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Influence of discharged industrial effluents on the parameters of surface water in Onitsha urban area, southeastern Nigeria

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Abstract

Chemical industries in Onitsha urban area of southeastern Nigeria have been discharging large quantities of effluents into surface streams. These streams are the primary sources of water used by poor households for domestic purposes. This study examines the effects of effluents on the physicochemical and microbiological characteristics of the recipient streams. This objective was achieved by collecting eight effluents and twenty-two water samples from control points, discharge locations and exit chutes of the effluents for analysis. The results of the study characterised the effluents and their effects on the recipient streams. The effluents cause gross pollution of the streams as most of the parameters including pH, total dissolved solids (TDS), turbidity, biological oxygen demand (BOD), chemical oxygen demand (COD), Mg, NO_3, Fe, Cu, Pb, Cr, total heterotrophic count (THC) and total coliform group (TCG) returned high values that exceeded the World Health Organisation's (WHO) benchmark from 2011 for drinking water quality. Only dissolved oxygen (DO), Na, Zn, Ca, and Na returned values lower than the WHO guideline. *E. coli* was found in all the samples; TCG was also high. This paper, therefore, recommends that the effluent generating industries should treat their effluents before disposal.

Key words: *drinking water supplies, industrial effluents, streams contamination, water quality*

INTRODUCTION

Industrial and urban wastes, as well as intensive use of chemical fertilizers in agriculture, have contributed significantly to the growing deterioration of water quality across the globe [ATTOUI *et al.* 2016]. Industrial wastes constitute growing problems for water quality and pose a severe danger to the recipient environments [BOUSSAHA, LAIFA 2017]. This study concerns the impact of one of the contaminants of surface water bodies in Onitsha urban, Nigeria. The focus is on the effect of industrial effluents on parameters of surface water in the study area. Industrial effluents refer to the liquid wastes that are generated from industries as a result of the production activities within the industries [UCHEGBU 2002]. There are deleterious effects of discharged industrial effluents on the physicochemical and microbiological characteristics of surface water bodies [OKAFOR 2017].

Industrial wastes contain toxic and hazardous substances, most of which are detrimental to human health. Examples of some harmful pollutants contained in industrial effluents discharges include lead, cadmium and mercury (heavy metals) and toxic organic chemicals such as pesticides, polychlorinated biphenyls (PCBs), dioxins, polyaromatic hydrocarbons and phenolic compounds [UCHEGBU 2002]. These wastes are generally residues of either uniform or diverse composition; and they have been found to be of various degrees of toxicity [ECHIEGU, LIBERTY

2013]. The assessment of the influence of point-source pollutants in surface water quality has become increasingly important [ATTOUI *et al.* 2016]. The investigation of the level of contaminations of the polluted rivers and the impacts of the pollution on the quality of the streams is pertinent because of the critical development roles these water resources play [MOSIEJ *et al.* 2007].

In many developing countries, including Nigeria, liquid industrial effluents are discharged directly into surface water bodies such as streams or lakes [ECHIEGU, LIBERTY 2013; OKAFOR 2017]. When this happens, the human society pays a high price for improper disposal of industrial wastes since the polluted water are mainly used for both domestic and drinking purposes by human population resident within the vicinity of the surface water bodies [AMADI 2012; OKAFOR 2017]. In Amazon, Brazil, for instance, DI-MARIO [2004] reported that prospecting for gold resulted in rivers and fish being contaminated severely with mercury used in the refining process in the country. KUPCHELLA and HYLAND [1993] also described the effects of acetaldehyde and chloride discharged from a factory into Mina-Mata Bay in Japan in the 1950s which killed many animals such as dogs, cats and pigs involved in the consumption of water extracted from Mina-Mata Bay. In 1958, when the number of victims exceeded 50 people, 21 of whom died, a ban was placed on the sale of fish from Mina-Mata Bay, though there was no restriction on disposal of industrial effluents on surface waters. In India, industrial effluents discharged into surface streams were also reported to pose severe threats to human health [MASON 1992].

In Nigeria, the disposals do not always comply with pre-treatment requirements [ECHIEGU, LIBERTY 2013; OKAFOR 2017]; less than 10% of industries treat their effluents before being discharged, usually into rivers [ECHIEGU, LIBERTY 2013]. Consequently, there is a high load of inorganic and hazardous metals such as lead (Pb), chromium (Cr) and iron (Fe) in many of the receiving water bodies. AMADI [2012] observed that indiscriminate disposal of industrial wastes in Nigeria remains a significant threat to surface water quality. OSIBANJO [2000] highlighted that after a survey of the backlog of Nigeria's environmental problems from independence in 1960, the Federal Environmental Protection Agency (FEPA) in 1990 identified industrial waste as a significant ecological problem requiring urgent attention. Although there are policies and laws which guide and control the production and management of industrial wastes because of their hazardous nature in Nigeria [UCHEGBU 2002]; the low compliance to and the non-enforcement of the regulatory laws, has led to the improper disposal of industrial effluents both in urban and rural areas [MOZIE, AYADIUNO 2008].

This study aims to examine the effects of disposing of liquid effluents from industries into streams in Onitsha urban of southeastern Nigeria. The study characterised the liquid effluents discharged by industries in the area and established their harmful effects on the quality of the receiving water bodies. It is hoped that the results of this study will assist relevant state agencies in designing mitigation measures to ensure that the quality of the water in the streams of the study area is protected from the adverse effects of effluents from industries. The results may also contribute to the knowledge base for future research on the management of liquid effluents discharged from industries in urban areas of a developing country like Nigeria.

THE STUDY AREA

Onitsha urban area is located between latitude 6°07’–6°09’N and longitude 6°47’–6°48’E. It is situated at the bank of the Niger River in Anambra State, southeastern, Nigeria. The urban area covers about 50 km^2 and is accessed through the East-West national main road from Lagos through Benin which links the eastern-north-south route via the Niger Bridge at Onitsha [MOZIE 1992]. Onitsha lies at the major east-west crossing point of the Niger River and occupies the northern end of the river that is regularly navigable by large vessels. These factors have historically made Onitsha a major centre for trade between eastern and western Nigeria. Also the favourable site of Onitsha, as a meeting point of two different regions, providing the link between the savanna of the North and the delta region of the South enabled Onitsha to develop into an important commercial and manufacturing centre. The urban area is now an economic nerve centre and the industrial hub of southern Nigeria. Most of the industries operating in Onitsha are without waste water treatment. Effluents are routinely discharge directly into nearby streams or on open surfaces. Unfortunately, the disposal or discharge of effluents is not stringently regulated by state or federal authorities. These discharged effluents deter beneficial uses of the receiving streams for domestic, industrial and agricultural water uses.

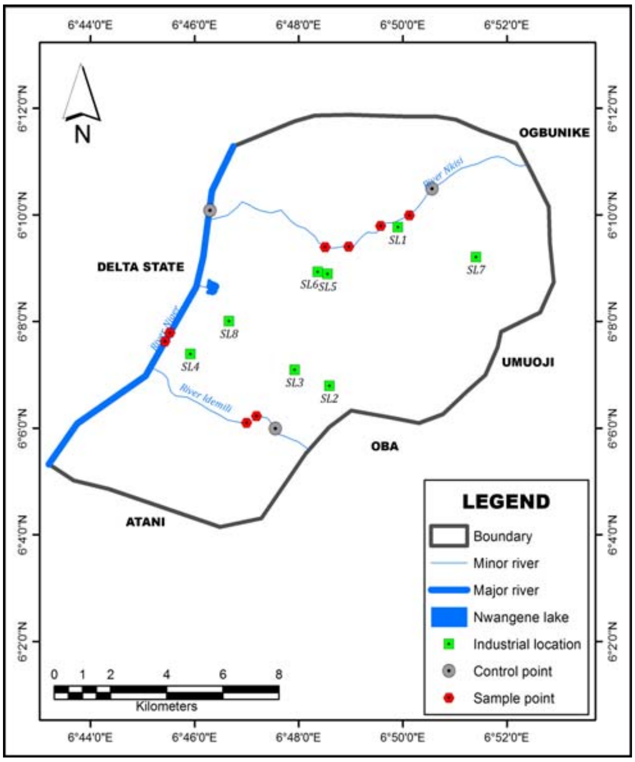

Fig. 1. Sample points for all the water samples collected in the study area; source: own elaboration

The city is split up into two local government areas namely, Onitsha North and Onitsha South local government areas. Ogbaru and Idemmili North bound Onitsha in the South and the East respectively. The climate of the study area belongs to THORNTWAITE'S [1948] humid forest mega thermal climate which ILOEJE [1972] regards as subequatorial and INYANG [1975] classified as 8-month rainy season climate. The principal geologic units of the area are the recent deposits of the Holocene (Quaternary) occupying the active floodplains of the Niger and Anambra Rivers and the sandstone formations of the Upper-Middle Eocene (Tertiary) occupying the sandstones plains lying above and adjacent to the Niger-Anambra floodplains. The landscape of Onitsha urban area is lowland. Topographically, the area is traversed and drained mainly by the Niger River and its tributaries notably, the Idemmili and Nkisi Rivers all draining into the Niger River. The relief of Onitsha has made floodplains found in this area to be depositional. Lakes and ponds and levees pockmark the relief of the study area. The sandstone formation constitutes aggradations plains [OFOMATA 1975].

MATERIALS AND METHODS

Forty-seven (47) chemical industrial plants currently discharge their effluents into surface water bodies in Onitsha urban area. These industries were classified into eight groups; according to their production processes. One industrial plant, representing a category of the production process was chosen purposively from each of the eight groups for this study. The criteria for selection included availability for research, accessibility to exit chutes of wastes, and time of effluent discharges. Eighteen water quality parameters, including temperature, pH, dissolved oxygen (DO), nitrate, turbidity, total dissolved solids (TDS), biological oxygen demand (BOD), chemical oxygen demand (COD), copper, calcium, iron, zinc, chromium, magnesium, sodium, lead (Pb), total heterotrophic count (THC), and total coliform group (TCG) were investigated. The pH value of a water sample measures its hydrogen ion concentration and indicates whether the sample is acidic, neutral or basic [ABABIO 1990]. Turbidity is a measure of transparency (clarity) or the cloudiness of water due to fine suspended colloidal particles of clay or silt, waste effluents or microorganisms contained in water while total dissolved solids (TDS) is the measure of the combined dissolved content of all organic and inorganic substances present in water. Nitrate is a compound of nitrogen oxidation which shows the effect of organic pollution on water quality [AGBAZUE, AKPANISI 2012) while DO refers to dissolved oxygen i.e. oxygen gas molecules present in water. Chemical oxygen demand (COD) is the amount of oxygen consumed under specific conditions of organic and oxidizable inorganic matter in wastewater [AGBAZUE, AKPANISI 2012; AGUWAMBA 2000] while biological oxygen demand (BOD) is the amount of oxygen required by bacteria to stabilise decomposable organic matter under aerobic conditions [AGBAZUE, AKPANISI 2012; AGUWAMBA 2000). Sodium is a common element in the environment and occurs widely in soils, plants, water and foods [AGBAZUE, AKPANISI 2012]. Calcium is an essential dietary mineral for cell physiology and bone formation. Calcium is required for both strong bones formation and formation of blood clotting [EMMANUEL *et al.* 2009].

Magnesium is the fourth most abundant cation in the human body and the second most abundant cation in intracellular fluid [UN WATER 2011]. Zinc is an essential trace element needed by the human body [OCHERI *et al.* 2008]. Heterotrophic microorganisms are those organisms that obtain their food by feeding on organic substances for nourishment [BROOKS *et al.* 1998]. These organisms cannot make their food but are dependent on other substances for nutrition [BROOKS *et al.* 1998]. For example, bacteria, yeast and moulds are heterotrophic. The total heterotrophic count (THC) is used to estimate the number of live heterotrophic bacteria that are present in a water sample. THC provides useful information about water quality and supporting data on the significance of the coliform test results [KEHINDE 1996]. Total coliform group (TCG) are a collection of relatively harmless microorganisms that live in large numbers in the intestine of man and other animals [TAIWO 2011]. They aid in food digestion. The presence of fecal contamination is an indication that a potential health risk exists for individuals exposed to this water [TAIWO 2011].

The choice of these parameters was informed by the ease of interpretation, their association with industrial effluents and effects on human health. Eight (8) discharged effluents samples were collected from the exit chutes of the effluents at each of the sampled industrial plants; while 6 water samples were collected up-stream (at 3 control points) from the sampled streams (the Niger River, the Nkisi River, and the Idemmili River) about 100 m away before the discharge locations.

Two samples (one for physicochemical analyses and the other for microbiological analyses) were collected at each location according to recommended standard procedures for water quality analysis by American Public Health Association [APHA 1998]. Sixteen water samples were collected at the 8 effluents discharge locations (i.e. the point where the effluent enters the surface. Two water samples were collected per location, from the 8 different discharge locations. The effluent samples were collected during the period of heavy activity corresponding to the times when high volumes of effluents are discharged. The fieldwork involves collecting the samples aseptically in bottles with capacity of 2 dm^3. The samples were then placed in insulated containers and transported to the Water Science Laboratory of the Department of Microbiology, University of Nigeria, Nsukka for analyses. The temperature was measured directly using a glass thermometer, and pH was measured using the pH-meter.

RESULTS AND DISCUSSION

The results of the laboratory analysis of the liquid effluents collected from the exit chutes of the effluents of the sampled industries are presented in Table 1. The findings on the physicochemical and microbiological properties of

Table 1. Physico-chemical and microbiological characteristics of effluents discharged from various industries in the study area

Parameter	Measurement unit	Value in							
		SL1	SL2	SL3	SL4	SL5	SL6	SL7	SL8
Temperature	°C	**32**	**30**	**30**	**36**	**32**	**34**	**29**	**32**
pH	–	8	7.5	6.5	**12**	6.5	**6**	**6**	**5.5**
Turbidity	NTU	**200**	**320**	**200**	**150**	**100**	**200**	**110**	**310**
DO	mg·dm^{-3}	5.11	3.32	3.48	5.07	5.42	3.21	3.39	4.26
TDS	mg·dm^{-3}	5.8	1.1	3	1.7	2.8	0.8	0.7	6.10
COD	mg·dm^{-3}	**51.9**	7.9	0.36	**51.9**	6.9	**38.9**	**39.9**	1.08
BOD	mg·dm^{-3}	**14.4**	**31.43**	**13.17**	**32.02**	0.16	0.48	2.06	**41.9**
Nitrate	mg·dm^{-3}	1.24	0.32	0.54	1.31	0.61	0.82	0.52	0.15
Iron	mg·dm^{-3}	**0.52**	0.1	0.02	**0.82**	**0.92**	**0.4**	**0.76**	**0.84**
Zinc	mg·dm^{-3}	0.03	0.07	0.26	0.14	0.14	0.01	0.70	0.18
Copper	mg·dm^{-3}	0.72	0.56	**1.68**	**1.68**	**1.68**	0.72	0.66	0.02
Magnesium	mg·dm^{-3}	**2.90**	**0.50**	**0.43**	**0.32**	**0.35**	**2.5**	0.08	0.09
Calcium	mg·dm^{-3}	8.23	12.46	1.92	1.12	0.32	0.74	0.60	8.24
Sodium	mg·dm^{-3}	3.29	2.54	0.14	1.24	1.24	0.08	2.41	6.29
Chromium	mg·dm^{-3}	ND	**0.18**	**0.018**	**0.008**	**0.06**	**0.14**	ND	ND
Lead	mg·dm^{-3}	ND	**0.32**	**0.33**	0.001	**1.44**	**0.06**	ND	ND
THC	Cfu·(100 cm^3)$^{-1}$	**14**	8	**13**	**24**	**45**	**14**	ND	6
TCG	Cfu·(100 cm^3)$^{-1}$	**3**	**5**	**2**	**1**	**12**	**3**	ND	**2**

Explanations: SL1–SL8 as in Fig. 1; DO = dissolved oxygen, TDS = total dissolved solids, THC = total heterotrophic count, TCG = total coliform group, ND = not detected, bolded values = exceeded WHO standard [WHO 2011].
Source: own study.

discharged effluents evaluated in this study are summarised in Table 1. As shown in Table 1, the concentration levels of most of the parameters analysed exceeded the WHO [2011] benchmark for drinking water supplies at several sampling locations. A summary result of the physicochemical and microbiological characteristics of the recipients' stream based on parameter loadings of water samples obtained at the control sites are presented in Table 2. As shown in Table 2, the values returned by eight parameters (temperature, turbidity, DO, iron, lead, chromium, THC and TCG) exceeded the WHO [2011] benchmark

Table 2. Physico-chemical and microbiological characteristics of the recipient surface waters (control), 500 m before contact with effluents

Parameter	Measurement unit	Values in control point			WHO standard [WHO 2011]
		1 – the Niger River	2 – the Idemili River	3 – the Nkisi River	
Temperature	°C	24	**28**	**26**	25
pH	–	7.2	6.5	7.10	6.5-8.0
Turbidity	NTU	**100**	**300**	**300**	5.0
DO	mg·dm^{-3}	**136**	**93**	**96**	6.0
TDS	mg·dm^{-3}	176	330.2	318.10	500
COD	mg·dm^{-3}	4.00	3.60	5.90	10
BOD	mg·dm^{-3}	2.08	5.2	7.2	10
Nitrate	mg·dm^{-3}	0.10	0.28	0.12	50
Iron	mg·dm^{-3}	0.02	**1.41**	**1.42**	0.3
Zinc	mg·dm^{-3}	0.03	0.06	0.07	3
Copper	mg·dm^{-3}	0.10	0.22	0.10	1
Magnesium	mg·dm^{-3}	**1.03**	0.07	0.12	0.2
Calcium	mg·dm^{-3}	2.29	7.1	2.8	75
Sodium	mg·dm^{-3}	1.17	0.04	0.98	200
Chromium	mg·dm^{-3}	**0.008**	0.0025	0.002	0.003
Lead	mg·dm^{-3}	**0.048**	0.0041	0.002	0.01
THC	Cfu·(100 cm^3)$^{-1}$	**28**	**42**	**37**	10
TGC	Cfu·(100 cm^3)$^{-1}$	**20**	**31**	**19**	0

Explanations: DO, TDS, THC, TGC as in the Table 1.
Source: own study.

safe limits for drinking water supplies at one or more sampling locations. Chromium was higher than the maximum permissible level set by the WHO at only one control site; the values returned by the other parameters were within the safe limits for safe drinking water when compared with the WHO [2011] benchmark. These findings show that the water quality in the streams, even before contacts with industrial effluents, did not meet safety benchmark set the WHO at all the sampling locations.

Summary information on the quality status of the recipients' stream waters at the eight discharge locations are presented in Table 3. The results derived from these locations were used to determine the effects of the effluents on water quality of water from the recipients' streams. As Table 3 shows, the number of parameters and sampling stations with elevated values highly increased when compared with the control points. Except for a few parameters (sodium, calcium, zinc, nitrate, dissolved solids, turbidity and pH), all other parameters returned values which exceeded the WHO [2011] standard benchmarks for drinking water supplies. This shows that the level of contamination of the water in the streams worsened and this can be attributed to the impacts of the effluents discharged at those locations. Therefore, we conclude that the high concentration values returned by most parameters are indications of the effects of the effluents on the sampled streams. The effluents worsened the level of stream water pollution, making them further unsuitable for human uses. The ranges of the values returned by each of the sampled parameters and their implications for human consumption and aquatic life are discussed parameter by parameter below.

As Table 3 shows, the temperature values of the industrial effluents ranged from 29°C to 36°C and exceeded WHO [2011] standard benchmark of 25°C for drinking water supplies. The values of temperature returned at the various sampling locations reveal that the streams are unsuitable for human consumption and harmful to aquatic

Table 3. Physico-chemical and microbiological characteristics of water samples in rivers

Parameter	Measurement unit	Values in sampling points/locations								WHO standard [WHO 2011]
		SL4	SL8	SL2	SL3	SL1	SL5	SL6	SL7	
Temp	°C	**26**	**28**	**29**	**30**	**30**	**28**	**30**	**29**	25
pH	–	**8.2**	7.5	6.80	6.5	7	6.9	6.7	7.2	6.5–8.0
Turbidity	NTU	100	100	300	300	300	300	400	300	500
DO	mg·dm^{-3}	**130**	**143.6**	**78.34**	**82.16**	**90.18**	**35**	**62.85**	**89.42**	6.0
TDS	mg·dm^{-3}	176.8	126.10	331.40	303	326.27	318.80	435.12	312.27	500
COD	mg·dm^{-3}	3.97	2.08	4.19	3.60	**53.9**	5.90	**18.9**	**39.9**	10
BOD	mg·dm^{-3}	3.12	**41.9**	5.9	**13.17**	**14.6**	4.7	**21.9**	2.06	10
Nitrate	mg·dm^{-3}	0.17	0.15	0.12	0.54	1.28	0.23	0.68	0.52	50
Iron	mg·dm^{-3}	0.14	**1.84**	0.04	0.02	**0.56**	**0.40**	**0.52**	**0.76**	0.3
Zinc	mg·dm^{-3}	0.01	0.18	0.1	0.26	0.04	0.26	0.16	0.70	3
Copper	mg·dm^{-3}	0.30	0.02	0.10	**1.68**	0.68	0.20	0.40	0.66	1.5
Magnesium	mg·dm^{-3}	**0.86**	**3.09**	0.12	**0.43**	**2.46**	**0.33**	**0.28**	0.18	0.2
Calcium	mg·dm^{-3}	2.68	8.24	5.2	4.92	6.12	5.48	3.04	0.60	75
Sodium	mg·dm^{-3}	2.02	6.29	0.98	0.14	2.69	2.08	2.68	2.41	200
Chromium	mg·dm^{-3}	**0.018**	**0.032**	**0.014**	**0.018**	ND	**0.0162**	0.0418	**0.022**	0.003
Lead	mg·dm^{-3}l	**0.04**	**0.082**	**0.028**	**0.033**	ND	**0.028**	**0.076**	**0.074**	0.01
THC	Cfu·(100 cm^3)$^{-1}$	**30**	**62**	**68**	**53**	**26**	**61**	**76**	**43**	10
TCG	Cfu·(100 cm^3)$^{-1}$	**23**	**38**	**46**	**42**	**32**	**46**	**73**	**30**	0

Explanations: bolded values exceeded the WHO [2011] minimum benchmark for drinking water; other explanations as in Tab. 1.
Source: own study.

life. As shown in Table 3, all the returned values for pH fall within the WHO standards of 6.0 to 8.5 apart from sample location 4 (SL4) with a pH value of 8.2. The value returned for pH at this location falls outside the WHO [2011] standards benchmark for drinking water supplies.

The values returned for dissolved oxygen (DO) at the various discharge locations of the industrial effluents were generally high and are above WHO [2011] standards benchmark for domestic water supplies due to the influence of discharged effluents by the industries sampled. The values of TDS returned were generally low and were below the limit set by WHO [2011] standards benchmark for domestic water supplies. As shown in Table 3 the values ranged from 126.1 to 435.12 mg·dm^{-3}. From Table 3, the sample location that returned the highest value of total dissolve solids is SL6, with a value of 435.12 mg·dm^{-3}. SL2 follows this sample location with a value of 331.40 mg·dm^{-3}. The locations that returned the lowest values of TDS are SL8 (126.10 mg·dm^{-3}) and SL4 (176.8 mg·dm^{-3}). The returned values TDS of all the sample locations are all below the WHO [2011] standards benchmark for domestic water supplies standards for drinking water. The values returned for the COD for the sampled locations varied from 3.60 mg·dm^{-3} for SL3 to 39.9 mg·dm^{-3} and 53.9 mg·dm^{3} for SL7 and SL1.

The results of our analysis in Table 3 indicated that SL8 returned the highest value of BOD (41.90 mg·dm^{-3}). This location was followed by SL7 and SL6 (21.9 mg·dm^{-3} and 14.6 mg·dm^{-3} respectively). Sample location 7 returned the lowest BOD value 2.06 mg·dm^{-3} while SL4 returned a value of 3.12 mg·dm^{-3}. These low values may be due to the nature of effluents discharged by the industries in these locations. The result of our analysis revealed that nitrate concentration levels for all the sample locations were within the WHO [2011] recommended limits (10 mg·dm^{-3}) for domestic water consumption.

The values of iron at the discharge locations of the sampled industries were found to be high and above WHO standards benchmark for domestic water supplies standards for drinking water [WHO 2011]. Iron exists naturally in rivers, lakes, and underground water. It may also be released to water from natural deposits, industrial wastes, refining of iron ores and corrosion of iron-containing metals. Iron is an essential nutrient for good health. It is a significant component of haemoglobin, which is used to transport oxygen and carbondioxide in the blood. Iron deficiency can enhance lead absorption and toxicity. The ingestion of large quantities of iron can damage blood vessels, cause bloody stool and damage the liver and kidneys, and even cause death [STUMM, MORGAN 1996]. However, because ingestion is regulated, the body tissues are generally not exposed to high-level concentrations.

The values of sodium in the sampled discharge locations show that SL8 returned the highest value of sodium concentration level of 6.29 mg·dm^{-3}; this sample location was followed by SL6 with a value of 2.68 mg·dm^{-3}. The sampled industries may have contributed immensely to the varying values levels of sodium concentrations in the receiving surface waters. Sample locations near industries that use sodium by-products in their production processes returned relative high values of 6.29, 2.68 and 2.41 mg·dm^{-3} respectively. The SL8 returned the highest concentration value of 8.24 mg·dm^{-3} of calcium concentration; this sample location was followed by SL1 which returned a value of 6.12 mg·dm^{-3}. The lowest calcium concentration value of 0.60 mg·dm^{-3} was returned at SL7.

The varying levels of magnesium concentration values in sampled locations are summarized in Table 3. SL8 returned a relatively high-value 3.09 mg·dm^{-3}. This sample location was followed by SL1 which returned a value of 2.46 mg·dm^{-3}. SL8 and SL1 which returned relative high values are where chemical industries discharge their effluents. Copper concentrations in drinking water vary widely as a result of variations in water characteristics, such as pH, hardness and copper availability in the distribution system. From our study, SL3, returned the highest concentration value of 1.68 mg·dm^{-3} while the lowest copper concentration value of 0.02 mg·dm^{-3} was recorded in SL8.

The presence of chromium in drinking water is a significant health threat because of the carcinogenic effects of chromium content in water. SL3 and SL4 returned relative highest values of 0.18 mg·dm^{-3} for chromium while SL1 returned non-detectable value of chromium in the analysed samples. SL6, returned the highest value of 0.0418 mg·dm^{-3} while SL5, SL7 and SL8 returned values of chromium that were also above the WHO [2011] recommended limits for domestic water consumption in the analysed samples. The varying levels of zinc concentrations in analysed water samples reveal that the SL7 returned the highest concentration level of 0.70 mg·dm^{-3} for zinc while SL4 returned the lowest concentration value of 0.01 mg·dm^{-3}.

The results of our analysis of THC show that all the surface water bodies studied (except SL7) returned THCs levels well above WHO standard limits for drinking water supplies. All the water samples analysed (except SL7 again) returned TCG counts well above the WHO [2011] standard limits for drinking water supplies except SL7.

CONCLUSIONS

Contamination of surface waters represents a growing environmental health challenge in several regions around the globe. In this study, industrial effluents consisting of toxic substances that have a high concentration of nitrate, lead, chromium, and other pollutants worsened the level of stream water contamination in the study area. Generally, this development is a source of public concern, especially in our study area where surface water bodies account for a high proportion of people's water needs. Although some of the parameters tested returned mean values, which were below the WHO [2011] limits for consumption, industrial effluents impact on stream water quality negatively in the study area. Thus, it is still a severe problem that needs to be addressed because of the importance of the streams as a primary source of drinking water to so many households in the area. It is hoped that this research will aid appropriate state authorities in designing mitigation measures to ensure that the quality of the water in the streams of the study area is protected from the adverse effects of effluents from industries. The paper contributes to knowledge by adding to available literature on source water protection which is beneficial to future research and on management strategies of liquid effluents discharged from industries in urban areas of a developing country like Nigeria.

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Wpływ zrzucanych ścieków przemysłowych na parametry wód powierzchniowych na obszarze miejskim Onitsha w południowowschodniej Nigerii

STRESZCZENIE

Przemysł chemiczny na obszarze miejskim Onitsha w południowowschodniej Nigerii odprowadza duże ilości ścieków do strumieni. Strumienie te są podstawowym źródłem wody dla ubogich gospodarstw domowych. W pracy analizowano wpływ ścieków przemysłowych na fizyczne, chemiczne i mikrobiologiczne właściwości wody w strumieniach. Cel ten osiągnięto, pobierając próby wody do analiz z 8 odpływów, z 22 punktów kontrolnych i miejsc zrzutu. Wyniki charakteryzują odpływy i ich wpływ na wody odbiornika ścieków. Zrzuty ścieków powodowały znaczne zanieczyszczenie strumieni, ponieważ większość parametrów (pH, zawiesiny, mętność, BZT, ChZT, Mg, NO_3, Fe, Cu, Pb, Cr, suma bakterii heterotroficznych, bakterie grupy coli) przekraczała normy jakości wody pitnej ustalone przez WHO w 2011 r. Jedynie stężenie rozpuszczonego tlenu, Na, Zn, Ca i Na spełniały te normy. Obecność *E. coli* stwierdzano we wszystkich próbkach, duże były także wartości stężenia bakterii grupy coli. Zaleca się, aby zakłady przemysłowe poddawały ścieki oczyszczaniu przed ich zrzutem do strumieni.

Słowa kluczowe: *jakość wody, ścieki przemysłowe, zanieczyszczenie strumieni, źródła wody pitnej*