Investigation of Some Factors Influencing Corrosion on Refrigerator

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Abstract:
The corrosion of steel reinforcing bar can proceed out of sight and eventually result in failure of a section of the highway. The collapse of electrical towers, damage to building, leakages in refrigerator all these result in significant repair cost, endangering public safety and health. This paper presents investigation of some factors influencing corrosion on refrigerator, such as presence of dissolved mineral, organic impurities and dissolved gasses in the water. The survey results are presented using graphs. T-test and Anova were used to ascertain the significance of the factors. The result of alternative Hypothesis and null Hypothesis on the T-test and Anova test were carried out on the factors causing corrosion and responsible for the corrosion were able to be identified. The results revealed that the corrosive effect of fresh water varies from locality to locality due to the wide variety of dissolved impurities, the organism causing the greatest corrosion problems are bacteria and fungi, time of exposure to a corrosive environment influences metal corrosion, most salt solution is good electrolyte and can promote corrosive attack and corrosion effects reduce the life span of refrigerator. The result of this research would guide environmental and material engineers in better planning to minimize corrosion.

1. Introduction

The word corrosion is as old as the earth, but it has been known by different names. Corrosion is commonly known as rust, undesirable phenomena which destroy the luster and beauty of objects and shortens their life. Corrosion since ancient times has affected not only the quality of lives of people, but also their technical progress. There is historical record of observation of corrosion by several writers, philosophers and scientist, but it was noted that there was little curiosity regarding the causes and mechanism of corrosion (Davis, 2000). Corrosion is deterioration of the destructive attack of a metal by chemical or electrochemical reaction with the environment. It was observed that corrosion was not restricted only to metals and their alloys alone but incorporates ceramics, polymers, composite and semiconductors. The term corrosion now embraces all types of natural and non-natural material including biomaterial and nanomaterial (Alum *et al.*, 2014 & Navid *et al.*, 2007). This form of corrosion frequently occurs within crevices or gap and other shielded areas on metal surfaces exposed to corrosives. "The damage was found mainly in the vicinity of welded area" (Meligi, 2010). It is one of the most frequently encountered forms of localized corrosion and at the same time one of the most harmful ones because it happens in the alloys that normally exhibit perfect corrosion resistance such as stainless steel and it also occurs in areas that are not immediately visible (Navid *et al.*, 2007). Therefore crevice corrosion may lead to sudden devastating failure of the metal in service. Pitting corrosion is localized accelerated dissolution of metal that occurs as a result of a breakdown of the otherwise protective passive film on the metal surface (Frankel, 1998). When corrosion does occur, it sometimes hollows out a narrow hole or *pit* in the metal (Stephen, 2012). Cracks have been observed to form from pits under cyclic loading conditions. These holes may be small or large in diameter, but in most cases they are relatively small. Pits are sometimes isolated or so close together that they look like a rough surface. It causes equipment to fail because of perforation with only a small percent weight loss of the entire structure (Eberle, 1997).

Grain boundary effects are of little or no consequence in most applications or uses of metals. If a metal corrodes, uniform attack results since grain boundaries are usually only slightly more reactive than the matrix. In Inter granular Corrosion, Localized attack at grain boundaries, with relatively little corrosion of the grains. As corrosion proceeds, the grains fall out and the metal or alloy disintegrates (Nieves *et al.*, 2012**).** Localized attack at and adjacent to grain boundaries with relatively little corrosion of the grains, is inter-granular corrosion. The alloy disintegrates (grains fall out) and/or loses its strength. The susceptibility to inter-granular corrosion is given by the loss of weight due to the dissolution of chromium depleted areas and is expressed as the rate of weight loss in mg per sq·dm per day (Mehmet, 2012). Inter-granular corrosion can be caused by impurities at the grain boundaries, enrichment of one of the alloying elements, or depletion of one of these elements in the grain-boundary areas.

This erosion-corrosion is resulting from the very high velocities experienced on the HP header of Amenam Drilling Platform 2 (AMD2), certainly combined with some production of sand (Alum *et al.*, 2014**)**. Erosion corrosion is characterized in appearance by grooves, gullies, waves, rounded holes, and valleys and usually exhibits a directional pattern. In many cases, failures because of erosion corrosion occur in a relatively short time, and they are unexpected largely because evaluation corrosion tests were run under static conditions or because the erosion effects were not considered (Hackerman, 1993).

Stress corrosion cracking is cracking due to a process involving conjoint corrosion and straining of a metal due to residual or applied stresses (Cottis 2000). It was noted that failure due to stress corrosion cracking and corrosion fatigue, is the main cause of centrifugal compressor impeller failure. The stress can be externally applied or it can be an internal residual stress. (Truhan *et al.,*1977). Flow Accelerated Corrosion (FAC) is distinct from erosion–corrosion and is primarily a corrosion process aided by chemical dissolution and mass transfer **(**Muhammadu *et al.,* 2013). It is recognized by its characteristic wormlike trace of corrosion products beneath the paint film. About 80% from all degradations produced by corrosion in the metallic constructions are due to the atmospheric corrosion (Badea1 *et al.,* 2011**)**. As steel, copper, magnesium, aluminum etc. exposed to the atmosphere, they react with free flowing air and moisture to develop oxides (Alavi, 2007),

Corrosion is accelerated by higher temperature environments which accelerate chemical reactions and allow greater moisture content at saturation in air. The results show that corrosion rate increased first and then decreased significantly with increasing temperature (Yameng *et al*., 2014). Corrosion of carbon steel occurs when the relative humidity of the air is 70% to 80% and the air temperature is above 32 F **(**Ovri *et al*., 2013**).** There is chemical reaction retarding either the anodic or cathodic reactions the rate of corrosion can be reduced. The concept of applying a more noble metal coating on active metal take advantages of greater corrosive resistance of the noble metal (Viktor, *et al.,* 2015). Preventive measures being used in the construction industry to salvage the service life of steel reinforcement in concrete structures includes cathodic protection, inhibitors, coatings, penetrating sealers and chloride (Singh *et al*., 2011 and Neville, 2015).

A more sophisticated strategy is to maintain a continual negative electrical charge on a metal, so that its dissolution as positive ions is inhibited. Since the entire surface is forced into the cathodic condition, this method is known as cathodic protection (**Zhang**, 2011). In refrigerator, the main components prone to corrosion are the metallic outer body, the flow tubes and the compressor machines. Corrosion is severe on the outer metallic body and inner metallic shelves. Minor scratches can transform from uniform to pitting corrosion. The pitting corrosion could leads to minute hole which allow for escape of working flood, hereby creates refrigerator inefficiency (Verma, 2002).

Therefore, adequate protection must be provided during transportation and installation to prevent scratches. Corrosion of the working components could leads to total breakdown of the whole system (Evans, 1972). Many of the challenges of using wood as an engineering material (e.g. decay, corrosion of fasteners, and dimensional instability), arise from changes in the wood moisture content or an abundance of moisture within the wood (Samuel, 2016**).** Refrigerators are usually kept on wooding or metal stands to allow proper ventilation and protect the base from water which is sometimes trapped under the system. Most people prefer wooden stand to metal as they don't know that it can corrode the metal. Organic chemicals are used in textile, chemical, food and fibers (Samuel, 2016).

The study would cover five different areas in Oyo and Offa metropolis of Oyo and Kwara state respectively. Alakaa Area ,Sabo Area ,Kosobo Area ,Awe Area and Oroki Area,while Offa areas covered Federal polytechnic community ,Atari Area ,Amuyo Area ,Isale Ago Area and Secteriat Area .

2. Material and Method

The following research design, population size, sample frame, sample size, sampling technique, source of data, instrument for data collection, validation, method of data collection and questionnaire design and data analysis. The study of "Corrosion assessment and its control on refrigerator" was carried out in five different areas each within Oyo and Offa metropolis in Oyo State and Kwara State of Nigeria. One hundred samples of refrigerators from different manufacturers and models were investigated. Sampling procedure in Oyo and Offa area are shown in Table 1:

The various factors causing corrosion of refrigerator, the condition of equipment at the time of purchase, the probable life span, individual usage style and likely maintenance method adopted were examined. Other factors considered is environmental condition in which this equipment are been operated and materials stored or place on the refrigerator apartment and several factors causing corrosion are examined.

2.1 Data Analysis

In this study both descriptive which includes mean frequency distribution and statistical test: t-test (Two Sample Assuming Unequal Variance) and Anova (Two-Factor without Replication) were used to analyze the data.

2.2 Two Sample t Test: unequal variances

The two-sample t-test is one of the most commonly used hypothesis tests to compare whether the average difference between two groups is really significant or not.

2.3 Two Factor ANOVA without Replication

In Two Factor ANOVA without Replication there was only one sample item for each combination of factor A levels and factor B levels.

$$df_A + df_B + df_{AB} + df_W = (r-1) + (c-1) + (r-1)(c-1) + (n-rc) = n-1 = df_T \quad (1)$$

Property 1: Note that between group terms are as for the one-way ANOVA, namely

$$SS_{Bet} = m\sum_{i,j}\left(\bar{x}_{ij} - \bar{x}\right)^2 \qquad df_{Bet} = rc - 1 \quad (2)$$

Property 2: If a sample is made as described in Definition 1 and 2, with the x_{ijk} independently and normally distributed and with all σ_j^2 (or σ_i^2) equal, then

$$MS_T \sim \frac{\sigma_T^2}{df_T}\chi^2(df_T) \qquad MS_A \sim \frac{\sigma_A^2}{df_A}\chi^2(df_A) \qquad MS_B \sim \frac{\sigma_B^2}{df_B}\chi^2(df_B)$$

$$MS_{AB} \sim \frac{\sigma_{AB}^2}{df_{AB}}\chi^2(df_{AB}) \qquad MS_W \sim \frac{\sigma_W^2}{df_W}\chi^2(df_W) \quad (3)$$

Property 3:

$$E[MS_W] = \sigma_\varepsilon^2 \qquad E[MS_{AB}] = \sigma_\varepsilon^2 + \frac{n}{df_{AB}}\sum_j\sum_i \delta_{ij}^2 \quad (4)$$

3. Results and Discussions

Data analysis are regard as an effort to seek patterns and relationships within the information collected. The data analysis could either be descriptive or inferential. In the presentation of data, the use of tables, T-test, ANOVA-test, correlation and other visual aid permit that information to be quickly grasped and understand. As an overture to the "Corrosion assessment and his control on refrigerator" in Oyo and Offa of Oyo and Kwara state Nigeria within the study area. The data were collected, analyzed and interpreted. The information collected was based on the following; years when the refrigerator was purchased, when was the corrosion damage was first noticed, the part that started corrosion fast after purchased, Types of maintenance practices adopted by the users, type of stand used, when was electricity supplied on weekly bases and the hypothesis (i-vii).

The distribution of respondent in Oyo and Offa based on the year of purchased are presented in Figure 1. The t-test at 8 degree of freedom, t-stat = 0 is less than t-critical at one tail = 1.859548038 and two tail = 2.306004135, it can be deduce that there is no significant difference in the responses of respondent based on year of purchase in Oyo and Offa.

The distribution of respondent in Oyo and Offa based on parts when corrosion first noticed is presented in Figure 2 and t-test two-sample assuming unequal variances of respondent from Oyo and Offa based on parts when corrosion first noticed shows that there is no significant different in the responses of the correspondent in Oyo and Offa because t-stat = 0 is less than t-critical at one tail = 1.943180281 and two tail = 2.446911851 it can be deduce that there is no significant difference in the responses of respondent based on when corrosion first noticed in Oyo and Offa.

The distributions of respondent in Oyo and Offa based on when corrosion started after purchased are presented in Figure 3 and t-test was also used to confirm if there is significant different in the responses of the correspondent in Oyo and Offa. The t-test two-sample assuming unequal variances of respondents in Oyo and Offa based on when corrosion started after purchased at 6 degree of freedom, t-stat = 0 is less than t-critical at one tail = 1.943180281 and two tail = 2.446911851. It can be deduce that there is no significant difference in the responses of respondent based on when corrosion first noticed in Oyo and Offa.

The graph distribution of respondent in Oyo and Offa based on type of maintenance practices is shown in Figure 4 and t-test was used which shows that no significant different in the responses of the correspondent in Oyo and Offa. t-Test: two-sample assuming unequal variances of respondent of Oyo and Offa based on type of maintenance practices at degree of freedom of 3, t-stat = 0.197397377 is less than t-critical at one tail = 2.353363435 and two tail = 3.182446305. It can be deduce that there is no significant difference in the responses of respondent based on type of maintenance practices in Oyo and Offa.

The graph distribution of respondent in Oyo and Offa based on type of stand used is shown inFigure 5 and t-test was also used which shows no significant different in the responses of the correspondent in Oyo and Offa. t-Test: two-sample assuming unequal variances of respondent of Oyo and Offa based on type of stand used, at degree of freedom of 5, t-stat = 0 is less than t-critical at one tail = 2.015048373 and two tail = 2.570581836 it can be deduce that there is no significant difference in the responses of respondent based on type of stand used in Oyo and Offa.

The graph distribution of respondent in Oyo and Offa based on electricity supplied on weekly bases is presented in Figure 6 and t-test was also used which shows that no significant different in the responses of the correspondent in Oyo and Offa. t-Test: two-sample assuming unequal variances of respondent based on Oyo and Offa based on electricity supplied on weekly bases, at degree of freedom of 5, t-stat = 0 is less than t-critical at one tail = 2.015048373 and two tail = 2.570581836 it can be deduce that there is no significant difference in the responses of respondent based on electricity supplied on weekly bases in Oyo and Offa.

The graph distribution of respondent in Oyo and Offa Offa based on presence of dissolved mineral and organic impurities and dissolved gases is shown in Figure 7 and t-test was also used which shows no significant different in the responses of the correspondent in Oyo and Offa. t-Test: two-sample assuming unequal variances of respondent from Oyo and Offa based on presence of dissolved mineral and organic impurities and dissolved gases, at degree of freedom of 6, t-stat = 0 is less than t-critical at one tail = 1.943180281 and two tail = 2.446911851 it can be deduce that there is no significant difference in the responses of respondent based on presence of dissolved mineral and organic impurities and dissolved gases in Oyo and Offa.

The graph distribution of respondent in Oyo and Offa Offa based on the corrosive effect of fresh water varies from locality to locality due to wide variety of dissolved impurities is presented in Figure 8 and t-test was also used which shows no significant different in the responses of the correspondent in Oyo and Offa. t-Test: two-sample assuming unequal variances of respondent from Oyo and Offa based on the corrosive effect of fresh water varies from locality to locality due to wide variety of dissolved impurities, at degree of freedom of 5, t-stat = 0 is less than t-critical at one tail = 2.01504873 and two tail=2.5705836 it can be deduce that there is no significant difference in the responses of respondent based on the corrosive effect of fresh water varies from locality to locality due to wide variety of dissolved impurities in Oyo and Offa.

The graph distribution of respondent in Oyo and Offa based on the organism causing the greatest corrosion problems are bacteria and fungi is shown in Figure 9 and t-test was also used which shows that no significant different in the responses of the correspondent in Oyo and Offa. t-Test: two-sample assuming unequal variances of respondent from Oyo and Offa based on the organism causing the greatest corrosion problems are bacteria and fungi, at degree of freedom of 5, t-stat = 0.017616303 is less than t-critical at one tail = 2.01504873 and two tail=2.570581836 it can be deduce that there is no significant difference in the responses of respondent based on the organism causing the greatest corrosion problems are bacteria and fungi in Oyo and Offa.

HYPOTHESIS USED AND ANOVA TEST RESULT

Hypothesis (i) null hypothesis, Ho: Presence of dissolved minerals and organic impurities and dissolved gasses in the water does not aid corrosion and alternatives hypothesis, Hi: Presence of dissolved minerals and organic impurities and dissolved gasses in the water aids corrosion. Anova results of two factor without replication for presence of dissolved minerals and organic impurities and dissolved gasses in the water aids corrosion are presented in Table 2. From Table 2, F calculated 4.697536 is greater than F critical 3.490295 while p value is 0.021575 which is less than 0.05, therefore alternative Hypothesis (H_i) accepted and null hypothesis Ho is rejected. It is confirmed that presence of dissolved minerals and organic impurities and dissolved gasses in the water aids corrosion

Hypothesis (ii) null hypothesis: the corrosion effect of fresh water does not varies from locality to locality due to the wide variety of dissolved impurities and alternatives hypothesis: the corrosion effect of fresh water varies from locality to locality due to the wide variety of dissolved impurities**.** Anova results of two-factor without replication for the corrosion effect of fresh water varies from locality to locality due to the wide variety of dissolved impurities is presented in Table 3. From Table 3, F calculated 5.095325 is greater than F critical 3.490295 while p value is 0.016733 which is less than 0.05 therefore alternative Hypothesis accepted and null hypothesis is rejected. It is deduced that the corrosion effect of fresh water varies from locality to locality due to the wide variety of dissolve impurities

Hypothesis (iii) - null hypothesis- the organisms that causing the greatest corrosion problems are not bacterial and fungi and alternatives hypothesis: the organisms causing the greatest corrosion problems are bacterial and fungi. Anova results of two-factor without replication for the organisms that causing the greatest corrosion problems are bacterial and fungi are presented in Table 4. From Table 4, F calculated 5.454688 is greater than F critical 3.490295 while p value is 0.013415 which is less than 0.05 therefore alternative Hypothesis accepted and null hypothesis is rejected. It is confirmed that the organisms that causing the greatest corrosion problems are bacterial and fungi.

Hypothesis (iv): null hypothesis - microbial growth should not be removed completely to avoid corrosion and alternatives hypothesis - microbial growth should be removed completely to avoid corrosion. Anova results of Two-Factor without Replication for microbial growth should be removed completely to avoid corrosion is presented in Table 5. From Table 5, F calculated 5.948163 is greater than F critical 3.490295 while p value is 0.010025 which is less than 0.05, therefore alternative hypothesis accepted and null hypothesis is rejected. It is deduced that microbial growth should be removed completely to avoid corrosion**.**

Hypothesis (v) - null hypothesis - time of expose to a corrosive environment does not influence metal corrosion and alternatives hypothesis - time of expose to a corrosive environment influence metal corrosion. Anova results of two-factor without replication for time of expose to a corrosive environment influence metal corrosion is presented in Table 6. From Table 6, F calculated 5.186964 is greater than F critical 3.490295 while p value is 0.015804 which is less than 0.05 therefore alternative Hypothesis accepted and null hypothesis is rejected. It is deduced that the time of expose to a corrosive environment influence metal corrosion.
Hypothesis (vi) - null hypothesis: most salt solution is good electrolytes and cannot promote corrosive attack and alternatives hypothesis: most salt solution is good electrolytes and can promote corrosive attack. Anova results of Two-Factor without Replication for most salt solution is good electrolytes and can promote corrosive attack is presented in Table 7. From Table 7, F calculated 4.97084 is greater than F critical 3.490295 while p value is 0.018098 which is less than 0.05 therefore alternative Hypothesis accepted and null hypothesis is rejected. It is confirmed that most salt solution is good electrolytes and can promote corrosive attack.
Hypothesis (vii) - null hypothesis: corrosion effects reduce the life span of refrigerator and alternatives hypothesis: corrosion effects reduce the life span of refrigerator. Anova results of two-factor without replication for corrosion effects reduce the life span of refrigerator is presented in Table 8 From Table 8, F calculated 4.566532 is greater than F critical 3.490295 while p value is 0.023513 which is less than 0.05 therefore alternative hypothesis accepted and null hypothesis is rejected. It is confirmed that the corrosion effects reduce the life span of refrigerator.

4. Conclusions

The following conclusions were drawn from the research that the corrosive effect of fresh water varies from locality to locality due to the wide variety of dissolved impurities, the organism causing the greatest corrosion problems are bacteria and fungi, time of exposure to a corrosive environment influences metal corrosion, most salt solution is good electrolyte and can promote corrosive attack and corrosion effects reduce the life span of refrigerator. The result of this research would guide environmental and material engineers in better planning to minimize corrosion

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Table 1: Sampling procedure in Oyo Area and Offa

S/N	OYO AREA	OFFA AREA	NO OF SELECTED USERS
1.	Alakaa Area	Federal polytechnic community	20
2.	Sabo Area	Atari Area	20
3.	Kosobo Area	Amuyo Area	20
4.	Awe Area	Isale Ago	20
5.	Oroki Area	Secteriat Area	20
	Total	Total	100 Samples

Table 2: Anova:- two factor without replication for presence of dissolved minerals

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	1516	4	379	3.078798	0.058356	3.259167
Columns	1734.8	3	578.2667	4.697536	0.021575	3.490295
Error	1477.2	12	123.1			
Total	4728	19				

Table 3: Anova: two-factor without replication for the corrosion effect of fresh water

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	1545	4	386.25	4.690346	0.01642	3.259167
Columns	1258.8	3	419.6	5.095325	0.016733	3.490295
Error	988.2	12	82.35			
Total	3792	19				

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Table 4: Anova: two-factor without replication for the organisms that causes the corrosion

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	1545	4	386.25	9.091801	0.001285	3.259167
Columns	695.2	3	231.7333	5.454688	0.013415	3.490295
Error	509.8	12	42.48333			
Total	2750	19				

Table 5: Anova:two-factor without replication for microbial growth

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	1545	4	386.25	5.223124	0.011343	3.259167
Columns	1319.6	3	439.8667	5.948163	0.010025	3.490295
Error	887.4	12	73.95			
Total	3752	19				

Table 6: Anova: two-factor without replication for time of exposure to environment

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	1552	4	388	3.993139	0.027587	3.259167
Columns	1512	3	504	5.186964	0.015804	3.490295
Error	1166	12	97.16667			
Total	4230	19				

Table 7: Anova: two-factor without replication for most salt solution

ANOVA

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Rows	1552	4	388	3.327616	0.047195	3.259167
Columns	1738.8	3	579.6	4.97084	0.018098	3.490295
Error	1399.2	12	116.6			
Total	4690	19				

Table 8: Anova: two-factor without replication for corrosion effects

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	1545	4	386.25	2.836945	0.07219	3.259167
Columns	1865.2	3	621.7333	4.566532	0.023513	3.490295
Error	1633.8	12	136.15			
Total	5044	19				

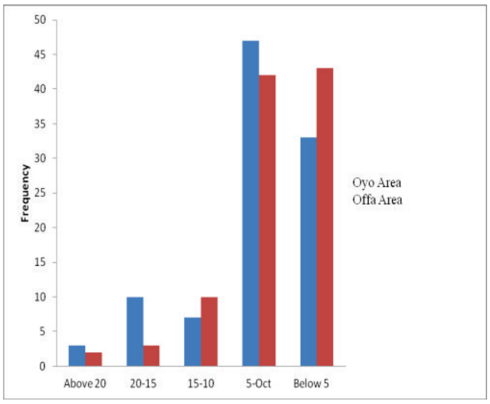

Figure 1: Graph of respondent in Oyo and Offa based on the year of purchased

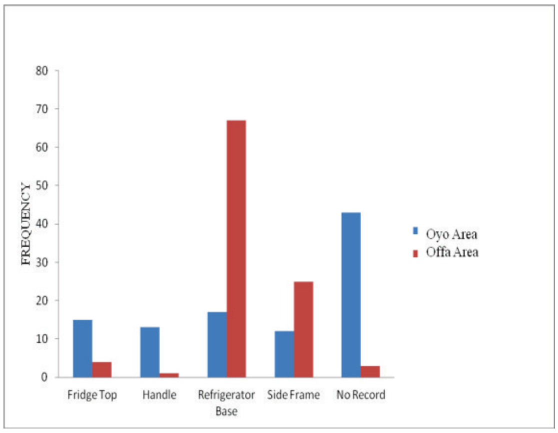

Figure 2; Graph of respondent from Oyo and Offa based on parts when corrosion first noticed

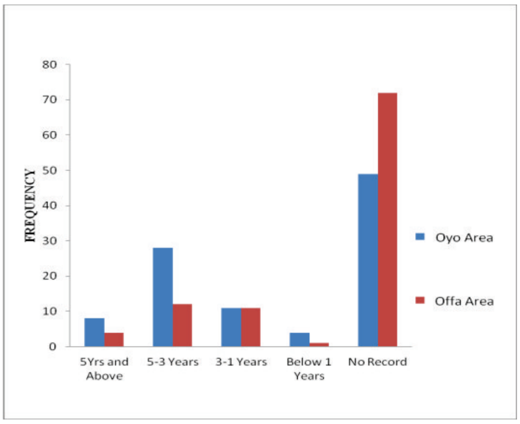

Figure: 3: Graph of respondents in Oyo and Offa based on when corrosion started after purchased

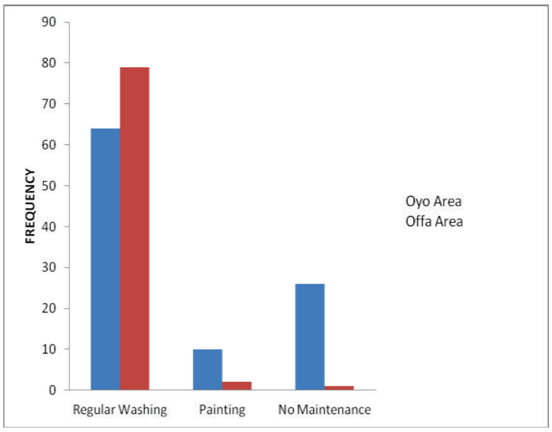

Figure: 4 Graph of respondent of Oyo and Offa based on type of maintenance practices

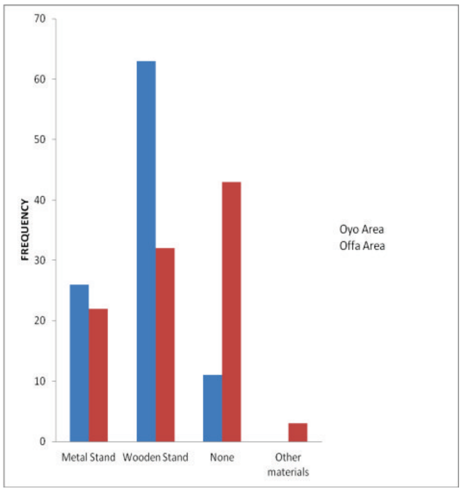

Figure: 5 Graph of respondent of Oyo and Offa based on type of stand used

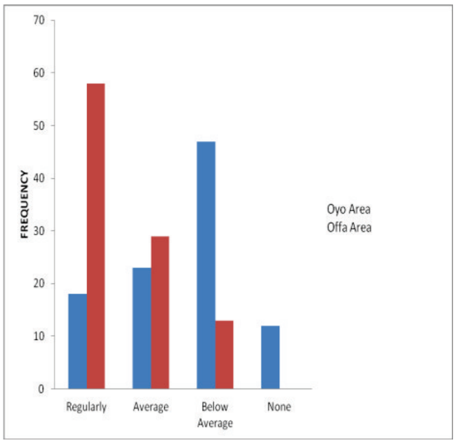

Figure 6 Graph of respondent in Oyo and Offa based on electricity supplied on weekly bases

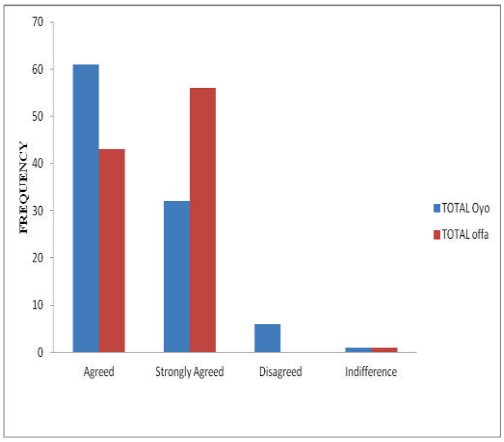

Figure 7: Graph of respondent from Oyo and Offa based on presence of dissolved mineral and organic impurities and dissolved gases.

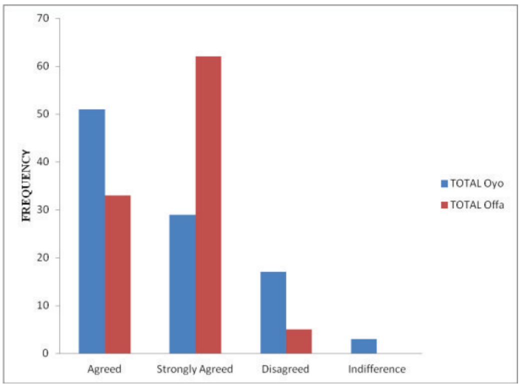

Figure 8: Graph distribution of respondent in Oyo and Offa

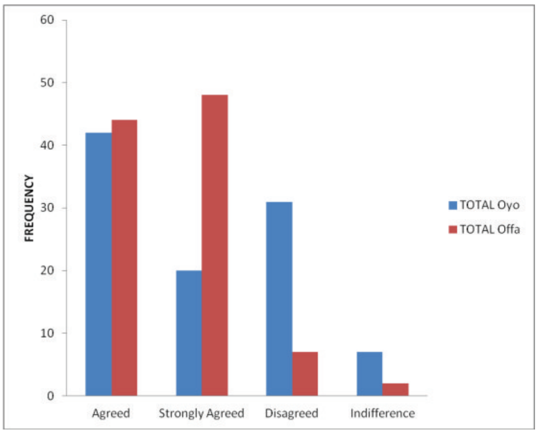

Figure 9: Graph of respondent from Oyo and Offa based on the organism causing the greatest corrosion problems are bacteria and fungi

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