African Scientist Vol. 18, No. 3, September 30, 2017
Printed in Nigeria

1595-6881/2016 $10.00 + 0.00

http://www.niseb.org/afs

AFS 2017038/18307

Physicochemical Parameters and Heavy Metals Assessment of Effluent Discharges from Some Industries in Benin City, Nigeria

*Michael O. Akharame[1,2], Romeo C. Ofomata[3] and Daniel I. Olorunfemi[2]

[1]Department of Chemistry, Cape Peninsula University of Technology, Cape Town, South Africa
[2]Department of Environmental Management & Toxicology, University of Benin, Benin City
[3]Department of Plant Biology & Biotechnology, University of Benin, Benin City

*Corresponding author E-mail: michael.akharame@uniben.edu.

(Received August 10, 2017; Accepted in revised form September 2, 2017)

ABSTRACT: In Nigeria, the continuous discharge of industrial wastewater with non-complaint quality parameters as stipulated by the National Environmental Standards and Regulation Enforcement Agency (NESREA) is a daunting challenge. This precarious situation has led to the continuous decline in our freshwater quality, with adverse environmental and health implications. Consequently, monitoring of wastewater discharged from industries is of utmost importance in order to check them and raise awareness, where necessary. In this study, wastewater samples were collected from four processing facilities around Benin City and environs, namely: a carbonated soft drink company, a brewery, glass manufacturing company and a meat processing outfit (abattoir). Physicochemical parameters and heavy metal concentrations were evaluated in the samples. Results obtained were compared with set standards for effluent discharge by the National Environmental Standards and Regulations Enforcement Agency (NESREA) and the United States Environmental Protection Agency (USEPA) to determine the effluent quality and compliance level of the concerned industries. Data obtained from physicochemical analyses of the effluents from the industries revealed that some parameters, namely: PO_4^{3-} (90.60-311.55 mg/L), SO_4^{2-} (605.9-765.0 mg/L), Cl^- (590.14-765.0 mg/L), calcium hardness (283.35-370.0 mg/L), and a heavy metal [Zn (1.90-2.11 mg/L)] had values higher than the maximum permissible limits of NESREA and USEPA while effluents from the carbonated drink and abattoir recorded Pb levels of 0.03 mg/L which was above the permissible limit stipulated by both regulating bodies. The study shows non-compliance of these industrial outfits with standards/guidelines set by the regulatory bodies and calls for appropriate action to stem the present trend whereby poor quality effluents are indiscriminately discharged into receiving water bodies.

Keywords: Industrial wastewater, Water quality assessment, Physicochemical parameters, Heavy metals

Introduction

In today's world, water which is one of man's greatest resources is facing huge pollution threats and challenges. The quality and quantity of our freshwater reserve is reportedly declining mainly due to anthropogenic activities (Elkharraz *et al*., 2012; Qasim and Mane 2013; Zeng *et al*., 2013). Increasing industrialization is one of the culprits that have been identified as a major contributor to this global trend (Cundy *et al*, 2008; Chong *et al*, 2010), as most wastewater from these industries end up in receiving surface waters and underground aquifers. Generally, these industries carryout complex processes involving several stages that tend to produce high volume of wastewaters. Measures taken by national, regional and international environmental bodies to ameliorate or curb this challenge are by formulating guidelines and standards for the discharge of various industrial wastewaters or effluents into the environment, and also monitor/supervise compliance. In Nigeria, a developing country still battling with environmental abuse by many companies, this responsibility lies with the National Environmental Standards and Regulations Enforcement Agency (NESREA), a body set up for this purpose on 30th of July 2007 by the Nigerian government.

Despite this proactive step by government, some industries still cut corners or do not maintain their effluent treatment plants properly to obtain minimal treatment as stated in NESREA's guidelines. This scenario has led to unabated dumping of pollutants into our water bodies with attendant adverse effects to their biota, and also reducing the aesthetics and recreational quality of the water bodies (Kanu and Achi 2011; Odutayo *et al*., 2016; Okereke *et al*, 2016).

Several studies have been conducted which confirm this disturbing trend. For example, the evaluation of some industrial effluents in Jos metropolis, Nigeria by Chris-Otubor *et al*. (2015) reveals non-compliance in some parameters such as BOD, COD, TSS, sulphide, nitrates, free chlorine, iron and lead amongst the selected industries (which include a food industry, pharmaceutical outfit and water treatment plant). Similarly, Nkwocha *et al*. (2013) reported similar scenario in which some quality parameters such as BOD, DO, THC, oil and grease, and even pH were not within set limits for discharge of effluent samples collected from a vegetable oil plant facility. Also, monitoring of the effects of the discharged wastewater on receiving bodies has been largely investigated to ascertain probable pollution levels (Osibanjo *et al*., 2011; Ayobahan *et al*., 2014; Akpen *et al*., 2016; Amoo *et al*., 2017). In all these reports, the need for proper monitoring of effluents discharged from industries to ensure compliance with standards by the regulating agencies were emphasised.

In this study, we sought to find out the quality of wastewaters discharged from some processing facilities in Benin City and environs in Edo State, Nigeria to determine the level of compliance level of the concerned industries with existing regulatory framework for effluent discharge.

Materials and methods

Wastewaters collection and samples analysis: The wastewater samples were collected at the points of discharge from a carbonated soft drink company, a brewery and an abattoir in Benin City, Edo State, Nigeria (6.3350° N, 5.6037° E) and a glass manufacturing company in Ughelli, Delta State, Nigeria (5.5002° N, 5.9938° E).

The sampling was done using appropriate 2 L plastic containers as required for the different analysis. Prior to sample collection, the sampling containers were washed with dilute hydrochloric acid followed by distilled water and dried. At the sampling point, they were further rinsed twice with the water samples to be collected. The samples were collected thrice (i.e. morning, afternoon and evening) and pooled together to form a composite sample. Collected samples were stored in ice chest for preservation and finally transported to the laboratory for analysis.

Nitrates, phosphates, sulphates, chloride, ammonia, as well as turbidity levels of the samples were analysed using a spectrophotometer, HACH DR 3900 model (APHA 1998). The conductivity was measured using Adwa multi-parameter meter (model AD8000), $CaCO_3$ hardness was evaluated by EDTA Titrimetric method (APHA 1998), while the total suspended solids (TSS) was determined by the method established in APHA (1992). The Atomic Absorption Spectrophotometry method for rapid determination of heavy metals was used to analyse the levels of Pb, Cd, As, Al, Cr, Cu, Co, Mn, Ni and Zn in the wastewater samples. Digestion of the samples was done as described by Radojevic and Bashkin (1999) to eliminate particulate or organic matter interference. They were analysed for their various metallic contents using an Atomic Absorption Spectrophotometer, Unican 929 AA spectrometer following standard procedures.

Results and discussion

Experimental results obtained from selected industrial wastewater samples analysis for physicochemical assessment are presented in Table 1. Physicochemical parameters of any water body play a vital role in maintaining the fragile ecosystem that sustains various life forms (Kumar and Puri 2012). Hence, they are primarily evaluated in water/wastewater samples as a form of quality assessment. The nitrate values obtained ranged from 30.90-51.33 mg/L. The levels were higher than the maximum permissible limit of 10.0 mg/L stipulated by USEPA (2009), however, the levels recorded for the brewery effluent (36.11 mg/L) and glass effluent (30.90 mg/L) were below the 40.0 mg/L set by NESREA (2011).

The carbonated drink company and the abattoir effluent had high nitrate values of 46.05 mg/L and 51.33 mg/L respectively. The effluent discharged from the carbonated drink company had a high nitrate value of 46.05 mg/L which probably stems from the use of nitrogen-based fertilizer (e.g. urea) as supplement for the microorganisms employed for the biological treatment process as normally practised. The dosing ratio or frequency tends to be much as revealed by this result. Abattoir wastewater has been reported to characteristically contain high levels of nitrates (Chukwu *et al*., 2011) especially when not properly treated. This collaborates with the highest nitrate level of 51.33 mg/L recorded for the abattoir effluent analysed in this study.

Ammonia levels (0.010-0.040 mg/L) obtained for all the effluents were far below NESREA's maximum permissible limit (2.0 mg/L); however the value recorded for carbonated drink effluent (0.040 mg/L) was above the 0.03 mg/L limit stipulated by USEPA.

Table 1: Physicochemical assessment of industrial wastewaters

Test Effluent	Physicochemical Parameter								
	NO_3^- (mg/L)	**NH_4^+ (mg/L)**	**PO_4^{3-} (mg/L)**	**SO_4^{2-} (mg/L)**	**Cl^- (mg/L)**	**Calcium hardness (mg/L)**	**Conductivity (µS/cm)**	**Turbidity (NTU)**	**TSS (mg/L)**
Carbonated Soft Drink	46.05	0.040	311.55	605.90	750.11	343.93	10,300	12.2	0.009
Brewery	36.11	0.010	90.60	700.51	630.55	320.00	8,600	10.9	0.004
Glass company	30.90	0.020	100.50	680.30	590.14	283.35	6,500	9.18	0.003
Abattoir	51.33	0.013	295.70	720.45	765.00	370.00	11,900	15.0	0.013
NESREA Limit (2011)	40.0	2.0	3.5	500	350	-	-	-	0.75
US EPA Limit (2009)	10	0.03	-	250	250	0-75	-	-	-

NESREA= National Environmental Standards and Regulations Enforcement Agency (2011), US EPA= United States Environmental Protection Agency (2009).

Phosphates levels recorded ranged from 90.60-311.55 mg/L which was far above the 3.5 mg/L maximum permissible limit set by NESREA. The high levels of phosphates in these effluents may have come from the use of phosphate-based detergents such as Trisodium phosphate (TSP), mostly employed for cleaning/sanitation purposes in industries, utilization of phosphoric acid as raw material (e.g. phosphoric acid in most cola products of carbonated drinks) and also for disinfection purpose in some of these industries, and application of phosphate-based fertilizers such as NPK as nutrient for the microorganisms employed in biological treatment of wastewater. High levels of phosphates (and other nutrients such as nitrates) in effluents discharged into surface waters may encourage eutrophication (Nassef, 2012) which could deplete the dissolved oxygen level of the receiving water body and endanger the biota.

Sulphates levels of 605.90-720.45 mg/L were recorded for the effluents, and these were higher than limits set by both NESREA (500 mg/L) and USEPA (250 mg/L). The high concentrations observed may have been due to the sulphuric acid (H_2SO_4) employed for pH adjustments or alum ($Al_2(SO_4)_3.16H_2O$) used as a coagulant in the effluent treatment processes of these industries, especially when effort was not made to remediate the levels of the sulphates by simple procedures like applying lime (Christoe, 1976). A high level of sulphates in wastewater generates hydrogen sulphide with the characteristic offensive smell.

Chloride levels obtained ranged from 590.14-785.0 mg/L with all values higher than the limits set by NESREA (350 mg/L) and USEPA (250 mg/L). The abattoir effluent gave the highest value of 785.0 mg/L, while the effluent from the glass industry had the least value of 590.14 mg/L. The high chloride levels recorded could have resulted from the use of calcium hypochlorite [$Ca(OCl)_2$] or sodium hypochlorite (NaClO) as major primary disinfectants in water/wastewater treatment operations. Also, various concentrations of chlorine solution are employed for sanitation/disinfection purposes in industries like breweries, carbonated drink, food (meat) processing companies, etc. The use of chloride-containing salts and other chloride-based raw materials or additives may be another contributing source of chloride in the effluents from these industries. Again, pH adjustments of wastewater during treatment processes are at times carried out using HCl.

Closely influenced by the levels of chloride in wastewaters is conductivity (Ogbu *et al*., 2016). Increasing conductivity with increase in chloride levels has been reported (Nweke and Sander 2009). The conductivity values obtained in this study followed this trend. The abattoir effluent (which had the highest chloride concentration of 765.0 mg/L) gave the highest conductivity value of 11,900 µS/cm; while the glass manufacturing company effluent with the least chloride levels (590.14 mg/L) recorded the lowest conductivity (6,500 µS/cm).

The values obtained for calcium hardness ranged from 283.35-370.0 mg/L. The abattoir wastewater gave the highest value of 370.0 mg/L, while the effluent from glass manufacturing company recorded the lowest value of 283.35 mg/L. All values were much higher than the range of 0-75 mg/L stipulated for total hardness by USEPA. The levels of the calcium hardness also correlate with the conductivity values recorded. Generally, the use of hard water can cause increased soap usage, scale deposition in water distribution systems and reduction in efficiencies of heating equipment such as heat exchangers. Water hardness has been suggested as a possible risk factor in eczema exacerbation (WHO, 2011).

The turbidity and total suspended solids (TSS) recorded for the wastewater samples ranged from 9.18-15.0 NTU and 0.003-0.013 mg/L, respectively. As observed in most trends, the abattoir effluent had the highest values of 15.0 NTU and 0.013 mg/L for turbidity and TSS respectively; while the effluent from the glass industry gave the least values. The TSS values were all lower than the maximum permissible limit if 0.75 mg/L set by NESREA.

Results obtained from the analysis of the industrial wastewater samples for heavy metal assessment are presented in Table 2. Effluents from industries laden with heavy metals may adversely impact environmental and human health (Alam *et al*., 2007), making their monitoring in wastewater an important quality assessment criteria.

Heavy metal levels obtained showed that As, Al, Cd, Cu and Cr had concentrations lower than the maximum permissible limit stipulated by both NESREA and USEPA, while only the Mn concentration for the abattoir effluent (0.06 mg/L) was higher than the 0.05 mg/L set by USEPA.

The levels obtained for Zn ranged from 1.90-7.11 mg/L which was higher than 0.2 mg/L and 0.12 mg/L set by NESREA and USEPA, respectively.

For Pb levels, effluent concentration (0.03 mg/L) from the carbonated soft drink plant and the brewery gave values higher than the set limit of 0.02 mg/L by USEPA, while all other values obtained conformed with the standard (0.1 mg/L) established by NESREA. Only Ni concentration for the carbonated soft drink plant effluent (0.02 mg/L) was higher than the 0.005 mg/L stipulated by USEPA.

Table 2: Heavy metals levels in industrial wastewaters

Test Effluent	**Heavy metals levels (mg/L)**									
	As	**Al**	**Cd**	**Co**	**Cu**	**Mn**	**Ni**	**Pb**	**Zn**	**Cr**
Carbonated Soft Drink	ND	0.01	ND	0.01	0.11	0.04	0.02	0.03	5.10	0.07
Brewery	ND	ND	ND	ND	0.02	0.02	ND	0.01	2.16	0.03
Glass company	ND	ND	ND	ND	0.01	0.03	0.01	0.01	1.90	0.04
Abattoir	0.01	ND	0.01	0.02	0.05	0.06	0.01	0.03	7.11	0.09
NESREA Limit (2011)	0.1	0.2	0.01	-	0.01	-	0.01	0.1	0.2	0.5
US EPA Limit (2009)	-	-	0.002	-	1.3	0.05	0.005	0.02	0.12	0.1

NESREA= National Environmental Standards and Regulations Enforcement Agency (2011), US EPA= United States Environmental Protection Agency (2009).

Conclusion

Quality assessment of the wastewaters from the selected industries revealed instances of non-compliance with NESREA and USEPA guidelines. Results obtained showed that all effluents contained high levels of phosphate, sulphate, chloride and calcium hardness than the stipulated limits set by NESREA and USEPA. There was resultant high conductivity due to the presence of elevated levels of ions in the wastewater, especially major contributors like chloride and calcium ions. Nitrates levels recorded were higher than the set standards in the abattoir and carbonated drink effluents only, while ammonia and TSS values were within limits stipulated by NESREA. The heavy metal results showed that As, Al, Cd, Cu and Cr had concentration lower than the maximum permissible limit stipulated by both NESREA and USEPA. The Mn and Ni levels were within NESREA's limits for all samples, but fell outside the limit set by USEPA for Abattoir effluent (Mn) and Carbonated Soft Drink (Ni). Both effluents also recorded higher values for Pb with levels obtained more than the maximum permissible limits set by both regulating bodies. All the industrial effluents revealed higher levels of Zn.

From the foregoing, the unabated discharge of the wastewaters as revealed in this study may lead to possible ecological and environmental implication with devastating consequences. The need for effective monitoring of industrial wastewater discharges by the regulatory bodies to ensure good quality effluent and compliance with set standards is cannot be overemphasized. NESREA, the regulating body in Nigeria and other stakeholders should map out holistic measures to tackle this continuous menace to our receiving water bodies and environment. Lastly, industry owners/operators should as a matter of urgency obey the laws governing their operations and should perform their corporate and social responsibilities and ensure that effluent treatment plants are installed in their facilities, and should be operated at optimum conditions and manned by qualified personnel.

References

Akpen GD, Ekanem EJ, Agunwamba JC: The effects of sewage effluent discharges on water quality of Wupa River in Abuja, Nigeria. J Sci Technol 36(2): 86-95. 2016.

Alam ASMM, Hossain KM, Hossain B, Ahmed A, Hoque MJ: A study on industrial waste effluents and their management as selected food and beverage industries of Bangladesh. J Appl Sci Environ Manage 11(4): 5-9. 2007.

American Public Health Association/American Water Works Association/Water Pollution Control Federation: Standard Methods for the Examination of Water and Wastewater. 20th Ed. APHA, Washington, DC. 1325p. 1998.

American Public Health Association/American Water Works Association/Water Pollution Control Federation: Standard Methods for the Examination of Water and Wastewater. 20th Ed. APHA, Washington, DC. 1992.

Amoo AO, Zakari AW, Ijanu EM, Adeleye AO, Amoo NB: Physico-chemical and bacteriological assessment of surface water quality: A case study of Jakara River, North-Western Nigeria. Int J Appl Res Technol 6(9): 65-74. 2017.

Ayobahan SU, Ezenwa IM, Orogun EE, Uriri JE, Wemimo IJ: Assessment of anthropogenic activities on water quality of Benin River. J Appl Sci Environ Manage 18(4): 629-636. 2014.

Chong MN, Jin B, Chow CWK, Saint C: Recent developments in photocatalytic water treatment: A review. Water Res 44(10): 2997-3027. 2010.

Christoe JR: Removal of sulphates from industrial wastewaters. J Water Pollut Control Fed 48(12): 2804-2808. 1976.

Chris-Otubor GO, Olorunfemi P: Evaluation of some industrial effluents in Jos metropolis, Plateau State, Nigeria. Afr J Environ Sci Technol 9(6): 566-572. 2015.

Chukwu O, Adeoye PA, Chidiebere I: Abattoir waste generation, management and the environment: A case study of Minna, North Central Nigeria. Int J Biosci 1(6): 100-109. 2011.

Cundy AB, Hopkinson L, Whitby RLD: Use of iron-based technologies in contaminated land and groundwater remediation: A review. Sci Total Environ 400(1): 42-51. 2008.

El Kharraz J, El-Sadek A, Ghaffour N, Mino E: Water scarcity and drought in WANA countries. Proc Eng 33: 14-29. 2012.

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

Kumar M, Puri A: A review of permissible limits of drinking water. Indian J Occup Environ Med 16(1): 40-44. 2012.

Nassef E: Removal of phosphates from industrial waste water by chemical precipitation. Eng Sci Technol: Int J 409-413. 2012.

NESREA: National Environmental Standards and Regulations Enforcement Agency: National Environmental (Surface and Ground water Quality Control) Regulations- Effluent discharges, irrigation and reuse standards. 2011. (Accessed on 17th of February 2018).

Nkwocha AC, Ekeke IC, Kamen FL, Oghome PI: Quality assessment of effluent discharges from vegetable oil plant. Ethiop J Environ Stud Manage 6: 717-723. 2013.

Nweke, OC, Sander WH: Modern environmental health hazards: A public health issue of increasing significant Africa. Emviron Health Perspect 117(6): 863-870. 2009.

Odutayo FOI, Oyetade OB, Esan EB, Adaramola FB: Effects of industrial effluents on the environment using *Allium cepa* and *Zea mays* as bioindicators. Int J Environ Pollut Res 4(4): 1-12. 2016.

Ogbu KC, Ebenebe CI, Abajue MC: Physico-chemical characteristics of Ama brewery effluent and its receiving Ajali River in Udi, Enugu State, Nigeria. Anim Res Int 13(2): 2392-2399. 2016.

Okereke JN, Ogidi OI, Obasi KO: Environmental and health impact of industrial wastewater effluents in Nigeria- A review. Int J Adv Res Biol Sci 3(6): 55-67. 2016.

Osibanjo O, Daso AP, Gbadebo AM: The impact of industries on surface water quality of River Ona and River Alaro in Oluyole Industrial Estate, Ibadan, Nigeria. Afr J Biotechnol 10(4): 696-702. 2011.

Qasim W, Mane AV: Characterization and treatment of selected food industrial effluents by coagulation and adsorption techniques. Water Resour Ind 4: 1-12. 2013.

Radojevic M, Bashkin VN: Practical Environmental Analysis. The Royal Society of Chemistry: Cambridge, UK. 466p. 1999.

US EPA: United States Environmental Protection Agency: Drinking water contaminants. Washington, DC, USA. 2009. Available at: http:water.epa.gov/drink/contaminants/index.cfm#list.

WHO: World Health Organisation: Hardness in Drinking Water - Background document for development of WHO guidelines for drinking water quality. Geneva, Switzerland. 2011. WHO/HSE/WSH/10.01/10/Rev.1. (Accessed on the 22nd of February 2018).

Zeng Z, Liu J, Savenije HHG: A simple approach to assess water scarcity integrating water quantity and quality. Ecol Indic 34: 441-449. 2013.