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Health implications of stream water contamination by industrial effluents in the Onitsha urban area of Southeastern Nigeria

Uchenna P. OKAFOR[1] ✉, Michael C. OBETA[1], Romanus U. AYADIUNO[1], Anthony C. ONYEKWELU[1], Godson C. ASUOHA[1], Eberechukwu J. EZE[1], Chetachi E. ORJI-OKAFOR[2], Emeka E. IGBOELI[1]

[1] University of Nigeria, Faculty of the Social Sciences, Department of Geography, Nsukka Road, 410001, Nsukka, Nigeria
[2] University of Nigeria, Nursing Services Division, Teaching Hospital, Ituku-Ozalla, Enugu State, Nigeria

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Abstract

Nigeria has abundant surface and ground water resources many of which are polluted and can be detrimental to human health when consumed. This study investigated the effects of effluents discharged by industries into streams on the health of people who depend on stream water for domestic purposes in the Onitsha urban area of eastern Nigeria. Water samples collected from eleven discharge locations underwent physico-chemical and microbiological analyses. Data on the effects of industrial effluents on health were obtained from records in the public hospitals located in Onitsha as well as through questionnaire surveys and field observations. The results of the analyses revealed that the effluents grossly degrade surface water bodies; several parameters (temperature, iron, dissolved oxygen, turbidity, biological oxygen demand, chemical oxygen demand, lead, magnesium, total heterotrophic counts, total coliform group, pH) had values which were higher than the WHO (2011) safety limits for drinking water. The contamination of investigated streams by effluents had negative impact on the health of stream users. The discussion included health effects of polluted water and the prevalence of water borne or related diseases in the area. Implications of these findings were also discussed. Management measures capable of minimizing contamination of surface water in the study area were suggested.

Key words: *contamination, health implication, industrial effluents, Onitsha urban, stream water*

INTRODUCTION

Contamination of surface water sources is a major environmental issue that attracts a lot of interest in Nigeria because of the importance of water quality for human health [OBETA, AJAERO 2010]. ABAJE *et al.* [2009] quoted in OBETA [2019] state that Nigeria has abundant surface and ground water resources, many of which are polluted and can be detrimental to human health when consumed. Manufacturing industries have long been associated with the discharge of industrial wastes directly into the environment [UCHEGBU 2002]. BOUSSAHA and LAIFA [2017] state that industrial wastes constitute growing problems for water quality and pose a severe danger to the recipient environments. ATTOUI *et al.* [2016] highlight that "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". KANU and ACHI [2011] observe that "industrial effluents are characterized by their abnormal turbidity, conductivity, chemical oxygen demand (COD), total suspended solids (TSS), biological oxygen demand (BOD), and total hardness. These chemical parameters influenced by effluents when discharged into surface water bodies affect the water quality as well as the microbial and aquatic flora which has an impact on the health of the general public when such polluted water is consumed without proper treatment.

In Nigeria, industrial effluents are generated from industries as a result of various production processes [UCHEGBU 2002]. Most of the industries dump their waste products directly into surface water sources which include lakes, streams, and into the sea. Pollutants originating from untreated effluents are major contributors to the deterioration of water quality in Nigeria. This improper handling of industrial wastes pollutes water used for domestic and drinking purposes and thereby causes much concern to human health. PHIRI *et al*. [2005] notes that wastes reduce the potential use of surface water, because wastes disturb the balance of the ecosystem inside water bodies. This results in the death of animal and plant species present in water [LONGE, BALOGUN 2010]. Liquid wastes make surface water not only unsuitable for various uses but also more difficult and expensive to treat to reach its acceptable quality.

In Onitsha, all the chemical industries studied discharge their liquid effluents directly into streams and lakes. Many of these liquid effluents include dye, mercury, cadmium, silver nitrate, chromium, lead and sulphur compounds which pollute water in streams. Physical and chemical water properties in water bodies are not monitored periodically; liquid wastes dumped into the streams are not monitored as well [EKIYE, ZEJIAO 2010]. This results in major uncertainty about changes in the quality of recipient streams, as well as on how to respond to water deterioration as a result of the frequent discharges of effluents.

This study therefore, focuses on health implications of industrial effluents discharged and the quality of recipient streams as well as on stream environments. Such information is almost non-existent at present in the study area. Many residents of communities in the Onitsha urban area use stream water for domestic, industrial and agricultural purposes without treatment or checking its quality status. The drainage pattern and topography make the available streams in the urban area vulnerable to pollution from industrial effluent discharges; still, many urban residents depend on the streams for domestic and related purposes (Photo 1).

Photo 1. Processing of bitter leaves in the Nkisi River (phot. *U. Okafor*)

In our study area, planners and urban managers lack reliable information on how industrial production and pollutants pose danger to surface water resources or public health. Considering the above, the research is very timely due to the unique relevance of water to life and health.

STUDY AREA

The study area (Onitsha urban area) is located in the Anambra State, southeastern Nigeria, between latitudes 06°04’07” and 06°11’51"N and between longitudes 06°43’11” and 06°52’53”E (Fig. 1). The urban area occupies about 51 km^2 [OBETA *et al*. 2019]. It can be accessed through the east west national main road from Lagos through the Benin City which links the eastern-north-south route via the Niger Bridge at Onitsha [MOZIE, AYADIUNO 2008]. The climate is tropical with high temperatures and high humidity, as well as distinct wet and dry seasons; annual rainfall is 1500–2000 mm [OFOMATA 2002]. The seasonal variation of rainfall combined with the phenomenal growth of the population creates two important water use scenarios. Firstly, direct collection and use of rain water is more pronounced in the rainy season. Secondly, extraction of water from springs and streams is more common during the dry season [ABAJE *et al*. 2009].

The main geologic units of the area are recent deposits of the Holocene (Quaternary) occupying active floodplains of Niger and Anambra rivers and sandstone formations of the Upper-Middle Eocene (Tertiary) occupying sandstones plains above and adjacent to the Niger-Anambra floodplains [MOZIE, AYADIUNO 2008]. The urban area is drained by numerous rivers, principally by River Niger and its tributaries, notably Idemili and Nkisi Rivers. All drain into the River Niger within the Onitsha urban area territory. The study area belongs to the rainforest-savanna ecotone. Although the urban area has abundant natural water resources, limited availability of potable water has been a problem for residents of the urban area. Approximately 68% of the urban population work in commerce and industrial sectors [BAGUMA *et al.* 2013]. Slum areas within the urban center exhibit great poverty, decayed infrastructure, poor health conditions and low access to social facilities as a result of deficiencies in urban planning and enforcement of regulatory laws. The water demand from the population in the Onitsha urban area has increased due to the growing population and consumption rates. According to 2006 population census, the population of Onitsha urban area is 974,541 [NPC 2006].

The city is split up into two local government areas, namely Onitsha North and Onitsha South, 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 sub-equatorial and INYANG [1975] classified as 8-month rainy season climate. Principal geologic units of the area are the recent deposits of the Holocene (Quaternary) occupying active floodplains of Niger and Anambra Rivers and sandstone formations of the Upper-Middle Eocene (Tertiary) occupying sandstones plains above and adjacent to the Niger-Anambra floodplains.

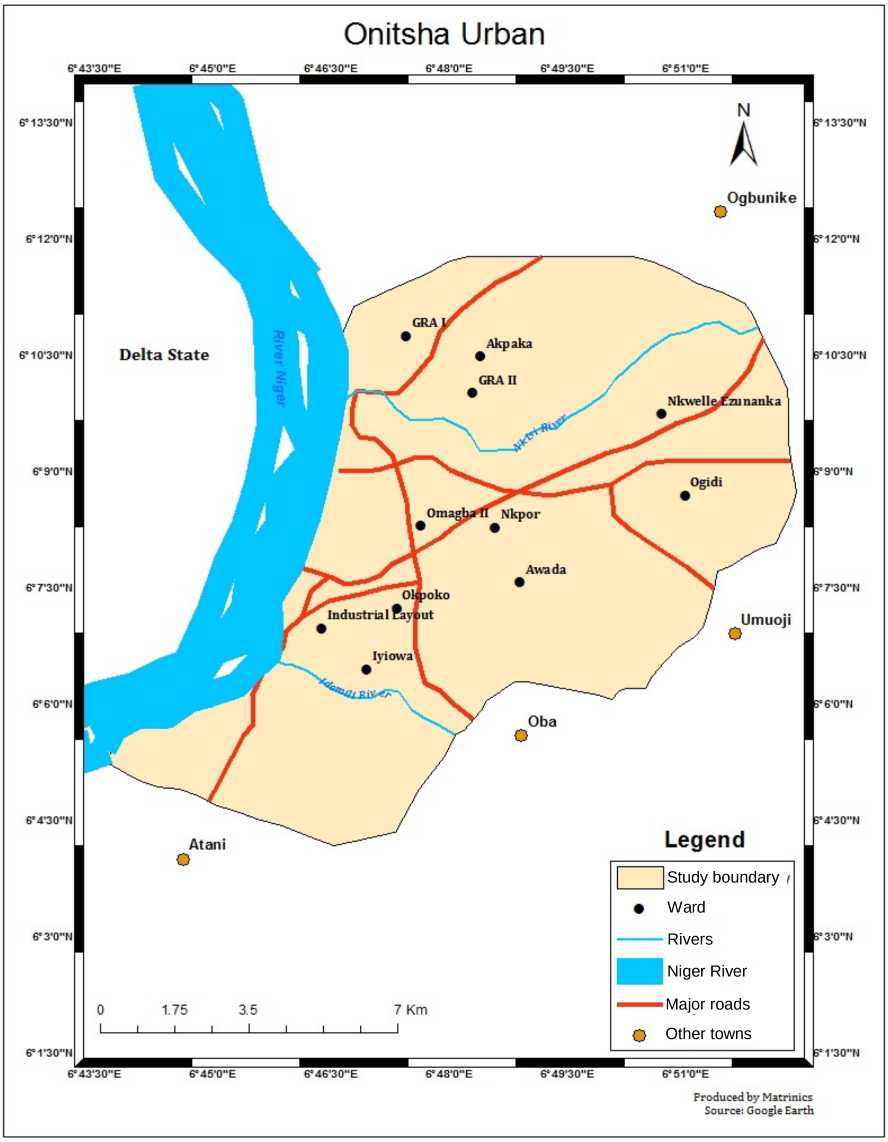

Fig. 1. Onitsha urban area; source: GIS unit, Geography Department, University of Nigeria, Nsukka

MATERIALS AND METHODS

Forty-seven (47) chemical industrial plants currently discharge their effluents into surface water bodies in the Onitsha urban area. These industries were classified into eight groups according to their production processes (Tab. 1). One industrial plant, representing a category of the production process was chosen from each of the eight (8) groups for the study. Thus, eight industries were sampled for the study. Also, water samples were collected for reference from three water bodies before the discharge point. This was done with the assistance of a laboratory technician at designated points.

Samples were collected within discharge environments and were denoted with numbers as stations 1, 2, 3 to 11 – see Figure 2 and Table 1. Samples were collected into 60 cm^3 saline water-cleaned white plastic bottles with well fitted covers in August–October, 2018. August and October were chosen because they are in the middle of the rainy season and the period of high effluent discharges in the study area due to availability of water for production purposes. Two samples (one for physico-chemical and the other for microbiological analyses) were collected at each location according to standard procedures for water quality analysis recommended by the American Public Health Association [APHA 1998]. In total twenty two water samples were collected for the study. The bottles containing samples were well secured and labelled by stating the source, date and time of collection. Collected samples were placed in insulated containers and transported to the Physical Chemistry Laboratory of the Department of Chemistry and the Microbial Physiology Laboratory of the Department of Microbiology at the University of Nigeria, Nsukka. These laboratories were chosen due to the availability of equipment and relevant expertise. Temperatures were measured directly through the use of glass thermometer and pH was also measured by the use of the pH meter. Concentration levels of parameters examined were first compared with the WHO Drinking Water Standard [WHO 2011] to determine water quality. The criteria for selection included availability for research, distance to waste discharge chutes, and the time of discharge. Eighteen water quality

Table 1. Description of surface water sampling stations

Station No.	Name of station	Sampling location	GPS location	Brief description on sampling station
1	NRS1 (control)	Harbour Industrial Layout, Atani	06°10’48”N 06°46’17”E	sampling point for water sample of Niger upstream (control), about 500 m after the Nkisi River enters the Niger River at Onitsha urban
2	IRS1 (control)	Obosi	06°05’59”N 06°47’33”E	point where water for domestic uses is collected by the Obosi community; it is not for drinking purposes but it is used for other domestic chores; about 500 m before the Obosi abattoir
3	NKRS1 (control)	Ogidi	06°10’29”N 06°50’34”E	about 500 m before the discharge of waste water from Kings Pharm. Ltd. Nkisi water is being fetched here for domestic uses as well
4	NRS2 (Krisoral)	Harbour Industrial Layout, Atani	06°07’37”N 06°45’26”E	about 3500 m after NRS1 and within the study area; receiving point of effluent discharges from Krisoral Industries Ltd.
5	NRS3 (Tonuch)	Awada Obosi	06°07’46”N 06°45’31”E	about 1.5 km after NRS1 and within the study area. Receiving point of effluent discharges from Tonuch Industries Ltd.
6	IRS2 (Citizen)	Obosi	06°06’14”N 06°47’11”E	point of effluent from Citizen paints into the Idemili River; about 1 km before the Obosi abattoir
7	IRS3 (Peter Ventures)	Obosi	06°06’05”N 06°46’59”E	about 500 m after the discharge of waste water from Peter ventures industries empties its waste water; within Awada Obosi
8	NKRS2 (Kings Pharm)	Ogidi	06°09’59”N 06°50’08”E	about 500 m before the control water from the Nkisi River
9	NKRS3 (Ginpat)	Onitsha	06°09’24”N 06°48’57”E	within the 500 m from the emptying of the waste water by Kings Pharm
10	NKRS4 (Zubix)	Onitsha	06°09’47”N 06°49’34”E	sampling point of immediately water entering to the Nkisi River
11	NKRS5 (New York)	Onitsha	06°09’23”N 06°48’31”E	place of water polluting waste dumps with high levels of water pollution entering into Nkisi River

Source: own elaboration.

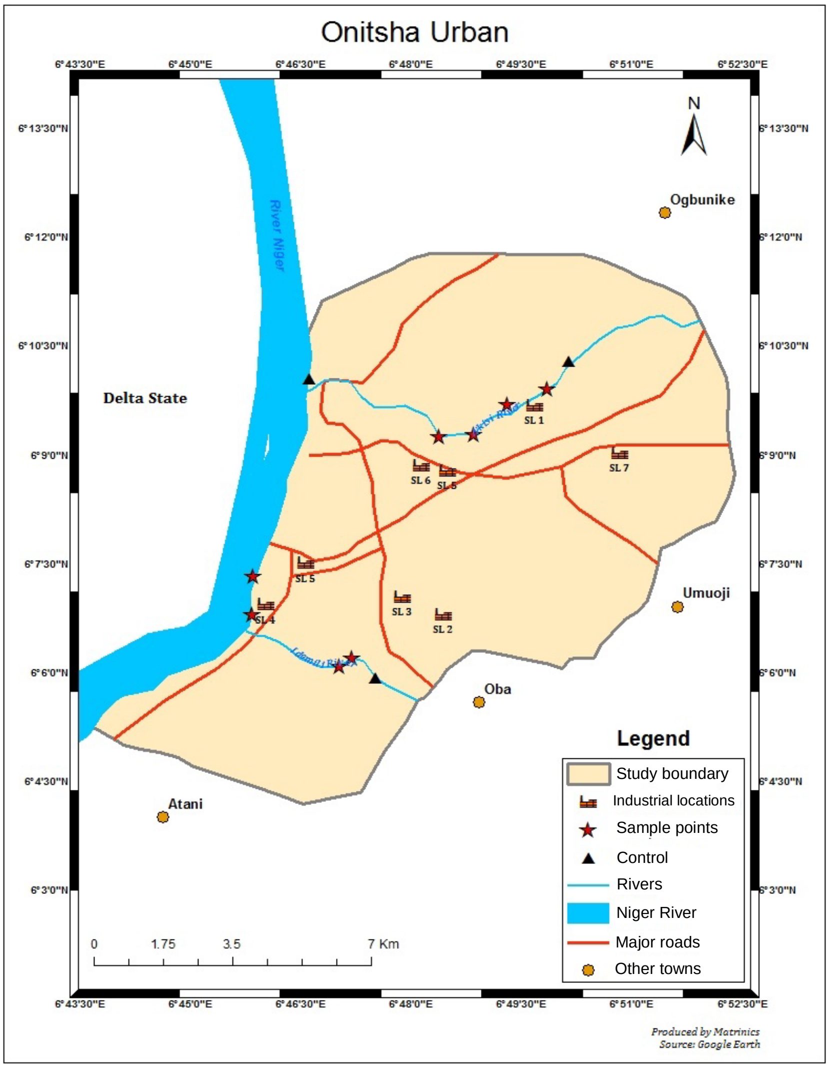

Fig. 2. Sample points for all water samples collected in the study area; source: own elaboration

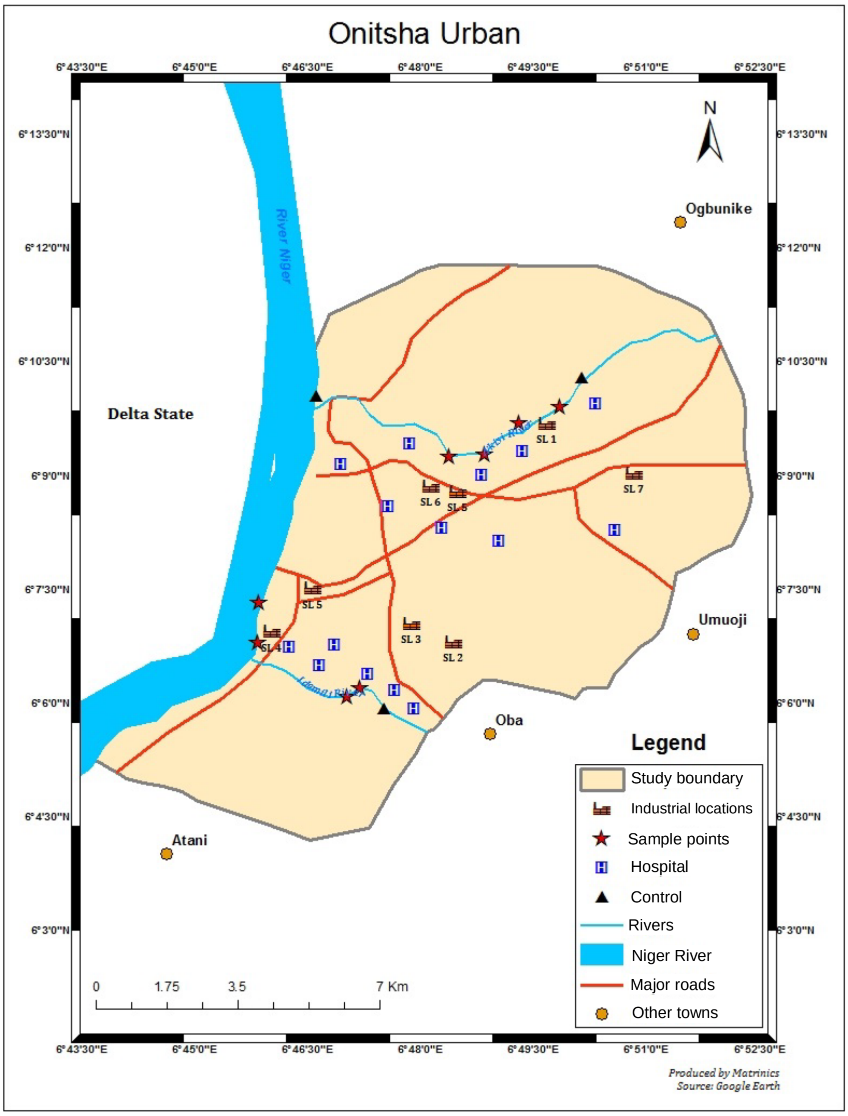

Fig. 3. Selected hospitals in the study area; source: own elaboration

parameters were investigated, 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). Descriptive and inferential statistical techniques were also used to interpret the results.

SOURCE OF INFORMATION ON THE EFFECTS OF CONTAMINATED WATER ON THE HEALTH OF WATER USERS

This study was carried out among community members living by the side of three rivers in the study area to explore common health problems attributable to industrial effluents. Information on effects of water pollution on the health of water users in the area were accessed based on hospital records. In order to gain access to hospital records, the researchers obtained permission from two hospital authorities, namely medical directors of private hospitals in the Onitsha urban area and the Head of Medical Records Department in the General Hospital Onitsha. To facilitate data collection, the researchers also secured and utilized the assistance of General Out Patient Department Nurses (nurses working at the GOPD unit) and desk officers working at the Medical Records Department of the GOPD section to trace patients' case notes for a period of three months (August–October 2018). A total number of five thousand five hundred and thirty-six (5536) patients' case notes from twenty (20) selected hospitals in the study area were examined to elicit information needed (Fig. 3). The data collection lasted for twenty-one (21) working days.

RESULTS AND DISCUSSION

PHYSICO-CHEMICAL AND MICROBIOLOGICAL CHARACTERISTICS OF WATER SAMPLES AT CONTROL LOCATIONS

A summary of stream waters quality status (i.e. physico-chemical and microbiological parameters) are presented in Table 2.

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

Parameters	Measurement unit	Control site on the Niger River	Control site on the Idemili River	Control site on the Nkisi River	Mean	WHO standard [WHO 2011]
Temperature	°C	24	**28**	**26**	26.00	25
pH	–	7.2	6.5	7.10	6.90	6.5–8.0
Turbidity	NTU	**100**	**300**	**300**	233.00	5.0
DO	$mg \cdot dm^{-3}$	**136**	**93**	**96**	108.00	6.0
Dissolve solid	$mg \cdot dm^{-3}$	176	330.2	318.10	274.70	500
COD	$mg \cdot dm^{-3}$	4.00	3.60	5.90	4.50	10
BOD	$mg \cdot dm^{-3}$	2.08	5.2	7.2	4.80	10
Nitrate	$mg \cdot dm^{-3}$	0.10	0.28	0.12	0.1667	50
Iron	$mg \cdot dm^{-3}$	0.02	**1.41**	**1.42**	0.9500	0.3
Zinc	$mg \cdot dm^{-3}$	0.03	0.06	0.07	0.0533	3
Copper	$mg \cdot dm^{-3}$	0.10	0.22	0.10	0.1400	1
Magnesium	$mg \cdot dm^{-3}$	**1.03**	0.07	0.12	0.4067	0.2
Calcium	$mg \cdot dm^{-3}$	2.29	7.1	2.8	4.10	75
Sodium	$mg \cdot dm^{-3}$	1.17	0.04	0.98	0.73	200
Chromium	$mg \cdot dm^{-3}$	0.008	0.0025	0.0019	0.0041	0.003
Lead	$mg \cdot dm^{-3}$	**0.048**	0.0041	0.002	0.0303	0.01
THC	$Cfu \cdot (100cm^3)^{-1}$	**28**	**42**	**37**	35.70	10
TCG	$Cfu \cdot (100cm^3)^{-1}$	**20**	**31**	**19**	26.70	0

Explanations: bolded values exceed WHO standards, DO = dissolved oxygen, COD = chemical oxygen demand, BOD = biological oxygen demand, THC = total heterotrophic count, TGC = total coliform group.
Source: own study.

As shown in Table 2, temperature at two control sites was higher than the WHO standard of 25°C; concentration levels of turbidity, DO, TCG, THC, and DO, were higher than the maximum permissible level set by WHO 2011 at all the control sites; iron (Fe) concentration was higher than WHO 2011 in both Nkisi and Idemili control sites, while the lead (Pb) concentration level was higher than the WHO 2011 standards in the River Niger control site. Values of other parameters were within limits for safe drinking water when compared with the WHO 2011 standards. Thus, the higher concentration levels for turbidity, DO, TCG and THC above the WHO 2011 permissible limits in the three sampling sites show that the streams were already polluted even before the contact with industrial effluents.

PHYSICO-CHEMICAL AND MICROBIOLOGICAL CHARACTERISTICS OF WATER SAMPLES AT DISCHARGE LOCATIONS

Table 3 presents summary information on the quality status of the recipient stream waters at the eight locations where industries discharge their effluents. Results derived were used to determine the impact of effluents on water quality in the streams.

Table 3. Physico-chemical and microbiological characteristics of water samples at discharge locations in the study area[1)]

Parameter	Unit	Value in the study location									WHO standard [WHO 2011]
		Krisoral	Tonuch Ltd	Citizen Paints	Peter Venture	Zubix biscuits	Ginpat Alum	New York Photos	Kings Pharm	mean	
		at Niger River		at Idemili River		at Nkisi River					
Temperature	°C	**26***	**28***	**29***	**30***	**30***	**28***	**30***	**29***	28.80	25
pH		8.2	7.5	6.80	6.5	7	6.9	6.7	7.2	7.10	6.5–8.0
Turbidity	NTU	100	100	300	300	300	300	400	300	263.00	500
DO	$mg \cdot dm^{-3}$	**130***	**143.6***	**78.34***	**82.16***	**90.18***	**35***	**62.85***	**89.42***	89.00	6.0
Dissolve solid	$mg \cdot dm^{-3}$	176.8	126.10	331.40	303	326.27	318.80	435.12	312.27	291.00	500
COD	$mg \cdot dm^{-3}$	3.97	2.08	4.19	3.6	53.9*	5.90	**18.9***	**39.9***	16.60	10
BOD	$mg \cdot dm^{-3}$	3.12	**41.9***	5.9	**13.17***	**14.6***	4.7	**21.9***	2.06	13.40	10
Nitrate	$mg \cdot dm^{-3}$	0.17	0.15	0.12	0.54	1.28	0.23	0.68	0.52	0.46	50
Iron	$mg \cdot dm^{-3}$	0.14	1.84	0.04	0.02	**0.56***	**0.40***	**0.52***	**0.76***	0.54	0.3
Zinc	$mg \cdot dm^{-3}$	0.01	0.18	0.1	0.26	0.04	0.26	0.16	0.70	0.21	3
Copper	$mg \cdot dm^{-3}$	0.30	0.02	0.10	**1.68***	0.68	0.20	0.40	0.66	0.51	1
Magnesium	$mg \cdot dm^{-3}$	**0.86***	**3.09***	0.12	0.43	**2.46***	**0.33***	**0.28***	0.18	0.97	0.2
Calcium	$mg \cdot dm^{-3}$	2.68	8.24	5.2	4.92	6.12	5.48	3.04	0.60	4.50	75
Sodium	$mg \cdot dm^{-3}$	2.02	6.29	0.98	0.14	2.69	2.08	2.68	2.41	2.40	200
Chromium	$mg \cdot dm^{-3}$	**0.018***	**0.032***	**0.014***	**0.018***	nd	**0.0162***	**0.04***	**0.022***	0.0203	0.003
Lead	$mg \cdot dm^{-3}$	**0.04***	**0.082***	**0.028***	**0.033***	nd	**0.028***	**0.076***	**0.074***	0.05	0.01
THC	$Cfu \cdot (100\ cm^3)^{-1}$	**30***	**62***	**68***	**53***	**26***	**61***	**76***	**43***	52.00	10
TCG	$Cfu \cdot (100\ cm^3)^{-1}$	**23***	**38***	**46***	**42***	**32***	**46***	**73***	**30***	41.00	0

[1)] The values in the Table are for waste samples collected from rivers where industries discharge their wastewater in the study area.
Explanations: * = parameters that exceeded WHO standards, nd = non detectable values, other as in Tab. 2.
Source: own study.

As shown in Table 3, temperature at all sampling locations was higher than the WHO 2011 standards of 25°C; the same applies to five other parameters (lead, chromium, THC, TCG, and DO). The values of iron, COD, BOD, copper and magnesium content exceeded the WHO 2011 maximum permissible limits for drinking water supplies at one or more sampling locations. Only seven parameters (nitrate, zinc, calcium, sodium, pH, turbidity, dissolved solids) had values lower than the WHO 2011 standards for drinking water supplies at all the discharge locations. The high values of THC and TCG at all the sampling locations at discharge points indicate high pollution by human or animal wastes. These show that effluents discharged from various industries into surface water bodies were all polluted.

VARIATIONS BETWEEN MEAN VALUES OF THE STREAM WATER QUALITY OBTAINED AT CONTROL AND DISCHARGE LOCATIONS

Mean values obtained at control and discharge locations for pollutants and variations between them are summarized in Table 4.

The data summarized in Table 4 show the extent to which discharged effluents impact water quality in the streams investigated. Apart from pH, dissolved oxygen (DO), lead (Pb), and iron (Fe), the mean values for all the parameters investigated (dissolved solid, COD, BOD, nitrate, zinc, copper (Cu), magnesium (Mg), calcium (Ca), sodium (Na), chromium (Cr), lead (Pb), THC and TGC) were higher at discharge locations than control sites. This shows that the stream water gets more polluted at the discharge locations as a result of contact with discharged industrial effluents.

IMPLICATION OF INDUSTRIAL WATER POLLUTION FOR HUMAN HEALTH

Lower water quality might be a potential threat in case such drinking water is consumed. The WHO guidelines for drinking water stipulate specific acceptable and safety limits for drinking water. Deviations from these limits usually have health implications due to either elevated or reduced levels and the nature of these parameters. There is a linkage between pollution and health issues. Disease causing microorganisms are known as pathogens and these pathogens spread the disease among humans. Health risk associated with polluted water includes different diseases such as respiratory disorders, cancer, diarrheal disease, neurological disorder and cardiovascular disease [BOTKIN, KELLY 1998]. Health implications caused by some of the parameters when they exceed their allowable limits recommended by the WHO are discussed below:

Health implications of elevated dissolved oxygen in drinking water. Dissolved oxygen is the oxygen present in water available to aquatic organisms. Organisms absorb oxygen through structures such as gills or their skin. The abundance of aquatic species is strongly associated with a DO concentration. A poor DO concentration can eliminate more sensitive species from an ecosystem, causing a decline in species diversity [KIBRIA 2004]. Waters with higher dissolved oxygen have ecosystems that are generally more diverse and stable. DO levels are often used to indicate the quality of freshwater, health of streams and rivers, and the intensity of aquatic pollution [KIBRIA 2004]. Oxygen depletion can occur due to discharges from food processing plants, sewage plants, abattoir wastes, and wastewater from paper mills. These pollutants feed bacteria which decompose organic matter using dissolved oxygen.

Table 4. Mean values of water quality parameters at control and discharge locations

Parameter	Measurement unit	Mean value at control sites	Mean values at discharge locations	Variation	Desirable limit acc. to WHO standard [WHO 2011] ($mg \cdot dm^{-3}$)	No. of locations where returned values exceeded WHO limits [WHO 2011]	Highest value
Temperature	°C	26.0	28.75	–2.75	25	11	30
Turbidity	NTU	233.3	262.50	–29.17	500	0	400
pH	–	6.9	7.10	0.17	6.5–8.0	1	8.2
DO	$mg \cdot dm^{-3}$	108.0	88.94	19.39	6.0	11	143.6
Dissolved solid	$mg \cdot dm^{-3}$	274.8	291.22	–16.45	500	0	435.12
COD	$mg \cdot dm^{-3}$	4.50	16.56	–12.10	10	2	39.9
BOD	$mg \cdot dm^{-3}$	4.80	13.42	–8.59	10	4	41.9
Nitrate	$mg \cdot dm^{-3}$	0.17	0.46	–0.30	50	0	1.28
Iron	$mg \cdot dm^{-3}$	0.95	0.54	0.42	0.3	6	1.42
Zinc	$mg \cdot dm^{-3}$	0.05	0.21	–0.16	3	0	0.70
Copper	$mg \cdot dm^{-3}$	0.1400	0.51	–0.37	1	1	7.1
Magnesium	$mg \cdot dm^{-3}$	0.4067	0.97	–0.56	0.2	6	2.46
Calcium	$mg \cdot dm^{-3}$	4.0633	4.54	–0.47	75	0	7.1
Sodium	$mg \cdot dm^{-3}$	0.73	2.41	–1.68	200	0	6.29
Chromium	$mg \cdot dm^{-3}$	0.0041	0.0203	–0.016	0.003	6	0.018
Lead	$mg \cdot dm^{-3}$	0.018	0.045	0.135	0.01	7	0.076
THC	$Cfu \cdot (100\ cm^3)^{-1}$	35.67	52.38	–16.71	10	11	76
TGC	$Cfu \cdot (100\ cm^3)^{-1}$	26.67	41.00	–14.33	0	11	73

Explanations as in Tab. 2.
Source: own study.

Thus, they reduce the DO level in the surface water environment [USEPA 2017]. Values of dissolved oxygen (DO) obtained from the study were generally low and were below the limit set by WHO [2011] standards.

Health implications of elevated drinking water turbidity. Elevated turbidity levels are often associated with higher levels of disease-causing microorganisms, such as viruses, fungi, parasites and bacteria. These organisms can cause diseases such as nausea, cramps, diarrhea and associated headaches [BROOKS *et al*. 1998].

Elevated turbidity levels were recorded at three sampling stations out of 100 for the Niger River (control), 300 for the Idemili River (control) and 300 for the Nkisi River (control). Also, the turbidity recorded at discharge points ranges from 100 to 400.

Health implications of elevated lead (Pb) in drinking water. Lead is one of the most abundant heavy metals and its toxic properties cause environmental and health problems because of its stability at a contaminated site and complexity of biological toxicity mechanism. It is particularly dangerous for children leading to mental retardation when present at an abnormal concentration in body fluids [TIWARI *et al*. 2013]. Lead in drinking water can cause a variety of adverse health effects. Lead is unlikely to be present in source water unless a specific source of contamination exists. However, lead has long been used in plumbing materials and solder that are in contact with drinking water as it is transported from its source into homes [TIWARI *et al*. 2013].

RIS *et al*. [2004], quoted in CDC [2012] also reported dangerous health effects due to the exposure to lead among children and adults, including early childhood exposure impact on neurodevelopment which persist into the second decade of life. Also, KLAASSEN (ed.) [2008] reports that "adults with occupational exposure to lead report more colds and influenza and exhibit suppressed secretory immunoglobulin A (Ig A) levels, demonstrating lead-induced suppression of humoral immunity". Adults with occupational exposure also might suffer neurotoxic effects, including peripheral neuropathy.

In infants and children, exposure to lead in drinking water above the accepted level can result in delays in physical and mental development, along with deficits in attention span and learning ability. In adults, kidney problems or high blood pressure can be caused if water with high levels of lead is ingested over a long period of time. It also disturbs the endocrine system, causes anemia, whereas a long term exposure may cause death [WHO 2011]. More than 400 $mg \cdot dm^{-3}$ of lead (Pb) in human body can cause brain damage, vomiting, loss of appetite, convulsions, helplessly amazed state, and coma. It can also lead to a high rate of miscarriages, affect skin, and respiratory system disorders [WHO 2011].

Health implications of elevated total coliform groups in drinking water. Coliform groups include *Escherichia coli*, *Shigella species*, *Salmonella typhi*, *Proteus spp.* etc. However, those associated with water are *E. coli* and *Salmonella typhi.* The coliforms are the most common group of Gram-negative rods cultured in clinical laboratories and some of the most common bacteria that cause diseases, along with Staphylococcus and Streptococci [BROOKS *et al*. 1998]. *E. coli* that causes diarrhea is extremely common worldwide. *E. coli* also causes diarrhea in infants in developing countries. The type of *E. coli* that causes diarrhea in infants is called Entero Pathogenic *E. coli* (EPEC). The result of the EPEC infection is watery diarrhea, which is usually temporary but can be chronic [BROOKS *et al*. 1998]. Salmonella is often pathogenic for humans or animals when ingested. It can be found in contaminated water and it is transmitted from animals and animal products to humans, where they cause enteritis, systemic infection and enteric fever [BROOKS *et al*. 1998]. In summary, the presence of *E. coli* is an indicator to monitor possible other more harmful microbes, such as *Crypto sporidium*, *Giardia*, *Shigella*, and *Norovirus. E. coli* in drinking water can cause four types of clinical syndromes: urinary tract infection, diarrhea or gastroenteritis, pyogenic infections and septicemia [SON 2007]. Hence, it becomes necessary to ensure that drinking water is free from bacteriological contamination.

PREVALENCE OF WATER-BORNE/ RELATED DISEASES IN THE STUDY AREA

A total of 5536 case notes of patients with water-borne diseases were accessed. Table 5 provides summary information on the occurrence of water-related diseases in the study area.

Table 5. Occurrence of pollution-related diseases in the study area

Station No.	Respondents reported diseases	Perception on frequency of occurrence	Category of people mostly affected
1	hepatitis, muscle cramp, abdominal pain, seizures, shock, liver damage, convulsions, cholera, coma	not common	all ages
2	typhoid fever, diarrhea, and nausea	common	all ages
3	eye, ear, nose, mouth, anus irritation	common	children and adults
4	high blood pressure, coronary heart disease	not common	mostly adults
5	dysentery (bacillary and amoebic), intestinal infections, catarrh and malaria	very common	children and adults
6	urinary tract, respiratory tract and kidney infection	not common	adults
7	disturbances in infants and health challenges in pregnant women	very common	all ages
8	parkinsonism, cognitive dysfunction, and ataxia	rare	adults

Source: own study.

Responses to the questionnaire survey in the study area suggest that people mostly at risk of having contact with water borne diseases are poor and uneducated individuals who do not have adequate knowledge of diseases associated with untreated water. Field observations confirmed that the uncontrolled discharge of wastewater by industries to the environment and the general unsanitary environment in the study area promote the spread of mosquitoes which cause malaria [CARABALLO, KING 2014]. The number of patients treated in the selected hospitals during a three-months period (August–October, 2018) in the study area are shown in Table 6.

Table 6. Number of patients treated in the sampled hospitals for three-month period (August–October, 2018) [1)]

Station No.	Disease	No. of patients treated	Percentage of patients treated	Remarks
1	cholera	5	0.1	very low
2	hepatitis	220	4.0	very low
3	diarrhea	418	8.0	low
4	typhoid fever	880	15.9	high
5	dysentery	484	9.0	low
6	urinary tract infection	412	7.0	low
7	malaria	2627	47.0	very high
8	URTI	490	9.0	low
Total		5536	100	–

[1)] All health cases that occurred less than three times within the study period were omitted.
Source: own study.

All pollutants which concentration in the analysed water samples exceeded the WHO maximum permissible limits [WHO 2011] at several sample locations (Tabs 3, 4) have severe health implications when consumed without treatment. Many of elements (iron, zinc, calcium and magnesium) are widespread in nature and perform useful functions in the body when present or absorbed at the right quantities. However, when taken in excess, they are generally toxic and harmful to human and aquatic life. For instance, chromium and lead are not only hazardous but carcinogenic when taken in a quantity above stipulated standards.

As shown in Table 3, the streams are polluted at many locations. Critical parameters at some of the sample stations include lead, chromium, magnesium, temperature, total dissolved solids, turbidity, dissolved oxygen, THC (total heterotrophic count) and TCG (total coliform group). Their elevated values may probably be due to the use of chromium salts for the production of goods by industries that discharge their wastes into the water bodies. Some of these parameters, such as chromium and lead, are metals which have the ability to accumulate along the food chain. They are not only very hazardous but also carcinogenic. Relatively elevated levels of lead (Pb) in the samples could indicate other sources than effluents from industries. Column 7 of Table 4 summarizes information on the number of stations where these critical parameters exceeded the WHO maximum permissible limits [WHO 2011] for drinking water. Many of the analysed water samples had odour, brownish particles and mean turbidity values which exceeded the WHO limits [WHO 2011]. The presence of coliform bacteria indicates that these effluents have been contaminated with faecal materials of man or animals. These pathogens can cause diseases, such as typhoid, gastroenteritis, hepatitis etc. [Brooks et al. 1998]. The contamination is an indicator of a health risk for individuals who consume the contaminated stream water. Temperature and DO exceeded the WHO 2011 limits at all the sample stations, while lead, chromium, iron, magnesium, COD and pH exceeded the limits in sample stations 1 and 7.

The study has demonstrated pollution of surface water sources by industrial effluents in the study area. Leachate and other toxic pollutants from discharged effluents migrate into the sampled surface waters and pollute them. The release and migration of these pollutants from effluents discharged into streams pose a high risk to surface water users. The danger associated with industrial effluents is that they may contain highly toxic substances, which may cause poisoning, cancer, and heart, liver, and kidney diseases, and other teratogenic abnormalities or lead to ingestion of dangerous pathogens. Tables 5 and 6 provide summary information on some of the health implications, disease prevalence and common health challenges faced by urban residents at the time of the research. As these tables show, many water-borne or related diseases occur in the area.

CONCLUSIONS

Safe drinking water is a basic need for all human beings. Stream water contamination is highly detrimental to the health of people, since the majority of the poor in developing countries depend on stream water for both domestic and drinking purposes. This is a source of public health concern especially in our study area where surface water bodies correspond to a high proportion of people's water needs. In this study, industrial effluents consisting of toxic substances that have high concentration of nitrate, lead, chromium, phosphorus, bacterial and other pollutants contaminate stream waters. It is recommended to develop a proper industrial effluents disposal system and the effluents should be treated before they are discharged into surface water bodies. Based on the findings, we conclude that the study area lacks proper industrial effluents management. Thus, the research posits that, among other things, the quality urban governance is indispensable for industrial effluent management as it will help to monitor and control indiscriminate and improper effluent discharges into surface water bodies, discharges which cause severe public health problems.

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