British Journal of Applied Science & Technology
11(2): 1-10, 2015, Article no.BJAST.16703
ISSN: 2231-0843

SCIENCEDOMAIN *international*
www.sciencedomain.org

SCIENCEDOMAIN

Biocorrosion Study of Mild Steel in Dumpsite Leachates

L. Salami[1*], O. Fadayini[2], O. A. Oso[2] and D. O. Samuel[2]

[1]Department of Chemical and Polymer Engineering, Lagos State University, Epe, Lagos State, Nigeria.
[2]Department of Chemical Engineering, Lagos State Polytechnic, Ikorodu, Lagos State, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author LS designed the study, wrote the protocol, and wrote the first draft of the manuscript and managed the literature searches. Author OF supervised the experiments and managed the analyses of the study. Authors OAO and DOS managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2015/16703
Editor(s):
(1) Marcin Lukaszewicz, Department of Biotransformation, Faculty of Biotechnology, University of Wroclaw, Wroclaw, Poland and Division of Chemistry and Technology Fuels, Wroclaw University of Technology, Wroclaw, Poland.
(2) Maria Laura Mastellone, Environmental and Health Sciences, Second University of Naples, Italy.
(3) Singiresu S. Rao, Prof. at Department of Mechanical and Aerospace Engineering, University of Miami, Coral Gables, USA.
Reviewers:
(1) Anonymous, Brasil.
(2) Elena Binkauskiene, Centre for Physical Science and Technology, Lithuania.
Complete Peer review History: http://sciencedomain.org/review-history/10581

Original Research Article

Received 11th February 2015
Accepted 18th April 2015
Published 16th August 2015

ABSTRACT

Biocorrosion due to dumpsite leachates can lead to rupture and failure of engineering materials such as mild steel. This study was carried out to assess the effect of dumpsite leachates in corrosion process of mild steel. Mild steel coupons were prepared and immersed completely in leachates from Olusosun dumpsite (A), Ewu Elepe dumpsite (B) and Abule Egba dumpsite (C). The following parameters were measured at regular interval in each of the leachate: Total Dissolved Solids (TDS), Conductivity, pH, Temperature and Dissolved Oxygen (DO) using a multi – parameter water quality monitor and Total Bacterial Count (TBC) using standard method for biological analysis of water flood injection water. The corrosion rate was determined using weight loss method. The results revealed that the weight loss varied between 0.27 and 0.58 g in leachate A, between 0.05 and 0.29 g in leachate B and between 0.02 and 0.50 g in leachate C. Corrosion rate varied between 2.35 and 7.61 mm/yr in leachate A, between 1.15 and 1.48 mm/yr in leachate B and between 1.48 and 7.03 mm/yr in leachate C. Leachate A has the highest range of TDS

**Corresponding author: E-mail: Salamilukumon@yahoo.com;*

ranging between 18, 686 and 125, 856 mg/L as well as highest range of Conductivity ranging between 8.62 and 57.75 μS/cm. Moreover, leachate A has the highest range of pH ranging between 5.11 and 5.34 while it has the least range of DO varying between 2.94 and 3.59 mg/L. Leachate B has the highest range of temperature varying between 27.60 and 32.30°C. Leachate C has the least range of TBC ranging between 100 x 10^3 and 126 x 10^3 Cfu/ml. The leachates from dumpsites have the potential to cause corrosion of mild steel due to the presence of bacterial in the leachates. It was recommended that dumpsites should not be cited where there are pipelines.

Keywords: Biocorrosion, mild steel, corrosion rate, leachates and dumpsite.

1. INTRODUCTION

Biocorrosion or Microbially-Influenced Corrosion (MIC) is the deterioration of materials due to the exposure of materials to microbial activities especially when microorganisms are in close contract with the surface of the materials. The role of microorganisms on corrosion of metals has received increasing attention in recent years. The presence and activities of microorganisms can cause serious problems in industries and wherever metals are present in our society [1-3]. Internationally, billions of dollars are lost every year due to damage caused by biocorrosion [3-8].

Many researchers have studied the activities of microorganisms in corrosion process. Measurements of corrosion potential and corrosion current are suitable to estimate the microbial corrosion of aluminum alloy [9,10]. Odokun and Ugboma, 2007 [3] revealed in their work that the use of stainless steel for pipelines in fresh water environment should be promoted as this serves as a mitigative action against microbial mediated corrosion in brackish water environments. The effect of water flow on biocorrosion of mild steel in the work of Amadi, et al. [11] revealed that the high corrosion rate in flowing water system was mainly a function of microbial activity, enhanced by the velocity of the fresh water body. Microbial colonization of metal surfaces was known to cause severe change in the ions concentration, conductivity, pH and dissolved oxygen, altering the passive and active behaviour of the metallic substratum and its corrosion products as wells as electrochemical variables [11]. The identification of bacteria which cause corrosion on metal surface and role of the activity of microbial contaminants in a specific environment is essential and useful to prevent frequent microbiologically influenced corrosion problems [11,12].

Works on biocorrosion of mild steel due to the exposure to dumpsite leachates are very scarce in the literature. This work is aimed to study the effect of dumpsite leachates in corrosion process of mild steel. It is imperative that biocorrosion of mild steel due to the exposure to dumpsite leachates is carried out in order to make available fundamental corrosion data base which can be used by corrosion engineers, environmental engineers, designers, scientists and other users of such material who might work within the vicinity of dumpsites which justifies this work. This work is unique and different from the works of previous authors who had worked on biocorrsion of mild steel, as works on biocorrosion of mild steel as a result of exposure to dumpsite leachates are hardly found in the literature which further justifies the work.

2. MATERIALS AND METHODS

2.1 Collection of Leachate Sample

Leachate samples were collected from three different dumpsites in Lagos State namely: OLusosun dumpsite (A), Ewe Elepe dumpsite (B) and Abule Egba dumpsite (C) using 1 litre plastic bottles that had been cleaned by soaking in 10% nitric acid and rinsed with distilled water in order to avoid contamination and allowed to dry before use. In each of the sampling site, the treated bottles were rinsed twice with the leachate to be sampled prior to filling to avoid dilution. In Olusosun dumpsite, leachate samples were taken in the month of May, 2014. Since the dumpsites were not equipped with leachate collector system, leachates were sampled from the four extremes of Olusosun dumpsite using the treated bottles after which the samples were properly mixed into an homogeneous sample in a 5-litre container which then formed the leachate sample for Olusosun dumpsite. The same was done for Ewu Elepe and Abule Egba dumpsites.

2.2 Preparation of Corrosion Coupons

The mild steel used in this study was obtained from Owode Market in Ketu area of Lagos State and the analysis of the chemical composition of the untreated mild steel was carried out in chemistry laboratory of University of Lagos. The chemical composition of the mild steel is shown in Table 1.

A sheet of mild steel was cold-cut into small sheets of length 100 mm, width 50 mm and 3 mm thickness. A hole of same diameter was drilled from the top of each coupon, midway along the width, for passage of a thread. Each of the three coupons used has a weight of 100 g.

2.3 Experimental Procedure

The temperature, Total Dissolved Solids (TDS), Conductivity, pH, Dissolved Oxygen (DO) and Total Bacteria Count (TBC) of pseudomonas microorganism of leachate sample A from Olusosun dumpsite were determined at time Zero. A 100 ml beaker was half filled with leachate sample A. One of the prepared mild steel coupons was immersed completely in the leachate sample A in the beaker with the aid of a rope tied to the coupon through the perforated hole. The coupon was allowed to remain in the leachate sample A for 168 hours after which the coupon was retrieved from the leachate sample and was weighed when the leachate had totally dropped from the coupon in order to ensure the volume of leachate sample in the beaker remain the same. After the coupon had been removed from the beaker at 168 hours, the temperature, TDS, Conductivity, pH and DO of leachate sample A were again measured in-situ using a multi-parameter water quality monitor (Model 600 UPG) and the TBC pseudomonas microorganism of biofilm scrapped off from the surface of the coupon with non metallic spatula was also determined using standard method for Biological analysis of water flood injection water (API RP, 1959) [13]. This process was repeated six other times. The same was done for leachate sample B from Ewu Elepe dumpsite and leachate sample C from Abule Egba dumpsite.

2.4 Measurement of Corrosion Rate

The method of Bradford [14] is used to calculate the corrosion rate. The corrosion rate is calculated using equation (1):

$$CR = \frac{\Delta M \times 3.45 \times 10^6}{A \ell t} \tag{1}$$

Where ΔM = Weight loss (g) of coupon
A = Total surface area of the coupon (cm^2)
ℓ = Density of the coupon (g/cm^3)
t = Time (hours)

The weight loss and total surface area of the coupon are calculated using equations (2) and (3) respectively:

$$\Delta M = M_0 - M_F \tag{2}$$

$$A = 2(LW + WT + LT) \tag{3}$$

Where M_0 = Initial weight of the coupon
M_F = Final weight of the coupon
L = Length of the coupon
T = Thickness of the coupon
W = Width of the coupon

3. RESULTS AND DISCUSSION

The results of the analysis of physicochemical and microbial parameters as well as the corrosion rate of mild steel in leachate samples A, B and C are presented in Tables 2, 3 and 4 respectively.

Figs. 1 and 2 showed the corrosion rate of mild steel against time and weight loss of mild steel against time respectively for dumpsite leachate samples A, B and C.

Fig. 3 showed the variation of TDS of dumpsite leachates with time while Fig. 4 presented the variation of conductivity of dumpsite leachates with time. Fig. 5 and 6 depicted the variation of pH of dumpsite leachates with time and variation

Table 1. Composition of mild steel used in the study

Element	C	Si	Mn	S	Pt	Sn	Cr	Cu	Fe
Composition (wt%)	0.14	0.2	0.42	0.25	0.85	0.05	0.01	0.05	98.03

Table 2. Physicochemical and microbial parameters of leachate sample a as well as corrosion rate of mild steel in leachate sample A

Time (hr)	Initial weight (g)	Final weight (g)	Weight loss (g)	TDS mg/L	Conductivity µS/cm	pH	DO mg/L	Temp. (ºC)	TBC ($x10^3$) Cfu/ml	CR mm/yr
0.00	100	100	0.00	18686	8.62	5.49	2.81	28.80	100	0.00
168	100	99.73	0.27	33167	15.22	5.43	2.75	29.50	118	7.61
336	99.73	99.41	0.32	54900	25.19	5.39	2.73	29.00	125	4.54
504	99.41	99.04	0.37	67908	31.16	5.35	2.69	30.00	132	3.51
672	99.04	98.61	0.43	82395	37.80	5.32	2.80	28.90	122	3.01
840	98.61	98.13	0.48	96882	44.45	5.19	2.97	27.90	118	2.70
1008	98.13	97.60	0.53	111369	51.10	5.03	2.68	32.30	115	2.50
1174	97.60	97.02	0.58	125856	57.75	5.01	2.78	29.60	111	2.35

Table 3. Physicochemical and microbial parameters of leachate sample b as well as corrosion rate of mild steel in leachate sample B

Time (hr)	Initial weight (g)	Final weight (g)	Weight loss (g)	TDS mg/L	Conductivity µS/cm	pH	DO mg/L	Temp. (ºC)	TBC ($x 10^3$) Cfu/ml	CR mm/yr
0.00	100	100	0.00	20024	8.83	5.34	2.94	27.60	100	0.00
168	100	99.95	0.05	27309	12.53	5.31	2.98	29.30	112	1.33
336	99.95	99.85	0.10	31929	14.65	5.28	3.20	29.10	117	1.48
504	99.85	99.70	0.15	37988	17.43	5.27	3.40	30.20	122	1.43
672	99.70	99.51	0.19	43873	20.13	5.24	3.45	28.10	128	1.33
840	99.51	99.26	0.25	51479	23.62	5.21	3.49	27.20	125	1.39
1008	99.26	99.00	0.26	59107	27.12	5.19	3.57	32.30	121	1.26
1174	99.00	98.71	0.29	68327	31.35	5.11	3.59	29.70	108	1.15

Table 4. Physicochemical and microbial parameters of leachate sample c as well as corrosion rate of mild steel in leachate sample C

Time (hr)	Initial weight (g)	Final weight (g)	Weight loss (g)	TDS mg/L	Conductivity µS/cm	pH	DO mg/L	Temp. (ºC)	TBC ($x 10^3$) Cfu/ml	CR mm/yr
0.00	100	100	0.00	18652	7.93	5.28	2.72	28.80	100	0.00
168	100	99.98	0.02	24606	11.29	5.25	2.81	27.90	110	7.03
336	99.98	99.87	0.11	33499	15.37	5.24	3.10	29.50	117	1.48
504	99.87	99.66	0.21	42347	19.43	5.22	3.32	29.00	123	2.01
672	99.66	99.27	0.39	50478	23.16	5.21	2.91	30.10	126	2.70
840	99.27	98.87	0.40	62355	28.61	5.18	3.42	28.50	119	2.27
1008	98.87	98.40	0.47	68305	31.34	5.10	2.80	31.20	114	2.24
1174	98.40	97.90	0.50	78679	36.10	5.00	3.45	29.40	104	2.02

of DO of dumpsite leachates with time respectively. Figs. 7 and 8 presented the variation of temperature of dumpsite leachates with time and variation of TBC of dumpsite leachates with time respectively.

Figs. 1 to 8 were generated using Tables 2 to 4. Olusosun and Ewu Elepe dumpsites are active dumpsites while Abule Egba dumpsite is a closed dumpsite. In Table 2, Corrosion rate decreases as weight loss and time increase that is dumpsite, the corrosion rate is inversely proportional to time and weight in leachate from Olusosun. In Table 3, as the weight loss and time increase, the corrosion rate has no definite pattern which shows that the corrosion rate of mild steel in leachate from Ewu Elepe dumpsite has irregular trend. This is also the case in Table 4 where the corrosion rate of mild steel in leachate from Abule Egba dumpsite has no particular trend as weight loss and time increase.

Fig. 1 showed the comparison of corrosion rate of mild steel with respect to time in leachates A, B and C from Olusosun, Ewu Elepe and Abule Egbe dumpsites respectively.

The corrosion rate of mild steel increased speedily within the first 168 hours after immersion in leachate A. This initial rise in the

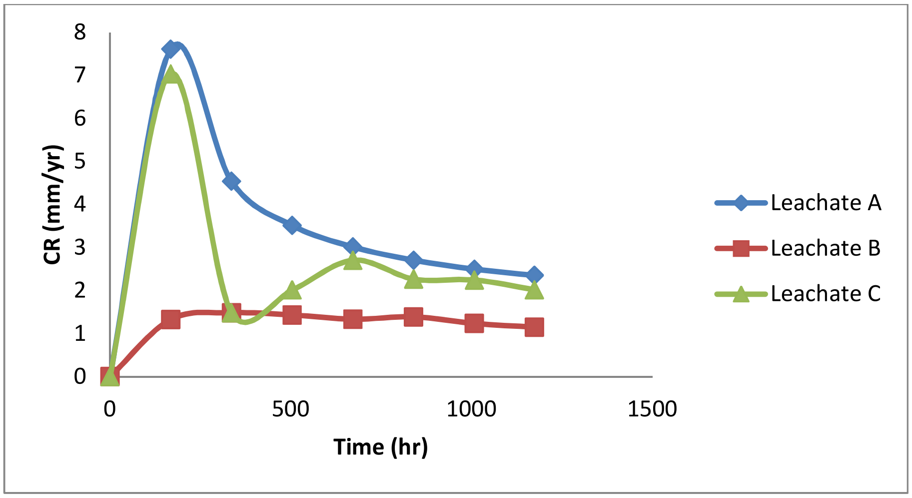

Fig. 1. A graph of corrosion rate of mild steel against time in dumpsite leachates

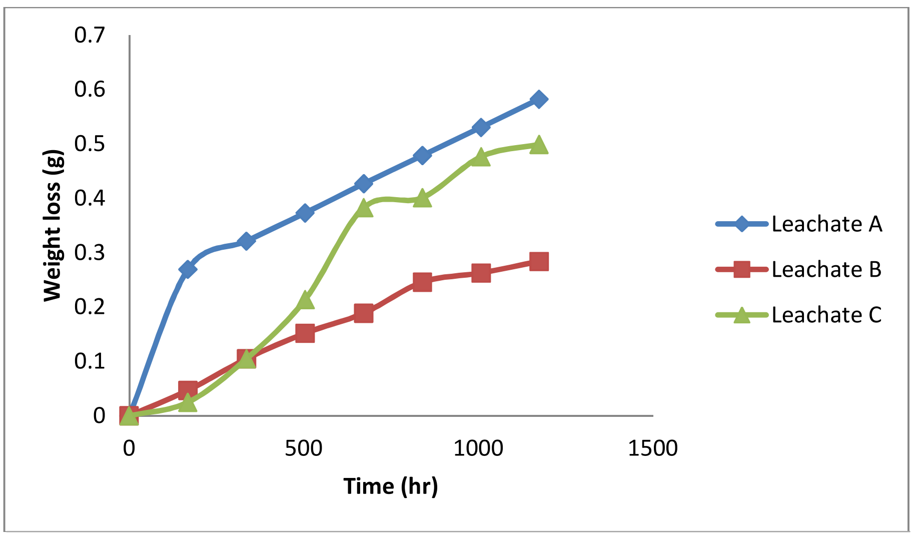

Fig. 2. A graph of weight loss of mild steel against time in dumpsite leachates

corrosion rate of mild steel in leachate sample A for the first 168 hours may be attributed to high level of direct contact with oxygen and the aerobic bacteria in the leachate environment as the biofilm or corrosion product formed was still very thin [3]. After the first 168 hours, the corrosion rate of mild steel in leachate sample A dropped sharply until 336 hours. After 336 hours, the decrease in corrosion rate of mild steel in leachate sample A started decreasing exponentially. The fall in corrosion rate of mild steel in leachate sample A after 168 hours may be attributed to the formation of biofilm or corrosion product on the surface of the mild steel. This biofilm formation, to an extent inhibited direct contact of the mild steel with the leachate environment [11,15].

The corrosion rate of mild steel in leachate sample B increased but not sharply until 336 hours after which it remained fairly constant as shown in Fig. 1. The corrosion rate of mild steel in leachate sample C increased speedily for the first 168 hours and dropped sharply between 168 and 336 hours and started increasing again after 336 hours till 504 hours as shown in Fig. 1. After 504 hours, the corrosion rate of mild steel in leachate sample C started declining again. The corrosion pattern of mild steel differs in leachate samples A, B, and C. This implies that the corrosion trend of mild steel in leachates does not have a particular behavior. It depends on the composition of the leachate which in turn depends on the composition of wastes being dumped on the site. This is also case in Fig. 2 where the behaviour of mild steel in term of weight loss with respect to time in leachate samples A, B and C differs.

In Fig. 3, the TDS increased from 18,686 to 125,856 mg/L in leachate A while it sample increased from 20,024 to 68,327 mg/L in leachate sample B. In leachate C, TDS increased from 18,652 to 78,679 mg/L. Leachate sample A has the highest range while leachate sample B has the least range. Total dissolved solids are soluble materials present in leachates. As the corrosion rate of mild steel decreases in leachate A, the TDS increases as shown in Table 2. In leachate sample B, there is no particular relationship between the corrosion rate of mild steel and TDS as depicted in Table 3.

In leachate sample C, there is also no particular pattern between the corrosion rate of mild steel and TDS as presented in Table 4.

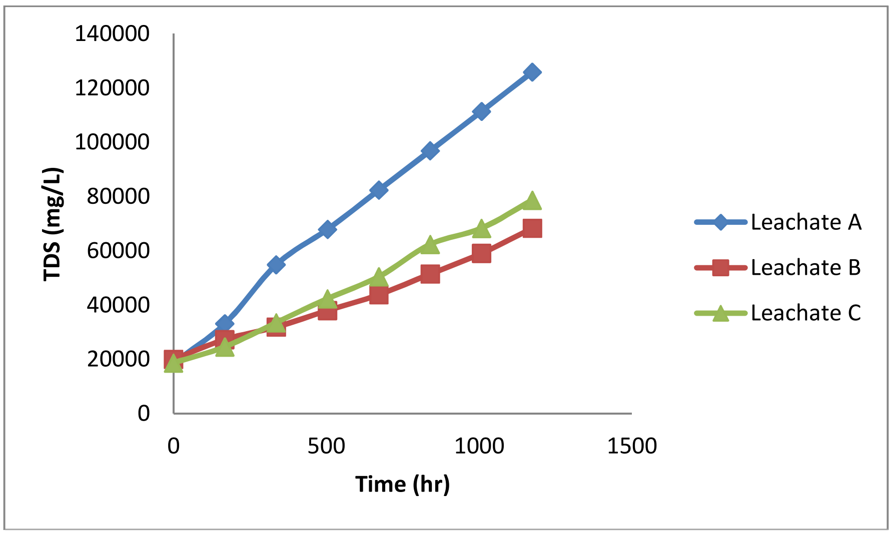

Fig. 3. Variation of TDS of dumpsite leachates with time

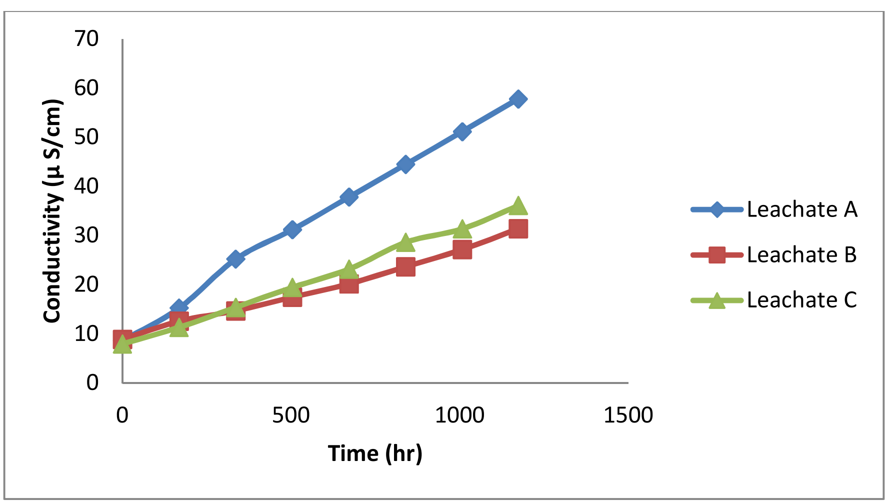

Fig. 4. Variation of conductivity of dumpsite leachates with time

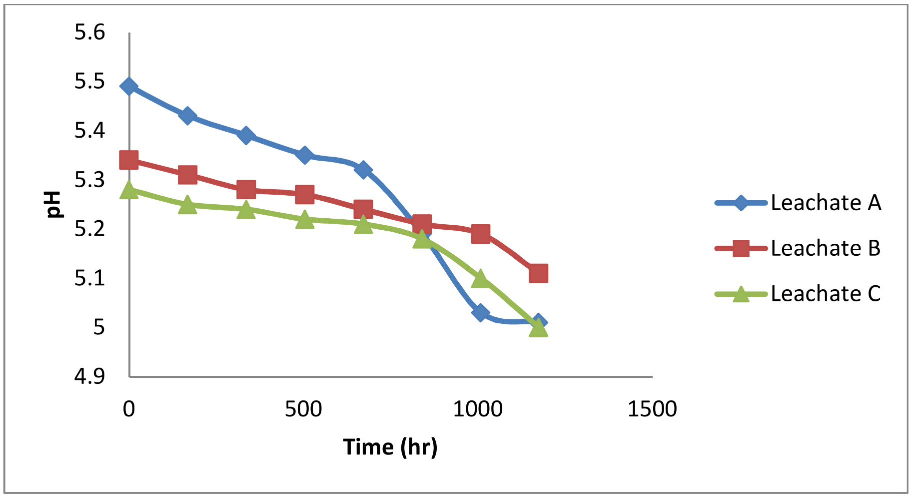

Fig. 5. Variation of pH of dumpsite leachates with time

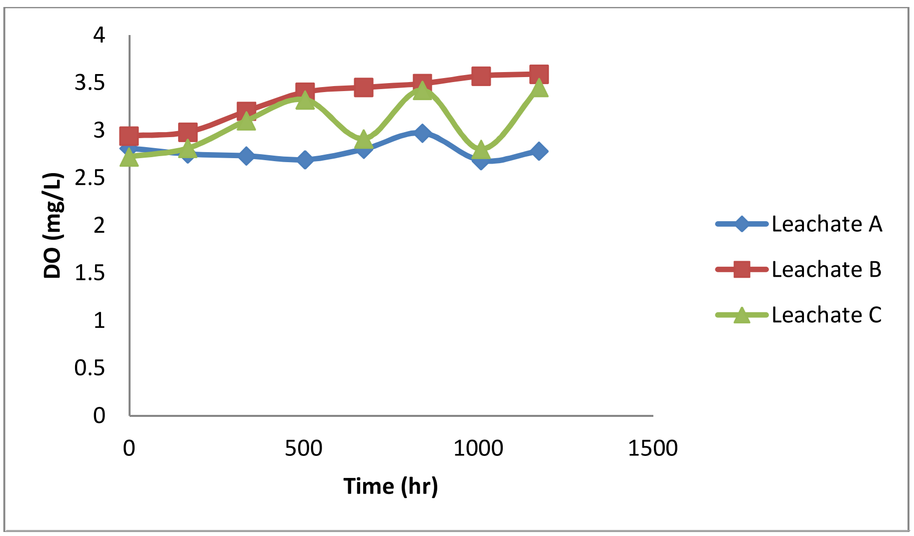

Fig. 6. Variation of DO of dumpsite leachates with time

In Fig. 4, leachate sample A has the highest conductivity with respect to time while lechate sample C has the least conductivity with respect to time. Conductivity expresses the ability of an aqueous solution to carry electric current and it indicates the presence of ionisable ions [11]. The highest range of conductivity in leachate sample A among the three leachates resulted in the highest range of corrosion rate of mild steel in leachate sample A while the least corrosion rate of mild steel in leachate B may be attributed to the least range of conductivity in leachate sample B. In Table 2, the pH for leachate sample A ranged between 5.01 and 5.49. The pH for leachate sample B varied between 5.11 and 5.34 as shown in Table 3 while the pH for leachate sample C ranged between 5.0 and 5.28 as depicted in Table 4. This indicates that the leachates medium is acidic. Leachate sample A has the highest range while leachate sample B has the least range. This corresponds to the corrosion rate of mild steel in the leachates samples. Leachate A has the highest range of corrosion rate while leachate B has the least range of corrosion. The pH range for bacteria growth lies between 4 and 9, with the optimal pH as 7.2 [11,16]. The pH ranges of the leachate samples used were within the range for bacteria growth. The highest pH range of leachate sample A resulted to the highest corrosion range. This is because there was more bacterial growth in leachat sample A than leachate samples B and C which corrode the mild steel.

The dissolved oxygen ranged between 2.69 and 2.81 mg/L for leachate A as depicted in Table 2. It ranged between 2.94 and 3.59 mg/L for leachate sample B and between 2.72 and 3.45 mg/L for leachate sample C as shown in Tables 3 and 4 respectively. Dissolved oxygen is an important parameter in environmental water quality assessment [11].

The level of oxygen in an environment plays an important role in corrosion process since oxygen is an agent of corrosion [17]. Dissolved oxygen ranging between 2.69 and 3.45 mg/L promotes growth of aerobic organisms which corrode mild steel as shown in this study. There is no definite pattern between corrosion rate of mild steel and dissolved oxygen in this present study. This is also the case in the work of Amadi et al. [11] who worked on biocorrosion of mild steel in stagnant and flowing fresh water stream conditions.

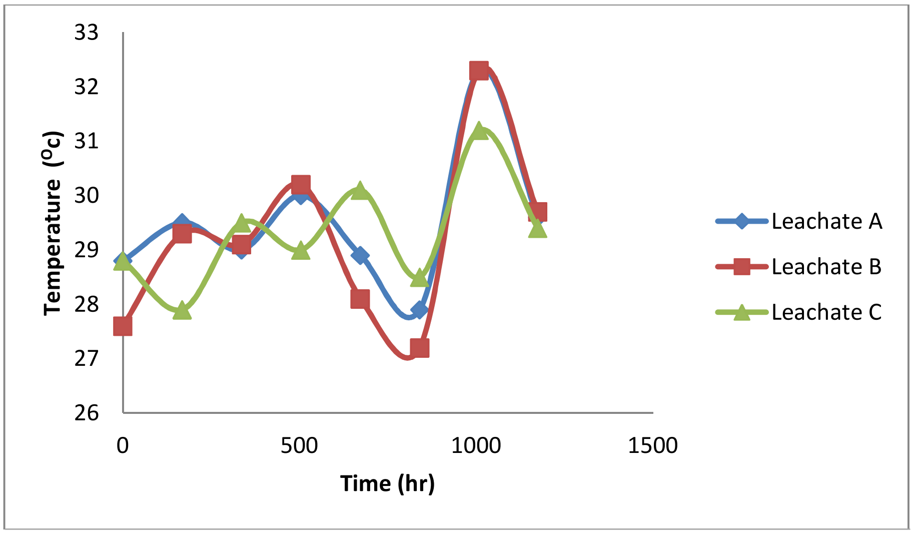

Fig. 7. Variation of temperature of dumpsite leachates with time

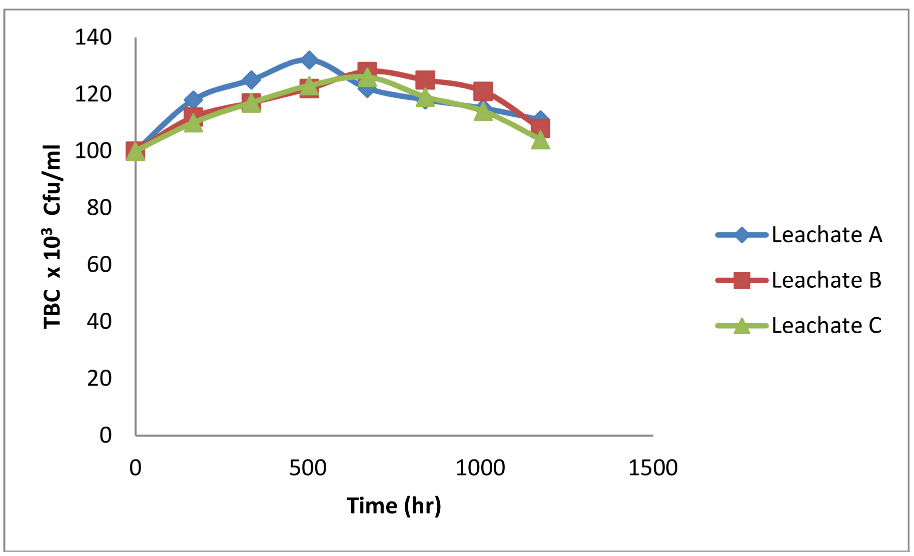

Fig. 8. Variation of TBC of dumpsite leachates with time

From Table 2, the temperature of leachate sample A varied between 28.80 and 29.60ºC. The temperature of leachate samples B ranged between 27.60 and 29.70ºC as depicted in Table 3 while that of leachate sample C ranged between 27.90 and 30.10ºC as shown in Table 4. The temperatures of leachate samples A, B and C have an undulating pattern with respect to time as can be seen in Fig. 7. Temperature is an important rate controlling factor in bacterial activity which directly or indirectly affects all the factors that govern microbial growth in any environment [11,14]. The optimal temperature range for bacterial growth is 25ºC – 30ºC [18]. The range of temperature in this study falls between 27 and 32ºC which is within the ambient temperature and can be taken to be suitable for bacterial growth in the study.

From Table 2, the TBC ranged between 100 x 10^3 and 132 X10^3 CFU/ml for leachate sample A. It ranged between 100 x 10^3 and 128 x 10^3 Cfu/ml for leachate sample B while it varied between 100 x 10^3 and 126 x 10^3 CFU/ml for leachate sample C as shown in Tables 3 and 4 respectively. Leachate sample A has the highest range of TBC while leachate sample C has least range of TBC. Materials used for most equipment in manufacturing sector and pipelines are mild steel because of its strength, ductility and weld-ability [19] but it is prone to microbial induced corrosion [3,20,21]. The biofilm formation in this study has resulted in the corrosion of mild steel in leachate.

4. CONCLUSION

This work has shown clearly that leachates from dumpsites have the potential to cause corrosion of mild steel due to the activity of bacterial in the leachates. The corrosion of mild steel varies from one leachate to the other which in turn depends on the composition of wastes being dumped on the site. The results of the study revealed that emphasis should not only be given to physicochemical corrosion in dumpsite areas. Microbial induced corrosion due to leachate from dumpsites can cause pipeline rupture and failure. Hence dumpsites should not be cited where there are pipeline.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ines TE, Fonseca M, Jose F, Ana R, Valter LR. Biocorrosion of mild steel by SRB: electro chemical studies. Journal of the Brazilian Chemical Society. 1997;8(2):1-5.
2. Lee W, Lewandowski Z, Nielsen PH, Hamilton WA. “Biofouling”. 1995;8:165.
3. Odokuma LO, Ugboma CJ. Microbial corrosion of steel coupons in a freshwater habit in the Niger Delta. Journal of Ecology and the Natural Environment. 2011;4(2): 42-50.
4. Bitton G, John W. Biocorrosion: Role of sulphate reducing bacteria. Encyclopedia of Environmental Microbiology. 2007; 465-475.
5. Gerald M, Stam JM. Nature review: Micro biology. 2008;6:441-458.
6. ICEM. International Conference and Exhibition on Corrosion Management. Parkistani Press International; 2011.
7. Ashassi SH. Corrosion inhibition of mild steel in acidic media. Material Chemistry. 2009;114(1):267-271.
8. Smith WF, Hashemi J. Foundation of material science and engineering. 4th ediction, MC Graw-Hill, New York; 2006.
9. Ovri JEO, ofeke BG. The corrosion behavior of mild steel in a marine environment. Journal of Science Engineering and Technology. 1998;5(2): 117–129.
10. Balaji GA, Radhakrishnan TK. Estimation of microbiologically influenced corrosion of aluminum alloy in natural aqueous environment. Nature and Science Journal. 2006;4(3).
11. Amadi TN, Amadi SA, Wami EN. Biocorrosion of mild steel in stagnant and flowing fresh water stream conditions. Journal of the Nigerian Society of Chemical Engineers. 2010;25(1):95-108.
12. Videla HA, Herrera LK. Microbiologically influenced corrosion, looking to the future. International Microbiology Journal. 2005;8: 169-180.
13. API RP 38. Recommended Practices for Biological Analysis of Waterflood injection waters; 1959.
14. Bradford SA. Corrosion control. Van Nostrand, New York; 1993.
15. Rim-Rukeh A. Biocorrosion in crude oil and gas pipe line system. Ph.D Thesis, Department of Chemical Engineering, River State University of Science and Technology, Port Harcourt. 2007;1-55.

16. Costerton JW, Geesey GG, Cheng KJ. How bacteria stick. Scientific American. 1978;286:86-91.
17. Loyd WJ. Corrosion and water technology for petroleum proceducer. OGCI publications, Oil and Gas Consultants International. 1998;103-139.
18. Booth GH. Microbiological Corrosion. London, Mills and Boon Limited. 1971; 27-29.
19. Smith WF, Hashemi J. Foundation of material science and engineering. 4th edition, MC Graw-Hill, New York; 2006.
20. Pitonzo BJP, Amy PS, Castro L. Microbiologically induced corrosion. 2004; 60:64-67.
21. Newman DK. Microbial iron respiration; impacts on corrosion processes. Applied Microbial Biotechnology. 2005;62:134-139.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/10581