Encrustation Index Parameters (EIP) against water quality parameters (After Obiefuna and Orazulike, 2011)

4.1 Encrustation Parameters

The encrustation occurrence around the screen slot and the aquifers can be appraised based on encrustation index (Obiefuna and Orazulike, 2011; Johnson, 1975) parameters. These are; Iron (Fe), Manganese (Mn), Hydrogen iron concentration (pH) and Total Carbonate Hardness (TCH). Iron and Manganese are possible encrustation parameters that results to encrustation within the area under study and as well contributed to the water hardness of with the following values: Fe > 0.3 mg/l, Mn > 0.1 mg/l, THC > 100mg/l and $_{p}$H > 7. Iron concentration in the measured samples under study varies from 0.43 – 2.8 mg/l, 100 percent of the samples have iron concentration values greater than 0.3mg/l (Johnson, 1975). This may also results when suspended particles of are transported towards the slotted pipe (Amah *et al.*, 2008) possibly due to either inappropriate development of the wells, poor selection of screen slot size or wrong positioning of screen pipes in the hole with high content of these materials. The high iron concentration in some of the wells under study might have perhaps resulted from corrosion of well construction and pipes in contact with subsurface acid water, mostly when the well was either abandoned for a period of time or not developed prior pumping (Amah *et al.*, 2008). Thus, scaling of groundwater wells in the wells may principally be due to high total iron, high pH (alkalinity) and high TCH contents of the water (Fig. 2). This is an indication that the water samples from this study area if not subjected to treatment, will cause laundry stain and plumbing fixtures, while encrustation resulted from precipitation of iron and manganese compounds will deposit on well screens, pipes and the aquifers.

Further to the study Ryznar stability index parameter (Ryznar 1940) was conducted to predict the carbonate scale/ encrustation level present in the borehole water under study. The equation specifies that for any Ryznar index is greater than 6, this indicate the water is likelihood to form scale generated from $CaCO_3$, whereas when the value is lesser than 6, the water will dissolve $CaCO_3$ scale. The result of the Ryznar stability index of the samples (Table 4) under study shows that it ranges from 7.46 to 11.68 with a mean value of 10.38. This suggest that the water is prone to forming $CaCO_3$ scale around the screen slot. Organic oxidation in leachates around the study area may contribute to precipitates $CaCO_3$ mostly when the carbonate is near saturation. These may lead to $CaCO_3$ clogging of the screen slots thereby reduce well performance due to the accumulation of mineral around the screen leading to reduction of effective hydraulic conductivity of the system.

Table 4: Calculated Ryznar stability index parameter of the studied samples predicting the carbonate scale/ encrustation level in the groundwater (Ryznar 1940)

LOC	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14
pHs	8.24	8.23	8.18	8.28	7.18	7.22	7.18	8.97	9.00	9.02	8.64	8.55	8.74	8.95
RSI	10.88	11.06	10.56	7.46	7.56	7.54	7.56	11.34	11.50	11.44	11.68	11.6	11.64	11.48

Corrosion is the product of oxidation and reduction reactions whereby the metals act as electrodes and groundwater ionic constituents as the electrolytes. Corrosion effect can be controlled or minimized when the reactive mediums do not come in contact. It can be remediated through the application of protective coatings such as paints on the metallic pipes/ casing pipes in contact with water and also the use of PVC materials may be advised.

The rock types which consist of unconsolidated sandstones, limestone, and shale can be responsible for the possible exposure of the ground water to iron and manganese enrichment. The manganese concentration of the ground water samples is greater than 0.1mg/l (Table 1). The value makes water from the borehole to be encrusting as precipitation of the metals in the groundwater table. The total hardness varies from 22.0 mg/l -226.4 mg/l. The bicarbonate content of water sample was not determined in this analysis. The hardness values which are mainly from sulphate could also cause encrustation.

5. CONCLUSION AND RECOMMENDATION

The preliminary investigation of the CEIP from the area under study suggest the samples are corrosive to most metals such as surface tanks, pumps and metal pipes. The mean value shows the acidity nature, $_{p}$H (5.2 – 6.9), dissolved oxygen, DO (2.1mg/l – 2.6mg/l), and temperature (25 – 30˚C) respectively. This indicates that the groundwater in the area all have higher constituents than the minimum values required for corrosion to take place except for the electrical conductivity where none of the samples have EC values greater than the threshold of 1500µS/cm, EC (140.8 – 430.0µS/cm). Considering the variation in the constituents of these samples, it is indicative that they are corrosive and encrustation level is higher than Johnson (1975) CEIP. The high presence of iron and manganese in the water coupled with their hardness has contributed to the encrustation status of the samples.

This research indicates that the area under study generally has varied risk levels of corrosion and encrustation. It is also observed that the failure experienced in some of the boreholes might possibly resulted from improper selection of submersible pumps (Johnson, 1975), using inferior riser pipes (Ishiaku and Ezeigbo, 2000) and installation of inferior pump and operation activities. These could result to electrical default of the pumps and/or collapsing of the wells. The corrosion and encrustation risk observed in few groundwater well locations could be ameliorated by applying the appropriate drilling procedure, selecting the right materials such as corrosion resistant casings and well screens made of non-ferrous metal alloys (stainless steel) coupled with PVC pipes and coating of borehole installation materials with galvanized zinc and tar for well construction and completion of borehole by certified geologist, hydrogeologist, water engineers and drillers to design an appropriate section to locate the screen and using appropriate screen slot where necessary.

The encrustation observed from the borehole resulted from increased concentration of iron and manganese in the studied samples can be improved by oxidizing the soluble ferrous ions to insoluble ferric ion. The precipitates formed is removed by energetic flocculation, filtration and chlorination. Application of corrosion resistant paint on the walls and surface of the metals is required to provide protective coatings and prevent direct contact with water and the deposition of polyphosphate film on the pipe materials will also prevent the corrosive water from coming in contact with the pipe. It is advisable to conduct pumping test before selecting and installing the final pump and using original materials for riser pipes would sustain In addition the borehole be regular maintained using air lifting, jetting, acid treatment and chlorination is recommended.

ACKNOWLEDGMENTS

I wish to appreciate all that has contributed to this write up, mostly those whose research work had been cited and the laboratory where the analysis has been conducted. Thank you.

REFERENCES

Akpah, F. A. (2008) Hydro geochemical investigations on groundwater in Itakpe and its environs. M.Sc. Thesis, University of Nigeria Nsukka.

Alhameid, A.H., and Al-Naeem, A.A., (2014). Spatial Patterns of groundwater quality and its Applied Science Research, vol.9 (No 9) pp.545-556.

Alslaibi, T.M., Y.K. Mogheir and S. Afifi, (2011). Assessment of groundwater quality due to municipal solid waste landfills leachate. J. Environ. Sci. Technol., 4: 419-436.

Amah, E. A.; Esu. E. O, and Nketim E.E.U (2008) Evaluation of Corrosion and Encrustation Potentials of Groundwater wells in Calabar. Global Journal of Geol. Sci.; 6(1), pp 1-7

APHA,(1989) America Public Health Association, Standard method for examination of water and waste water, N. York.

Appelo, C.A.J. and D. Postma, (2007). Geochemistry, Groundwater and Pollution. A.A Balkema Publication, Amsterdam, The Netherlands.

Ayers, R.S. and Westcot, D. W., (1994). Water Quality for Agriculture (FAO Irrigation and Drainage paper).

Carrier Air Conditioning Company, (1965). Handbook of Air Conditioning System Design, Mc Graw Hill. New York.

Carter, J. D., Barber, W. &Tait, E.A. (1963). The geology of parts of Adamawa Bauchi and Bornu Provinces in north-eastern Nigeria. Bulletin of the Geological Survey, Nigeria, 30.

Clark, F.E., (1980). Corrosion and Encrustation in Water wells. A field guide for Assessment, Prediction and Control (FAO Irrigation and Drainage Paper).

Daghrah, G.A., (2009). Water quality study of Wadi Al Qilt-West bank-Palestine. Asian J. Earth Sci., 2: 28-38.

Fabian Apeh Akpah, Rufai Ayuba and Mercy Omojo Lekdunkun (2011) Preliminary Assessment of Corrosion and Encrustation Potentials of Groundwater in Itakpe, North Central, Nigeria Journal of Mining and Geology Vol. 47 (1) 2011, pp. 19 – 25.

Farnbauer, B. &Tietz, G.(2000).The individuality of laterites developed on the Jos Plateau/Central- Nigeria (in Deutsch).Zbl. Geol.Palaeont. Tiel I, Heft 5/6,509–525.

Gabriel Ike Obiefuna and Donatus Maduka Orazulike, (2011). Evaluation of Corrosion and Encrustation Potentials of Boreholes in Yola Area, Northeastern Nigeria. *Trends in Applied Sciences Research, 6: 1197-1205.*

Garg, S. K. (2005) Hydrology and water resources engineering.13th revised edition, Khanna Publisher Delhi, 764p

George, C. K. (2009). The Challenges of Urbanisation in Nigerian Urban Centres: The Lagos Mega city Situation– A Town Planner's Perspective. Libro-Gem Books Ltd., Lagos.

Hilles, A.H. and H. Al-Najar, (2011). Brackish water desalination is the merely potable water potential in the Gaza Strip: Prospective and limitations. J. Environ. Sci. Technol., 4: 158-171.

Ishaiku, J.M. and H.I Ezeigbo, (2000). On the longevity of boreholes/ water wells in Yola in Nigeria water resources. J. Nig. Assoc. Hydrogeol; 11:49- 54

Iwugo, K. O.; D'Arcy B.; Andoh, R. (2003). Aspects of Land-based pollution of an African Coastal Megacity of Lagos. Proceedings of the International Specialized IWA Conference, Dublin, Ireland.

Johnson E. E.; (1975). Groundwater and wells. Johnson Division, UOP Inc. pp. 317 – 344

Ladipo, K.O. (1988). Paleogeography, sedimentation and tectonics of the Upper Cretaceous Anambra Basin, Southeastern Nigeria. Journal of African Earth Sciences, 7,865–871.

Langelier, W. F., (1936). The analytical control of anti-corrosion water treatment. Journal of American Water Works Association. Vol. 28, Nos. 10, pp. 1500-1521.

Longe, E. O., Malomo, S. &Olorunniwo, M. A. (1987).Hydrogeology of Lagos metropolis. Journal of African Earth Sciences, 6, 163–174.

Mogg, J.L., (1972). Practical Corrosion and Incrustation Guidelines for water wells. Groundwater vol. 10, issue 2, pp.6-11.

Obiefuna, G.I. and D.M. Orazulike, (2010). Physicochemical characteristics of groundwater quality from Yola Area, Northeastern Nigeria. J. Applied Sci. Environ. Manage., 14: 5-11.

Odumosu, T.; Balogun, Y.; Ojo, K. (1999). Lagos State in Maps. Rex Charles Publication. Ibadan.

Offodile E. M. (2002) Groundwater study and development in Nigeria, Mecon Geology and Engineering Services, pp. 328 – 330.

Okosun, E. A. (1998). Review of the early Tertiary stratigraphy of Southwestern Nigeria. Journal of Mining Geology, 34, 27–35.

Oluyide, P. O., Nwajide, C. S. & Oni, A. O. (1998). The geology of Ilorin area with explanations on the 1:250,000 series, sheet 50 (Ilorin). Geological Survey of Nigeria Bulletin,42,1-84.

Ozoko, D. C. and Ugwu, I. M., (2010). Prediction of Bore- hole failure in Anambra Basin on the basis of Corrosion and Encrustation Studies. Journal of Environmental Research and Policies vol. 5, (Nos. 4) pp.52-60.

Raghunath H.N, (2007). Groundwater 3rd edition, New Age International Publishers Limited, New Delhi.Pp312-313.

Ryznar, J.N.,(1940). A new index for determining amount of calcium carbonate scale formed by a water. Journal of American water works Association. vol. 36, p472

Roberge, P.R., (2007). Corrosion Inspection and Monitoring John Wiley and Sons, New York. 373pp

Schwartz, F.W. and H. Zhang, 2003. Fundamentals of Groundwater. John Wiley and Sons Inc., New York, ISBN: 0-471-13785-5, pp: 577

Shomar, B., K. Osenbruck and A. Yahya, 2008. Elevated nitrate levels in the groundwater of the Gaza Strip: Distribution and sources. Sci. Total Environ., 398: 164-174.

Sundaramanickam, A., T. Sivakumar, R. Kumaran, V. Ammaiappan and R. Velappan, (2008). A comparative study of physico-chemical investigation along parangipettai and cuddalore coast. J. Environ. Sci. Technol., 1: 1-10.

The Corrosion Technology Laboratory (NASA) http:// corrosion.ksc.nasa.gov/index.htm

Todd, D.K., (1995). Groundwater Hydrology. John Wiley and Sons Inc. New York.

WHO, (2006).Guidelines for Drinking-Water Quality: Recommendations, 1st Addendum, Vol. 1. 3rd Edn., World Health Organization, Geneva.