IJRES 8 (2021) 48-54 ISSN 2059-1977

International Journal of Research in Environmental Studies
www.bluepenjournals.org/ijres

Physico-chemical characteristics and heavy metals in wastewater from paint industries in Yenagoa Metropolis, Bayelsa State, Nigeria

doi.org/10.33500/ijres.2021.08.005

Bekeowei R. A.[1]* and Bariweni P. A.[2]

[1]Department of Geography and Environmental Management, Faculty of Social Sciences, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.
[2]Department of Marine Environment and Pollution Control, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria.

Article History
Received 18 October, 2021
Received in revised form 20 November, 2021
Accepted 25 November, 2021

Keywords:
Water pollution, Atomic absorption spectrophotometer, Parameter, Effluent, Heavy Metals, Yenagoa Metropolis.

Article Type:
Full Length Research Article

ABSTRACT

This study investigated the physico-chemical parameters and heavy metals concentrations in wastewater samples from different paint industries in Yenagoa metropolis. Wastewater samples were collected from six different paint industry locations thrice monthly during morning and evening shift hours for six months. The samples were analyzed by standard methods for pH, DO, BOD, COD, NO_3, PO_4, Turbidity, Fe, As, Cr, Cu, Cd, Mn, Pb, Co, and Zn. The result of the laboratory analysis of the wastewater samples indicated that the mean values of pH ranged from 2.438 to 6.303, DO ranged from 3.364 to 5.541 mg/l, BOD from 3.842 to 4.298 mg/l, COD from 2.888 to 5.675 mg/l, NO_3 from 9.815 to 67.845 mg/l, PO_4 from 2.710 to 4.813 mg/l, Turbidity from 86.813 to 547.301 NTU, Fe 3.337 to 17.991 mg/l, Pb from 0.036 to 0.098 mg/l, Zn 0.478 to 3.302 mg/l, Cu.0345 to 1.343 mg/l, Co 0.253 to 0.447 mg/l, As 1.195 to 5.022 mg/l, Mn from 0.037 to 1.769 mg/l, Cd 0.002 to 0.528 mg/l and Cr from 0.141 to 0.733 mg/l. Results showed that the mean values of COD, BOD, NO_3, PO_4, Turbidity, Fe, As, Cr, Cu, Cd, Mn, Pb, Co in the wastewater samples were above the NIS and WHO permissible limits. The study also indicated that there was significant variation in the concentration of heavy metals in the wastewater samples from different locations. This may be due to raw materials of different chemical composition used at different test times. The implications of the high concentration of heavy metals in the wastewater discharged into the environment have been highlighted.

INTRODUCTION

Water is a very essential resource on which pureness man depends for survival. Water also serves as a refuge for many aquatic organisms. Water pollution is a major global problem as it a known cause of death and diseases worldwide (Ekubo and Abowei, 2011). About 80% of all diseases in the developing countries are directly related to poor water quality and unhygienic condition (Vasaithaigar et al., 2010). Water bodies which are major receptacles of untreated and partially treated industrial waste are becoming increasingly polluted with toxic heavy metals in the Niger Delta (Ayotunde and Bariweni, 2018). The resultant effect of this on public health and the environment are usually great in magnitude (Kannji and Achi, 2011). The occurrence and accumulation of metals in the environment has been attributed to direct and indirect human activities, such as rapid industrialization, urbanization or other anthropogenic sources (Ogoyi et al., 2011). According to Anwar et al. (2009), the presence of heavy metals in surface water has become a world-wide problem and has posed a serious threat to the environment. The indiscriminate discharge of industrial, domestic and

*Corresponding author. E-mail: bekeokoroalex@ gmail.com.

agricultural wastewater without treatment to comply with safe and standard disposal regulatory limit on agricultural land, into rivers, streams, ponds and lakes are the obvious pollution type that are of serious concern due to the negative effect of heavy metals in water and soil (Burmanu et al., 2014).

Trace amount of some heavy metals such as iron, cobalt, copper, zinc and manganese are essential for human metabolism but at higher concentrations they can lead to poisoning (Singh et al., 2017; Divya et al., 2012; Edokpayi et al., 2019). A good number of industries make use of heavy metal ions because of their technological relevance. Wastewater release from such industries into aquatic ecosystem may therefore cause toxic effects on man through the food chain. The discharge of heavy metals into any aquatic environment by human activities can pollute both natural and man-made ecosystems.

In the Niger Delta Region of Nigeria abounds several fresh water bodies including rivers, ponds, lakes, Stream, creeks etc. These water bodies serve as waste disposal ground for most municipal waste. These wastes depending on the origin may contain several substances that could alter water quality parameters including microbial counts, heavy metals and physico-chemical properties.

In recent times, there has been a tremendous population growth in Yenagoa Metropolis. The exponential growth in urbanization through migration of people from rural, semi-urban and other urban areas to Yenagoa City in search of livelihood, had contributed to the rapid increase in waste generation and discharge of solid waste and untreated wastewater into the environment (Bariweni et al., 2002). Though Yenagoa Metropolis is yet industrialized there are some industries and other anthropogenic activities that are generating a lot of wastes and discharging untreated wastewater that contains both nutrient pollutants and heavy metals into the aquatic environment. Studies have revealed that paint industries are some of the major sources contributing to heavy metal pollution in the aquatic environment (Lokhande et al., 2015). It is not certain, how the paint industries in the Yenagoa Metropolis may have contributed to the water quality deterioration. Therefore, this study is aimed at assessing the physico-chemical characteristics and heavy metals content of the wastewater effluents from paint industries in Yenagoa Metropolis, Bayelsa State, Nigeria.

MATERIALS AND METHODS

Study area

The study area is Yenagoa Metropolis in Yenagoa Local Government Area of Bayelsa State, Nigeria (Figure 1). Yenagoa is the capital of Bayelsa State. The study area lies between latitude 4° 48' 00'' North and 5° 24' 10'' East and longitude between 6° 12' 00'' East and 6° 39' 30'' East. Yenagoa is located in the core Niger Delta Region area lies between latitude 4° 48' 00'' North and 5° 24' 10'' East and longitude between 6° 12' 00'' East and 6° 39' 30'' East. Yenagoa city is the most economically viable town in the entire local government area and it occupies an area of 706 km^2 (Bariweni et al., 2002).

Yenagoa is bounded by River State on the North and East, Ogbia Local Government Area on the South East and Southern Ijaw Local Government Area on the South west. However, the population of Yenagoa Local Government area was put at 352,285 people by 1996 estimate (National Bureau of Statistics, 2016), with population growth rate of 2.9% (National Population Census) (Federal Republic of Nigeria Gazzete, 2007). Yenagoa is located on lowland with the elevation between 3 and 7 m above sea level and characterized by flood plains.

Iyorakpo (2015) stated that Yenagoa, the capital city of Bayelsa State, Nigeria lies along the Epie Creek which empties into the Ekole Creek. The main occupation of the people is farming, fishing and trading. Some of the communities that make up Yenagoa metropolis includes: Swali, Ovom, Amarata, Ekeki, Kpansia, Okaka, Yenezue-epie, Yenezue-gene, Biogbolo, Opolo, Okutukutu, Etegwe, Edepie, Agudama, Akenfa, Igbogene, etc. Figure 1 map showing Yenagoa metropolis. Since Yenagoa town attained the status of the state's capital in 1996, construction, manufacturing and other anthropogenic activities have increased appreciably, resulting in the increase of wastewater.

Iyorakpo (2015) and Olatunde et al. (2017) stated that the climate of Yenagoa the capital city of Bayelsa State is an equatorial type of climate. In the study area, rainfall generally occurs almost throughout the year. The mean temperature range is 25 to 31°C. The hottest months are December to April. The difference between the wet and dry seasons on temperature is about 2°C. Relative humidity is high throughout the year and decreases slightly during the dry season.

Method of wastewater sample collection and locations

Wastewater samples were collected thrice monthly during morning and evening hours from six paint factories between April and September 2020. The selection of these locations was purposively done on the basis that they were located along aquatic ecosystems in Yenagoa Metropolis into which the wastewaters are drained. 1 L Plastic bottles were used to collect the wastewater samples. The bottles were cleaned with nitric acid, washed with distilled water twice, again rinsed with the wastewater sample to be collected and filled up with the

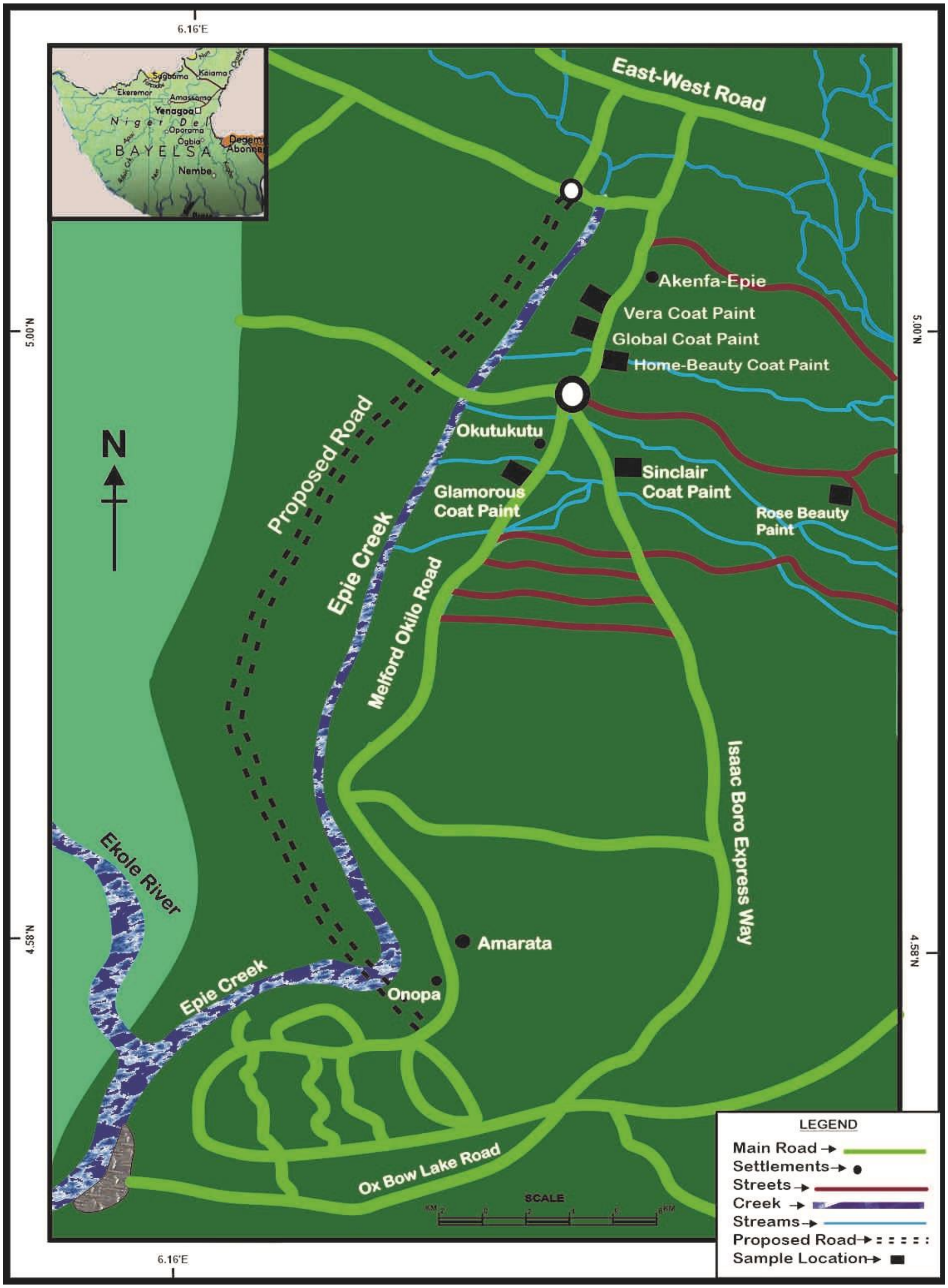

Figure 1. Yenagoa Mtropolis showing sample locations.

wastewater samples allowing only a small space at the neck of the bottle as adopted by Lokhande et al. (2011). Wastewater samples were filtered using Whatman No 1 filter paper for estimation of the heavy metals concentration in the samples and to the filtered wastewater samples were added 2ml of nitric acid to fix

Table 1. Unit, mean, NIS, WHO limits of physico-chemical parameters and heavy metals in wastewater samples.

Parameters	Unit	Mean	NIS	WHO Limits
pH	_	4.1950 ± 0.150	6.5 -8.5	6.5 -8.5
DO	(mg/l)	4.4066 ± 0.246	Minimum 4.0	8.0
BOD_5	(mg/l)	4.3434 ± 0.140	6.0	50
COD	(mg/l)	4.4727 ± 0.155	3.0	250
NO_3	(mg/l)	12.4398 ± 0.404	40	50
PO_4	(mg/l)	3.9467 ± 0.204	3.5	5.0
Turbidity	(NTU)	272.3667 ± 5.792	10	5.0
Fe	(mg/l)	8.0268 ± 0.449	0.3	0.3
Pb	(mg/l)	0.3696 ± 0.035	0.01	0.10
Zn	(mg/l)	0.2312 ± 0.393	0.2	5.0
Cu	(mg/l)	0.7282 ± 0.177	1.0	1.0
CO	(mg/l)	0.3547 ± 0.081	0.05	0.05
As	(mg/l)	6.1546 ± 0.191	0.01	0.04
Mn	(mg/l)	0.7423 ± 0.080	0.2	0.05
Cd	(mg/l)	0.1780 ± 0.062	0.003	0.02
Cr	(mg/l)	0.3536 ± 0.066	0.05	0.05

The mean values of the observations are at significantly ($p< 0.05$) different.

the metals from precipitation. In order to assess the biochemical oxygen demand, wastewater samples were collected in 250 cm^3 bottle with stoppers and one millimeter each of Winkler's solutions A and B was added to each of the samples on site to fix the oxygen as adopted by Adegbe (2014), APHA, 2012). The wastewater samples were stored in ice box and subsequently transported to the laboratory for analysis.

Laboratory Analysis for physic-chemical and heavy metals parameters

The Physico-chemical parameters and the heavy metals of the wastewater samples assessed were pH, turbidity, biological oxygen demand, chemical oxygen demand, dissolved oxygen, nitrate, phosphate, iron, arsenic, copper, cadmium, chromium, manganese, lead, cobalt, zinc. Each physico –chemical parameter was analyzed according to the standard methods prescribed in the manual of Ademoroti (1996). Meanwhile, the heavy metals such as iron, cadmium, copper, chromium, cobalt, arsenic, lead, manganese, zinc were analyzed using Atomic Absorption Spectrophotometer (AAS) model AA6300 as described in the manufacturer's instruction manual of American Public Health Association (APHA, 2012; Ademoroti, 1996).

Statistical analysis

Analysis of variance (ANOVA) was used to conduct a test of significance at $p < 0.05$, in order to assess the difference of the Physico-chemical parameters and heavy metals concentrations in the sample locations. However, the data obtained from the experiment were analyzed statistically using IBM SPSS VERSION 23.

RESULTS AND DISCUSSION

The results obtained from the wastewater samples from different paint factories in Yenagoa Metropolis for Hydrogen ion (pH), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Nitrate (NO_3), Phosphorus (PO_4) and Turbidity levels are presented in Table 1.

The results showed that there was significant variation in the mean pH, DO, BOD_5, COD, NO_3, PO_4 and turbidity in the sample locations. The pH values ranged from 1.59 to 7.37 (Table 1). Mean pH values recorded at all locations were below the World Health Organisation (WHO) (2011) permissible limit. The mean pH values from paint factories effluents in this study were also lower than the range values of 6.70-7.80 reported by Aboulhassan et al. (2014), Dessalew and Yonas (2015), Tesfalem and Abdrie (2017) from different paint industry wastewater samples in Addis Ababa Ethiopia, Kanu and Chioma (2017) and Ahenda et al. (2019) from different paint industrial effluents in Nkoho River, Abia State Nigeria and from paint and coating industries in Nairobi, Kenya respectively. The mean pH values reported in this study were however higher than those reported by Tolutope et al. (2019). The variation of the mean pH values across the study locations may be as a result of the different chemical raw materials used at different test times.

In this study, the dissolved oxygen (DO) values ranged from 2.08 – 6.30mg/l (Table 1) which are far lower than the values reported by Kanu and Chioma (2017), but comparable to the findings of Akpomie and Dawodu (2014) from different effluent samples of automobile and paint industries in Enugu and Anambra states, Nigeria. The DO range values also conform with the range of 0 – 6.7 mg/l recorded by Tolutope et al. (2019) from different paint industries in Lagos.

The BOD_5 values ranged from 2.00 – 5.48 mg/l (Table 1). The differences in the mean BOD_5 values in the wastewater samples could be attributable to possible variations in the types of paints produced with different chemical compositions at different test time during the study. It could be reasoned from this study that the discharge of untreated or poorly treated wastewater into the aquatic ecosystems might cause potential hazards to aquatic life and end users. The mean BOD_5 values recorded in this study were far lower than the values reported by Olaoye and Oladeji, (2015), Dessalew and Yonas (2017) and Tesfalem and Abdries (2017) from different paint industries in Ibadan and Addis Ababa, Ethiopia respectively. In the same vein, the BOD values observed in this study were also lower than the findings of Jolly et al. (2012), Akpomie and Dawodu, (2014); Kanu and Chioma, (2017) and Tolutope et al. (2019) from different industries in Bangladesh, in Enugu and Anambra states Nigeria, Abia state, Nigeria and Lagos, Nigeria respectively.

Results concerning COD values ranged from 2.00 to 6.31mg/l (Table 1). The observed mean of COD values were lower than those reported by Jolly et al. (2012) Akpomie and Dawodu (2014), Kanu and Chioma (2017), Tolutope et al. (2019) and Ahenda et al. (2019) for effluents from different paint industries around the world.

Nitrate (NO_3) levels ranged from 4.00 to 96.04 mg/l (Table 1). The findings of this study on the mean Nitrate (NO_3) levels were higher than the range reported by Kanu and Chioma (2017); from different paint industries in Abia State. The observed Nitrate (NO_3) range values were also higher than range values of 3.3457 – 21.2000 mg/l reported by Tolutope et al. (2019).

Phosphorus (PO_4) levels varied from 1.00 to 5.89mg/l (Table 1). The observed PO_4 range values were in consonance with those reported by Dessalew and Yonas (2017) and Tesfalem and Abdrie (2017). The findings were however lower than the values reported by Kanu and Chioma (2017), but were in contrary to below detection limit (bdl) < 0.02mg/l achieved by Tolutope et al. (2019).

The turbidity levels observed from this study ranged from 81.50 to 635.10 mg/l (Table 1). The observed turbidity levels were higher than the findings of Olaoye and Oladeji (2015), Dessalew and Yonas (2017) and Kanu and Chioma (2017) from different paint industries in Ibadan, Nigeria, Addis Ababa, Ethiopia, Abia state, Nigeria respectively.

The level of iron, lead and zinc concentrations of the wastewater samples was presented in (Table 1). Iron (Fe) values varied from 2.00 to 20.81 mg/l. The observed Fe range values were above the permissible limits of both NIS (2007) and WHO (2011) of 0.0300 mg/l; and higher than the findings of Jolly et al. (2012). Lead (Pb) values ranged from 0.01 to 0.40 mg/l. All the observed Lead (Pb) concentration values were above the WHO (2011) permissible limit of 0.010 mg/l. However, the Pb levels observed in this study was lower than the values reported by Akpomie and Daniel (2014), Dessalew and Yonas (2017) and Tesfalem and Abdrie (2017). Discharge of Pb above the permissible limit into the aquatic ecosystem of the area pose an unquantified human health risk to resident of Yenagoa Metropolis.

Zinc (Zn) values observed from this study ranged from 0.08 to 4.56 mg/l. The overview of the result indicated that there was a significant variation of the concentration of Zn in the wastewater samples across the study locations, with the p-value below 0.05. It was also observed that the zinc values fall below the WHO (2011) permissible limit of 5.0 mg/l; but higher than the values recorded by Jolly et al. (2012), Olaoye and Oladeji (2015) and Aly (2015). However, the range values were comparable to the Zn range values reported by Dessalew and Yonas (2015).

Copper (Cu) values fluctuated between 0.04 and 2.53 mg/l. It was observed that the Cu values in almost all the locations were below the permissible limits of both the NIS (2007) and WHO (2011) of 1.00 mg/l, except at location 3 and 4 where the mean Cu concentration values were above the permissible limits of NIS (2007) and WHO (2011) in surface water. The copper values observed in this study was lower than the reported findings by Akpomie and Dawodu (2014) and Tesfalem and Abdrie (2017) but higher than the range reported in the study carried out by Olaoye and Oladeji (2015) from different paint industrial effluents in Ibadan, Nigeria.

The Cobalt (Co) values observed in this study ranged from 0.13 to 1.35 mg/l. These values were above the WHO (2011) permissible limit 0.05 mg/l. Data obtained from this study for Arsenic (As) in the wastewater samples showed the As values ranged from 1.030 to 5.763 mg/l. Arsenic values observed were above the NIS (2007) and WHO (2011) permissible limit of 0.01 and 0.04 mg/l respectively in drinking water.

Manganese (Mn) values for this study ranged from 0.01 to 2.59 mg/l. It was noted that the values of Mn in all the locations were above the permissible limits of both the NIS (2007) and WHO (2011) of 0.2 and 0.5 mg/l respectively except at locations 3 and 4. The mean Mn values in this study were observed to be higher than the findings of Jolly et al. (2012) from different paint industrial effluents in Malaysia. The values of manganese recorded in this study were however lower than the findings of Akpomie and Dawodu (2014) and Olaoye and Oladeji (2015) from different paint industrial effluents in Enugu and Ibadan Nigeria respectively.

The Cadmium (Cd) concentration observed in this study ranged from 0.00 to 0.75 mg/l. The result indicated that the values of Cd in most locations within the period under investigation were above WHO permissible limit of 0.02 mg/l. The range values were lower than the range values of 0.5990 – 0.9001 mg/l, 1.5800 – 6.2220 mg/l and 1.23 – 6.09 mg/l recorded by Dessalew and Yonas (2015), Tesfalem and Abdrie (2017) and Akpomie and Dawodu (2014).

The Chromium (Cr) concentration in the wastewater samples ranged from 0.03 to 1.64 mg/l. The overall results indicated that the mean Cr concentration values recorded in this study were above the WHO (2011), permissible limit of 0.05 mg/l. The Cr values observed in this study were lower than the range values of 0.460 – 4.720 mg/l reported by Akpomie and Dawodu (2014) and Tesfalem and Abdrie (2017) from different paint and automobile industries in Enugu, Nigeria and Ghana respectively.

Conclusion

It can be concluded from this study that the discharge of untreated wastewater from the paint industries have greatly contributed to the deterioration of the aquatic ecosystems in the Yenagoa Metropolis. The study revealed that there is great variation in the level of the parameters investigated with Nigerian industrial standards and WHO permissible limits, The implications of the continuous discharge of pollutants into the environment especially heavy metals may caused environmental and public health effects. Therefore, untreated wastewater discharge should be discouraged.

REFERENCES

Aboulhassan M. A., Souabi S., Yaacoubi A. & Baubu M. (2014). Treatment of paint manufacturing, waste water. Int. J. Sci. Environ. Technol. 3(r):174701748.

Adegbe E. A. (2011). Physico-chemical analysis of some selected water resources around the waste treatment plant of Ahmadu Bello University Teaching Hospital Zaria, Nigeria: A M.Sc. Thesis.

Ademoroti C. M. O. (1996). Standard methods for water and effluents analysis. Foludex Press Ltd., Ibadan. 3:29-118.

Ahenda S., Kithure G. N. J., Njenga H. & Njugi A. (2019). Characterisation and absorption of heavy metals in industrial effluents from paint and coating industries in Nairobi Kenya. Int. J. Eng. Appl. Sci Technol. 4(5):41-46. Doi:10.33564/IJEAST.vo4.105.007.

Akpomie, K. F. & Dawodu, F. A. (2014). Physico-chemical analysis of automobile effluents before and after treatment with an alkaline-activated montmorilonite: volume 9. Issue 4 https://doi:org/10.1016/j.utusci:10.005. Journal of Talibah University for Science. Pages 465-476.

Aly O. H. I. (2015). A new development of wastewater treatment unit for paint shop in vehicle industry. Int. J. Sci. Basic Appl. Res. (IJSBAR). 21(1):15-25.

Anwar F., Ali M., Hussain A. I. & Shahib M. (2009). Antioxidant and antimicrobial activities of essential oil and extracts of fennel (*Foeniculum vulgare* Mill) seeds from Pakistan. Flavour Fragris. 24:170-176.

APHA (2012). Standard methods for the examination of water and wastewater. 22nd ed. American Public Health Association, 8001 Street, NW Washington DC, USA.

Ayotunde O. & Bariweni P. A. (2018). Impact of urban runoff on the heavy metals concentrations of the epic creek, Niger Delta, Wilberforce. J. Soc. Sci. 3(1):12-19.

Bariweni P. A., Izonfuo W. I. & Amadi E. N. (2002). Domestic waste levels and assessment of their current management strategies in Yenagoa metropolis. Global J. Environ. Sci. 1(1):15-19.

Burmanu B. R., Law P. L., Aliyu H. H. & Ibrahim Y. (2014). Environmental impacts and management strategies of solid waste. Int. J. Environ. Eng. Sci. Technol. Res. 2(3):1-8.

Dessalew B. & Yonas S. (2017). Assessment of the physico-chemical and heavy metal concentration from effluents of paint industry in Addis Ababa Ethiopia research article. Int. J. Waste Resour. 7(4):306. Doi.10.4172/2252-5211.1000306.

Dessalew B. & Yonas S. (2015). Assessment of the physico-chemical and heavy metal concentration from effluents of paint industry in Addis Ababa Ethiopia research article. Int. J. Waste Resour. 7(4):306. Doi.10.4172/2252-5211.1000306

Divya S., Archana T. & Richa G. (2012). Phytoremediation of lead from wastewater using aqatic plants. J. Agric. Technol. 8(1):1-11.

Edokpayi J. N., Enitan A., Mutileni N. & Odiyo J. (2019). Evaluation of water quality and human risks assessment due to heavy metals in groundwater around muledane area of Vhembe district, Limpopo province. South Africa. Chem. Cent. J. 12(1): 2. doi: 10.1186/S13065-017-0369-y

Ekubo A. T. & Abowe J. F. N. (2011). Aspects of aquatic pollution in Nigeria. Res. J. Environ. Earth Sci. 3(6):673-693.

Federal Republic of Nigeria Gazette (2007) Gazette Abuja., Nigeria.

Iyorakpo J. (2015). Impact of urbanisation on environmental quality in Yenagoa Metropolis. Bayelsa State, Nigeria. Vol. 11(23): 255-268.

Jolly Y. N., Hossain A., Saltar A. & Islam A. (2012). Impact of heavy metals on water and soil environment of a paint industry. Journal of Bangladershi Chemical Society. 25(2):1 159-165.

Kannji. I and Achi, O. (2011). Industrial effluents and their impact on water quality of receiving rivers in Nigeria. J. Appl. Technol. Environ. Sanit. 1(1):75-86.

Kanu C. & Chioma N. (2017). Assessment of saclux paint industrial effluent on Nkoho River in Abia State Nigeria. J. Ecosys. Ecograph.. 7:240. doi:10.4172/2157-7625.1000240

Lokhande R. S., Pravin U., Singare P. U. & Deepali S. P. (2011). Toxicity study of heavy metals pollutants in waste water effluents samples. Collected from Talora Industrial Estate of Mumbai India. Res. Environ. 1 (1) 13-19. Doi. 10.5923/j.re 20110101.02

Lokhande R. S., Singare P. U. & Pimple D. S. (2012). Toxicity study of heavy metals pollutants in wastewater effluents samples collected from Taloja Industries Estate of Mumbai India. Resour. Environ. J. 1(1):13-19. doi: 10:5923/j.res. 20110101.02.

National Bureau of Statistics (2016). Report on Nigerian population census.

Nigerian Industrial Standards (NIS) (2007).

Ogoyi D. O., Mwita C. J., Nguu E. K. & Shunda P. M. (2011). Determination of heavy metal content in water sediment and microalgae from Lake Victoria, East Africa. Open Environ. Eng. J. 4:156-161.

Olaoye R. A. & Oladeji O. S. (2015). Preliminary assessment of effects of paint industry effluents on local ground-water regime in Ibadan Nig. Int. J. Eng. Res. 4:518-552.

Olatunde S. E., Obafemi A. A. & Hardy T. (2017). Effects of urbanization changes on landuse in Yenagoa Metropolis, Bayelsa State, Nigeria (1986 – 2003). Int. J. Dev. Sustain. 6(8):728-745.

Singh S. M., Sharma K. & Kumar R. (2017). Heavy metal causing neurotoxicity in human health. Int. J. Innov. Res. Sci, Eng. Technol. (IJIRSET). 6:7721-7726. Doi: 10.15680/IJIRSET.2017.0605054

Tesfalem B. W. & Abdrie S. H. (2017). Toxicity study of heavy metals pollutants and physic-chemical characterisation of effluents collected from different paint industries in Addis Ababa Ethiopia. J Foren. Sci Crimin. Invest. 5(5):1-6. Doi. 10:19080/IFSCI. 2017.05555685.

Vasaithaigar M., Srinivasamoorthy K., Rajiv-Ganthi R., Vijayaraghavan K. & Sarma V. S. (2010). Characterisation and quality assessment of groundwater with a special emphasis on irrigation utility: Thirumanimurtar sub-basin.Tamil Nadu.India. Arab. J. Geosci. 5: 245-258 doi:10:1007/S/251-010-0190-6.

World Health Organisation (WHO) (2011). Who guidelines for drinking water quality. 4th ed World Health organisation. Geneva. Pp. 219-229.