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QUALITY CHARACTERISTICS OF EFFLUENTS FROM THE ASABA TEXTILE MILLS AND THE RECEIVING WATERS OF RIVER NIGER, NIGERIA

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ABSTRACT

Textile mill effluent are known to contain high quantities of organic and oxygen demanding pollutants. Effluent samples from Asaba Textile mill and water samples from River Niger were collected and analyzed for selected heavy metals (by flame atomic absorption spectroscopy) and physicochemical parameters of water. Important results obtained for parameters in water are: pH (7.00±0.10), Turbidity (54.4±9.3 NTU), Elect. Conductivity (41.9±3.9 μscm^{-1}), TS (1190±530 mg/L), TSS (180±21 mg/L), TDS (1010±520 mg/L), BOD_5 (89±11 mg/L), COD (110±9.6 mg/L), O & G (0.02±0.02 mg/L), phenol (1.6±1.1 mg/L), NH_3-N (1.00±0.50 mg/L), sulphate (99±13 mg/L), Phosphate (2.10±0.90 mg/L), Pb (87±18 µg/L), Fe (120±33 µg/L), and Zn (20±21 µg/L). The average values of most parameters in the study area are generally higher than those for the control area. The average values of some of the parameters exceeded national and international guidelines for drinking water quality and non-drinking uses of water. The average values of some effluent parameters also exceeded values of two effluent limitation guidelines in Nigeria, effluents therefore has the ability to pollute a receiving water body.

Key words: Asaba Textile Mill; effluent samples; Physicochemical parameters; water samples; heavy metals, effluent limitation guidelines; Nigeria; flame atomic absorption spectroscopy; River Niger.

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INTRODUCTION

The pollution effect of textile industries on the environment has been a source of concern to environmentalist and environmental bodies. Pollution effect in the textile industry can be divided into micro and macro effects [1] under the micro pollutants grade are air and noise pollution. These immediately affect the employees within the factories. Macro pollution can be traced to land and water pollutants which affects the entire population within the external environment of the textile industry. This is more important because of the wide range of people affected. A textile factory can be broadly divided into a "grey" and "finishing mills". Some processes in these mills can result in the release of chemicals into the environment.

Potential source of waste water pollution from a textile factory mainly comes from the finishing mill. These consist mainly of spent liquid from the following processes: sizing, de-sizing, scouring, bleaching, mercerization, dyeing and electroplating. [2] review on industrial effluent have identified the following: sizing process releases effluents with high BOD, COD; the desizing and bleaching process releases effluent of of high

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pH; the dyeing process releases highly coloured effluents and effluents of high BOD, dissolved solids (DS), suspended solids (SS) and heavy metals. Also printing effluents are highly coloured and contain High BOD and SS and has oily appearance. The chemical compounds involved in the processes mentioned above vary from simple chemical compounds to very complex organic or organo-metallic compounds. The entry of these complex organic compounds into the environment has been a source of concern for environmental researchers and environmental protection authorities ([3]; [4]; [5]; [6]; [7]; [8]). [3] in a review of the effect of textile industry waste observed that sludge from textile dyeing and finishing operation had been designated as hazardous waste and he outlined several treatment procedures for different effluents from different operations in the textile industry.

In Nigeria studies have been carried out on industrial effluents and their receiving water bodies ([9]; [10]; [5]; [11]; [12]; [8]; [13]; [14]; [15]; [16]). The waters of the Niger River serves for domestic use for non city dwellers and these uses sometimes includes for drinking. There is a high volume of fishing in the waters of the Niger River, these include collection of lobsters and other edible shell invertebrate such as periwinkles. The collection of these edible animal resources of the river constitutes one of the major occupations of the people in this area. The river also serves for transportation. The lands adjoining the river apart from serving for building residential houses and industrial warehouses in the cities of Asaba and Onitsha, is also used for Farming purposes. The arable crops include *Dioscorea sp.* (yam), *Solanum lycoperscium* (tomatoes), *Manihot esculanta* (cassava), *Zea mays* (maize),*Annas comosus* (pineapple), sweet potatoes vegetables such as *Telfera occidentalis* (fluted pumpkin). The tree and fruit crops include *Magnifera indica* (mango), *Elaeis guineensis* (oil palm), *Cocos nucifera* (coconut) and *Carica papaya* (pawpaw). The awareness of the fact that textile effluent do have deleterious effects on the environment around where textile industries are situated have made it imperative for the environment around textile industries to be audited regularly. There is currently a dearth of information on such auditing around Asaba Textile Mill in Nigeria. Asaba Textile Mill produces 2.5% of the total textile output in Nigeria (FEPA Effluent Guideline Project, 1970). Not much is known to what extent effluents from the Asaba Textile Mill are treated. The effluents enter the River Niger after passing through an under surface conduit which is exposed to the surface in some places along the length of the conduit. The conduit passes through parts of the Asaba metropolis before heading for the River Niger.

The present study examined the effect of effluents from the Asaba Textile Mill on the quality characteristics of the receiving waters of the Niger River by determining some physicochemical parameters, and selected heavy metals in effluents from the Asaba Textile Mill and receiving waters of the River Niger around Asaba in Nigeria.

MATERIAL AND METHODS

The Asaba Textile Mill is located towards the South Eastern side of Asaba Town. The conduit runs from this point Eastwards across the major urban road (Nnebisi Road) to the River Niger, this is shown in Figure 1 (Map of the study area showing a section of the Niger river and the sampling stations). Samples were collected once each season for four seasons (i.e. two dry seasons and two rainy seasons). Total period of sampling is two years (2000 and 2001). Effluent samples were collected at three points, the first is from the North West side of the wall, this drainage is believed to carry sizing effluents and this effluent sample is designated G-sizing E. The second is the drainage at the East side of the wall and this is believed to be carrying printing effluents and this effluent sample is designated as G-Print E. The third point of collection of effluent is from the conduit carrying the combined effluents at the point at which the effluents are discharged into the River Niger. The effluent sample at this point is designated G-comb E. Samples from the receiving River Niger were collected at four points. The first is at 500 metres upstream north of the point at which the effluents enter the River Niger. The samples at this point also acted as control samples and are designated as ContPUS samples. The next point of collection of samples is at the point of discharge of effluents into the River Niger and the samples collected here are designated as PODE samples. Samples were also collected at 500 metres downstream from the point of discharge of effluents into the river (i.e. at cable point). The samples collected here are designated as Cable point samples. The last sampling station is at 1 kilometre downstream from the point of discharge of effluents into the river near the bridge linking Asaba to Onitsha. The samples collected here are designated as Bridge point samples.

Samples were collected for the following parameters in effluents and river water: temperature, pH, electrical conductivity, turbidity, total solids (TS), total suspended solids (TSS), total dissolved solids (TDS), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), oil and grease (O&G), phenol, phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), total residual Chlorine, cyanide, ammonia-nitrogen (NH_3 – N) and the heavy metals (lead, copper, iron, chromium, cadmium, nickel, zinc and manganese). All effluent samples were collected by method of composite sampling. Grab samples of effluents were collected every 10 minutes into a sampling bottle for a period of 1 hour and composited (i.e. mixed) and preserved. Water samples from the river were collected at the surface (i.e. 1 metre to the surface of water) and at mid-depth; along the middle axis of the river. All water samples were collected in duplicates. Sample collection and preservation were carried out as described in standard methods [18]. Samples for bacteriological determinations (Total Coliform) were cooled at 4^0C and the total holding time did not exceed 2h [18].

The temperature was measured at the site with a mercury bulb thermometer with the bulb well dipped below the surface of water. The pH of samples was determined on site with a portable battery operated pH-meter. The electrical conductivity of samples was measured with a conductometer in accordance with procedure describe in standard methods [18. Turbidity was determined by the Nephelometric method as described in Standard Methods [17]. TS of samples was determined by evaporating 200ml of water sample in an evaporating dish and drying the residue in the oven at 103^0C – 105^0C to constant weight [18]. The TSS of samples was determined by filtering 200 mL of water sample using a gooch crucible-suction pump system and then drying the filtered solids at 103^0C – 105^0C to constant weight in an oven [18]. TDS was determined by drying filterate from the TSS determination at 180 ^{0}C in an oven to constant weight [18].

The 5-day BOD test was employed in the determination of BOD_5 of the samples [18]. COD of samples was determined by the open reflux method [18]. The turbidimetric method was used in the determination of Sulphate in samples of effluents and water as described in standard methods [18].Cyanide was determined by the method recommended by the Joint Committee of the Association of British Chemical Manufacturers and the society of Analytical Chemist for determining small amount of cyanide in trade effluents (1958) based on the method by Adridge [19]. Oil and Grease was determined by IR-spectrophotometric method as described in the Annual Book of American Society of Testing Material (ASTM) [20]. Phenol was determined by IR.-spectrophotometric method after bromination of phenols in water samples, followed by extraction with carbon tetrachloride (CCl_4), details of experimentation is as described by [21]. NH_5 – N was determined by the nesslerization method as described in standard methods [18]. The heavy metals (Pb, Cu, Fe, Cr, Cd, Ni, Zn and Mn) in effluents and in water samples were determined by first digesting sample by adding 5 mL of concentrated HNO_3 to 500 mL sample and then simultaneously pre-concentrating and evaporating almost to dryness. Residue was dissolved and made up to the mark in a 50 mL volumetric flask [18]. The metals were measured from the digest solution by flame atomic absorption spetrophotometer (Perkin Elmer AA 200, Waltham, USA) as described in manual by [22]. The total coliform a bacteriological parameter was determined by the membrane filteration method [18].

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A quality assurance programme was put in place in the study and it involved determination of blanks and duplicates, determination of glucose-glutamic acid check for BOD_5 determinations, determination of % recovery for COD by determining COD on standard solutions of potassium hydrogen phthalate (KHP) (i.e. solution which contains 425 mg/L of KHP) and comparing the mean of five determinations to the theoretical value of 500 mg/L [18]. The percentage recoveries of O&G and the eight heavy metals were also determined. The following average percentage recoveries were obtained for five determination of each parameter: COD (93.2±4.7%), O&G (94.6±8.7), Ni (93.6±7.7%), Cd (90.9±8.3%), Pb (97.3±7.3%), Cr (98.8±8.7%), Zn (101±9.2%), Cu (97.5±9.2 %), Fe (96.5±11 %) and Mn (103±9.8 %). These percentage recoveries all falls within the range 90 – 110 which means good percentage recoveries were obtained for all the parameters.

Comparison of the mean of concentrations of each parameter in the four seasons studied was carried out using analysis of variance (ANOVA- single factor) with Microsoft excel (2007 version) at o.o5 confidence level. Also the comparison of the mean of concentrations of each parameter in the three sampling stations in the study area was carried out using analysis of variance (ANOVA – single factor) with Microsoft excel (2007 version) at 0.05 confidence level. The student t-test was used in the comparison of the mean of a set of values for two areas (i.e. study area with control area) at 0.05 confidence level and at 23 degrees of Freedom. The levels of all parameters at the water surface were compared with those at mid-depth using T – test (two sample, assuming equal variance) (2-tailed) with Microsoft excel (2007 version) at 0.05 confidence level

RESULTS AND DISCUSSION

The results of the determinations of parameters in effluents are: temperature (47.8±3.5 ^{0}C), pH (7.3±0.6) (slightly in the alkaline region), turbidity (45±31 NTU), electrical conductivity (57.9±8.6 µscm^{-1}), TS (1430±95 mg/L), TSS (132±50 mg/L), TDS (1280±87 mg/L), BOD_5 (153±30 mg/L), COD (340±250 mg/L) and O & G (6.9±2.6 mg/L). The results for the following heavy metals are: Pb (38±42 µg/L), Fe (270±250 µg/L) and Zn (150±62 µg/L). A comparison of the results for all the parameters in effluents of Asaba Textile Mill with two effluent limitation guidelines in Nigeria i.e. The Federal Ministry of Environment's(FMEnv.'s) (Formerly named Federal Environmental protection Agency) Effluent limitation Guidelines for Textile Industry [23] and the Department of Petroleum Resources' (DPR) effluent limitation for inland waters (Nigeria) in Environmental Guidelines and Standards in the Petroleum Industry in Nigeria (EGASPIN) [24] (Table 1) reveals that the values of the following parameters exceeded corresponding guideline values: temperature (47.8±3.5 ^{0}C) exceeded FMEnv. limit standards for Temperature (35 – 40 ^{0}C) and the DPR's limit standards (25^{0}C) respectively, TSS average value (132±50 mg/L) exceeded both the FMEnv (30mg/L) and the DPR (30 mg/L) guideline values respectively. The average value of TDS in effluents (1280 mg/L) exceeded the FMEnv. guideline value (50 mg/L). Also the average value of COD in effluent (340±230 mg/L) exceeded the FMEnv. value (80 mg/L) and the DPR value (40 mg/L) respectively. The effluents from the mill is therefore of very low quality and is capable of polluting a receiving water body such as a river.

The average values of most parameters were higher in the study area (downstream from point of effluent discharge into the river) than in the control area (upstream from point of effluent discharge) (Table 2), the average value of turbidity, TS, TSS, TDS, BOD,, COD, Electrical conductivity, sulphate, Pb, Fe, and Zn were much higher in the study area than in the control area (Table 2). The pH was also slightly higher in the study area showing that the water of the study area to be more alkaline. A student t-test comparison of the average values of parameters of the study area sampling stations with the control area shows that the study area is statistically significantly different from the control area in terms of the quality of water (t-test values: $t_{calculated}$ (8.4702) > $t_{tabulated}$ (2.071) at 95% confidence level and 23 degrees of freedom). As expected the average values of pollutant parameters are lowest at the upstream (control) sampling station (i.e. at contPus station) (Table

2). Most of the parameters have their highest average values at point of discharge of effluents (PODE) sampling station as expected with the exception of a few. The variation of the values of most parameters also showed a pattern in which the values decreases with distance from PODE downstream to the furthest downstream sampling station (Bridge point) (Table 2). This must be due to increasing dilution as the river flows from point PODE downstream to Bridge point. Some of the parameters have their highest average value at Cable point sampling station. These parameters include turbidity (59.5±6.8 NTU), BOD_5 (96.1±7.2 mg/L) and NH_3-N (1.34±0.09 mg/L). O & G has its highest value at Bridge point (0.16±0.06 mg/L) the furthest downstream sampling station. This later observation may have arisen as a result of some other activities occurring around the downstream sampling station. It is worth noting that the River Niger in this stretch flows in between two major cities i.e. Asaba and Onitsha. There were no significant differences in the values of all the parameters with the depth of water when values of all parameters in the surface and mid-depth were compared using t-test (two sample, assuming equal variance). This may be as a result of much mixing in the body of water in the river in this stretch of the river. Apart from the average values of TS and TDS which are higher in the dry seasons and the average values of iron which are higher in the rainy seasons, the average values of all other parameters were not affected by seasonal changes (Table 3).

The quality characteristics of the river water from the point of discharge of effluents downstream (i.e. the study area) were also compared with major international and national drinking Water Quality Guidelines (Table 4). Three parameters namely Turbidity, TDS and Pb are of importance in this comparison. The average turbidity of water in this study area (54.4 $\pm$ 9.3NTU) exceeded the maximum acceptable concentration (MAC) of the Canadian drinking water standards (0.1 NTU) [25], the maximum contaminant Level (MCL) of 2012 edition of drinking water standards of United States Environmental Protection Agency (USEPA) (5.00 NTU) [26] and the maximum permitted level (MPL) of the Nigerian drinking water quality guidelines (5.00 NTU)(SON, [27]. The average TDS value in the study area (1010 $\pm$ 520mg/L) exceeded the MPL of Nigerian standard for drinking water quality (500 mg/L) [27], the AO (aesthetic objective) value of the Canadian drinking water standards (500 mg/L) [25] and the SWDR (secondary drinking water regulation) value of 2012 edition USEPA drinking water standards [26]. The average concentration of Pb of the study area water (87 $\pm$ 18 μg/L) exceeded the WHO's guideline for drinking-water quality (10 μg/L) [28], MCL of 2012 edition of USEPA drinking water standards (15 μg/L) [26], the MPL of Nigerian standard for drinking water quality (10μg/L) [27] and the MAC of the Canadian Drinking Water standards (10 μg/L) [25]. Based on these three parameters the waters of River Niger in this stretch (i.e. the study area) is polluted for the purpose of drinking by human (i.e. water is not potable). The high concentration of Pb observed in the water of the receiving water may not have come from the effluents of the textile mill since the average concentration of Pb in the effluent is 38±42 μg/L). The presence of high concentration of Pb in the water of the study area may be as a result of the location of the study area. The study area is located between two cities Asaba and Onitsha. Dumping into the river of lead containing materials such as lead batteries may be taking place in this stretch of the River.

The average values of the following parameters also exceeded the following guideline values for non-drinking uses of water: The average pH value of 7.0 $\pm$ 0.1 falls outside guideline range of the Canadian Water Quality Guidelines (CWQG) value for power generating industry water (boiler feed water) (8.8 – 9.4) [29]. The average turbidity of study area water (54.4 $\pm$ 9.3 NTU) exceeded CWQG guideline values for fine paper production in the Pulp and Paper Industry (< 10.0 NTU) [29], California State Water Quality control board (CSWQCB) 1963 recreational water quality guideline (water contact) (50.0 NTU) [30]. The average TSS value of study area water (180 $\pm$ 21 mg/L) exceeded the CWQG values for fine paper production in the Pulp and paper industry (10.0 mg/L), Petroleum Industry (<10 mg/L), Boiler feed water in Power generating industry (<0.05 mg/L) [29] and CSWQCB 1963 recreational water quality guideline value (water contact) (100 mg/L) [30]. The average TDS

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value of study area water (1190±530 mg/L) exceeded the CWQG values for fine paper production in pulp and paper industry (<200 mg/L), Petroleum Industry (<750 mg/L), boiler feed water in power generating industry (0.05 mg/L) [29]. The average oil and grease of study area water (0.02 ± 0.02 mg/L) exceeded CWQG value for iron and steel industry (ND) [29]. The average value of COD in study area water (110 ± 9.6 mg/L) exceeded CWQG value for boiler feed water in power generating industry (<10 mg/L) [29].The water is therefore not suitable for the following water uses: Power Generating (boiler feed water), Pulp and Paper Industry (fine paper production) Recreational water, Petroleum industry, Iron and Steel (manufacture), and aquatic life rearing. Using the Prati Classification Table [31], the water in the area can be classified into class V based on the value of BOD (89±11 mg/L). The water is therefore highly polluted and needs to be rigorously treated before being used for drinking.

Table 1: Comparison of average values of parameters in effluent with Effluent guidelines

Parameters	Average value for study area effluent	FMEnv.'s Limit standards for Textile Effluents [[23]	DPR Effluents Limitation for Inland Waters (Nigeria) [24]	Guideline value exceeded
Temp (^{0}C)	47.8 ± 3.5	35 – 40	25^0$_C$	FMEnv.
pH at 25^{0}C	7.3 ± 0.6	6.0 – 9.0	6.5 – 8.5	none
Turbidity (NTU)	45 ± 31	NS	10	DPR
Conductivity (μscm^{-1})	57.9±8.6	NS	NS	NA
TS (mg/L)	1430 ± 95	NS	NS	NA
TSS (mg/L)	132 ± 50	30	30	FMEnv. & DPR
TDS (mg/L)	1280 ± 87	200	<2,000	FMEnv.
BOD_5 (mg/L)	153 ± 30	50	-	FMEnv.
COD (mg/L)	340 ± 230	80	40	FMEnv. & DPR
O & G (mg/L)	6.9 ± 2.6	10	10 (THc)	none
Phenol (mg/L)	0.2 ± 0.2	0.2	NS	
T. R. Cl (mg/L)	ND	NS	0.08	none
NH3-N (mg/L)	1.9 ± 1.1	NS	NS	NA
Cyanide (mg/L)	ND	0.1	NS	none
Sulphate (mg/L)	110 ± 180	500	NS	none
Phosphate (mg/L)	1.9 ± 1.3	5.0	NS	none
Pb (μg/L)	38 ± 42	< 100	50	none
Cu(μg/L)	12.6 ± 7.9	<1000	1500	none
Fe (μg/L)	270 ± 250	No guideline	1000	none
Cd (μg/L)	ND	<1000	NS	none
Cr(μg/L)	0.08 ± 0.3	No guideline	30	none
Ni (μg/L)	ND	No guideline	NS	none
Zn(μg/L)	150 ± 62	<1000	1000	none
Mn (μg/L)	0.2 ± 0.6	5000	NS	none

NA = not applicable NS = not specified ND = not detected THc = total hydrocarbon content

The results obtained for analysis of effluent of Asaba Textile Mill and the receiving waters of the River Niger were compared with results obtained for other textile mill effluents (Tables 6a and 6b) and waters of other rivers receiving effluents respectively (Tables 7a and 7b). The results for most parameters in study area effluent are comparable with results obtained for corresponding parameters in effluent of other textile mills in

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other studies. A few of the results obtained in this study are however higher or lower than values obtained in the other studies (Tables 6a and 6b). For example the average temperature of Asaba Textile Mill (Asabatex) (i.e. study area effluent) (47.8±3.5 ^{0}C) is comparable with those of Kohinoor Textile Mill (Kohitex) effluent (40 ^{0}C) [7] and effluents of textile near Kabul river henceforth designated as KABRIVTEX (32 – 130 ^{0}C) [4]. The average TDS value of Asabatex effluents (1280±87 mg/L) is comparable with results obtained for KABRIVTEX (220 – 13430 mg/L) [4], Kaduna Textile Mill 4 (Kadtex 4) (848 mg/L) [5] and Raca paper industry (RACAIND) (1080mg/L) [32]. The average COD of Asabatex effluent (340±230 mg/L) is however lower than results for Kohitex (1632 mg/L) [7]. The average value of pH of Asabatex effluent (7.30±0.60) is lower than results obtained for Kadtex 4 (11.53) [5] i.e. effluents of Asabatex is less alkaline than Kadtex 4 effluents. It is comparable with results for KABRIVTEX (8.05 – 11.38) [4] and Kohitex (9.50) [7]. The average concentration of Pb of Asabatex effluent (38±42 µg/L) is lower than results obtained for KABRIVTEX (70 – 140 µg/L) [4]. The results for most parameters measured in the effluents of Asaba Textile mill are comparable with those obtained for effluents of other textile mills and paper industries.

Table 2: Average values of parameters in the study and control areas and average levels of each parameter in each the different sampling stations.

Parameters	Study Area	control Area (Upstream)	Downstream (Study area) sampling Stations		
		ContPUS (Sampling station)	PODE	Cable point	Bridge point
Temp (^{0}C)	26 ± 0.7	26 ± 0.37	27	25.5 ± 0.4	25.8 ± 0.3
pH at 25^{0}C	7.0 ± 0.1	6.8 ± 0.08	7.1 ± 0.09	7.0 ± 6.07	7.0 ± 0.1
Turbidity (NTU)	54.4 ± 9.3	16.8 ± 2.5	51.4 ± 2.7	59.5 ± 6.8	42.2 ± 4.4
Conductivity (µScm^{-1})	41.9 ± 3.9	38.9 ± 4.0	45.2 ± 2.7	40.5 ± 3.4	40.1 ± 3.6
TS (mg/L)	1190 ± 530	301 ± 3.1	1870 ± 51	1100 ± 150	620 ± 58
TSS (mg/L)	180 ± 21	117 ± 6.4	206 ± 11	171 ± 9.5	164 ± 7.1
TDS (mg/L)	1010 ± 520	178 ± 10	1680 ± 120	878 ± 55	473 ± 34
BOD_5 (mg/L)	89 ± 11	31.1 ± 5.9	90.2 ± 9.6	96.1 ± 7.2	80.1 ± 8.4
COD (mg/L)	110 ± 9.6	88.9 ± 3.9	115 ± 5.8	115 ± 4.3	97.8 ± 3.6
O & G (mg/L)	0.02 ± 0.02	0.02 ± 0.01	0.06 ± 0.03	0.01 ± 0.01	0.16 ± 0.06
Phenol (mg/L)	1.6 ± 1.1	0.06 ± 0.02	2.8 ± 6.2	1.75 ± 0.3	0.16 ± 0.06
T. R. Cl (µg/L)	ND	ND	ND	ND	ND
NH_3N (µg/L)	1.0 ± 0.5	0.74 ± 0.07	0.30 ± 0.04	1.34 ± 0.09	1.3 ± 0.1
Cyanide (µg/L)	ND	ND	ND	ND	ND
Sulphate (µg/L)	99 ± 13	29.4 ± 2.0	97.2 ± 5.9	112 ± 55	87 ± 12
Phosphate (µg/L)	2.1 ± 0.9	0.78 ± 0.06	1.2 ± 0.1	3.2 ± 0.5	1.7 ± 0.3
Pb (µg/L)	87 ± 18	39.6 ± 4.0	103 ± 4.2	94.3 ± 7.1	64.4 ± 6.1
Cu (µg/L)	11.0 ± 5.3	12.6 ± 2.2	16.6 ± 4.2	7.0 ± 3.4	9.5 ± 2.4
Fe (µg/L)	120 ± 33	78 ± 14	155 ± 30	112 ± 19	94 ± 12
Cd (µg/L)	ND	ND	ND	ND	ND
Cr (µg/L)	ND	0.5 ± 1.1	ND	ND	ND
Ni (µg/L)	ND	ND	ND	ND	ND
Zn (µg/L)	20 ± 21	3.6 ± 4.3	22 ± 21	18 ± 19	20 ± 22
Mn (µg/L)	ND	ND	ND	ND	ND
Total coliform (MPN/100 mL)	118±2.7	106±21	126±3.7	113±2.0	109±3.0

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The average values of physicochemical parameters and heavy metals of waters of the study area (i.e. River Niger) were also compared with results obtained for corresponding parameters in waters of other rivers in similar studies (Tables 7a and 7b). The comparison reveals that some of the results were comparable with results obtained in the other studies, some were however higher or lower. For example the average value of temperature of the Niger River (26.0±0.7 ^{0}C) is comparable with those obtained for Ibeshe Stream (27.0 – 34.0 ^{0}C [8] and Ogunpa/Ona rivers (26 – 32 ^{0}C [9]. Also the average TDS value of Niger River waters (1010±520 mg/L) compares well with results obtained for Ibeshe Stream (673 – 45216 mg/L) [8] but it is higher than that for Ogunpa/Ona rivers (0.10 – 5.90 mg/L) [9]. The average COD of Niger river (study area) (110±9.6 mg/L) is comparable with results for Ibeshe Stream (10 – 1703 mg/L) [8] and Ogunpa/Ona rivers (11.9 – 224 mg/L) [9]. Also the average value of pH of study area water (7.00±0.70) is comparable with results obtained for Ogunpa/Ona rivers (6.6 – 8.1) [9]. It is higher than those obtained for Ibeshe Stream (1.98 – 8.23) [8], Tinto river (2.60±0.21), Odiel River (6.2±2.2) [33]. Also the average concentration of Pb in study area water (87±18 µg/L) is comparable with results obtained for Ibeshe Stream (ND – 70.0µg/L [8] and Ogunpa rivers (<10.0 – 8600 µg/L) [9]. It can also be seen that the results obtained for waters of River Niger (study area) are generally comparable with results obtained for most waters of other effluent receiving rivers.

Table 3: Concentrations of Parameters of River Water in the four seasons

Parameter	1st Dry Season	1st Rainy Season	2nd Dry Season	2nd Rainy Season
Temp (^{0}C)	26 ± 0.71	26 ± 0.8	26 ± 0.65	26 ± 0.53
pH at 25^{0}C	7.0 ± 0.14	6.9 ± 0.11	7.0 ± 0.15	6.9 ± 0.15
Turbidity (NTU)	46 ± 20	44 ± 20	46 ± 19	44 ± 18
Conductivity (µS cm^{-1})	41.7 ± 1.2	40.1 ± 3.0	43.3 ± 5.3	39.6 ± 5.1
TS (mg/L)	1010 ± 650	950 ± 620	1000 ± 660	930 ± 620
TSS (mg/L)	163 ± 31	170 ± 36	160 ± 160	159 ± 37
TDS (mg/L)	840 ± 620	790 ± 590	850 ± 650	730 ± 540
BOD_5 (mg/L)	82 ± 29	72 ± 27	79 ± 28	65 ± 26
COD (mg/L)	102 ± 13	106 ± 11	104 ± 12	107 ± 15
O & G (mg/L)	0.01 ± 0.03	0.01 ± 0.02	0.02 ± 0.02	0.02 ± 0.02
Phenol (mg/L)	1.2 ± 1.3	1.2 ± 1.3	1.2 ± 1.2	1.2 ± 1.2
T. R. Cl (mg/L)	ND	ND	ND	ND
NH_3-N (mg/L)	1.0 ± 0.5	0.9 ± 0.5	0.9 ± 0.5	0.9 ± 0.4
Cyanide (mg/L)	ND	ND	ND	ND
Sulphate (mg/L)	85 ± 36	80 ± 33	86 ± 34	75 ± 32
Phosphate (mg/L)	1.8 ± 1.1	1.8 ± 1.1	1.8 ± 1.0	1.6 ± 0.9
Pb(µg/L)	75 ± 28	77 ± 30	75 ± 25	75 ± 27
Cu (µg/L)	9.1 ± 5.0	12.0 ± 5.1	11.4 ± 3.7	12.4 ± 5.0
Fe (µg/L)	104 ± 29	131 ± 43	94 ± 28	109 ± 33
Cd (µg/L)	ND	ND	ND	ND
Cr (µg/L)	ND	ND	ND	0.33 ± 0.58
Ni (µg/L)	ND	ND	ND	6
Zn (µg/L)	37 ± 18	33 ± 18	33 ± 16	30 ± 15
Mn (µg/L)	ND	ND	Nd	ND
Total coliform (mpn/100 ml)	115±6.3	117±8.7	115±7.8	116±11

T. R. Cl = total residual chlorine **ND = not detected**

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Table 4: Comparison of values of parameters with National and international guidelines for drinking water.

Parameter	Values from Study Area	Drinking water standards [28]	Nigerian Standard for Drinking water Quality [27]	2012edition USA Drinking Water Standard s (Health Advisory) [26]	Canadian Drinking Water standards [25]
Temp ^{0}C	26 ± 0.7	NS	Ambient		
pH at 25^{0}C	7.0 ± 0.1	NS	6.5 – 8.5	6.5 – 8.5 (SDWR)	6.5 – 8.5 (AO)
Turbidity (NTU)	54.4 ± 9.3	NS	5.00	5.00 (MCL)	0.10 (MAC)
Conductivity (μS)	41.9 ± 3.9	NS	NS	NS	NS
TS (mg/L)	1190 ± 530	NS	NS	NS	NS
TSS (mg/L)	180 ± 21	NS	NS	NS	NS
TDS (mg/L)	1010 ± 520	NS	500	500 (SDWR)	500 (AO)
BOD_5 (mg/L)	89 ± 11	NS	NS	NS	NS
COD (mg/L)	110 ± 9.6	NS	NS	NS	NS
Oil & Grease (mg/L)	0.02 ± 0.02	NS	NS	NS	NS
Phenol (mg/L)	1.6 ± 1.1	NS	0.001	NS	0.002 (MAC)
T. R. Cl (mg/L)	ND	5.0	0.2 – 0.25	NS	NS
NH3-N (mg/L)	1.0 ± 0.5	NS	NS	NS	NS
Cyanide (mg/L)	ND	0.07	0.01	0.2 (MCL)	NS
Sulphate (mg/L)	99 ± 13	NS	100	250 (SDWR)	500 (AO)
Phosphate (mg/L)	2.1 ± 0.9	NS	NS	NS	NS
Pb (μg/L)	87 ± 18	10	10	15 (MCL)	10 (MAC)
Cu (μg/L)	11.0 ± 5.3	2000	1000	1300 (MCL)	1000 (MAC
Fe (μg/L)	120 ± 3.3	NS	300	NS	300 (MAC)
Cd (μg/L)	ND	3.0	3.0	5.00 (MCL)	5.0 (MAC)
Cr (μg/L)	ND	50	50	100 (MCL)	50 (MAC)
Ni (μg/L)	ND	70	20	NS	NS
Zn(μg/L)	20 ± 21	NS	3000	5000 (SDWR)	5000 (MAC)
Mn (μg/L)	ND	400	200	NS	50 (AO)
Total coliform (mpn/100 ml)	115±6.3	NS	10 (Cfu/mL)	5% (MCL)	None (MAC)

SDWR = secondary drinking water regulations of USEPA (i.e. not enforceable) MCL = maximum contaminant level
AO = aesthetic objective value of Health Canada) MAC = maximum acceptable concentration,ND = not detected NS = not specified

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Table 5: Comparison of water characteristics of study area with quality guideline for water uses other than for drinking.

Parameter	Values from Study Area	Guidelines for Pulp and paper Industry water (Fine paper) [29]	Guidelines for Iron and Steel industry water(steel manufacturing) [29]	FWPCA, 1968Guidelines for Petroleum Industry [30]	Power Generating (Boiler Feed water) [29]	FAO 1985 Guideline for Irrigation water [30]	CSWQCB 1963 Water Quality Guidelines for aquatic life (freshwater) [30]	CSWQCB 1963 Water Quality guideline for Recreational Water (water contact: limiting Threshold) [30]	Water Quality Guidelines for livestock rearing [30]
pH at 25^{0}C	7.0 ± 0.1	NS	6.8 – 7.0	6.0 – 9.0	8.8 – 9.4	6.0 – 9.0	6.5 – 8.5	6.0 – 10.0	NS
Turbidity (NTU)	54.4 ± 9.3	<10*	NS	NS	5	<1	NS	50	NS
TSS (mg/L)	180 ± 21	<10*	NS	NS	NS	NS	NS	100*	NS
TDS (mg/L)	1010 ± 520	<200*	NS	NS	500	NS	NS	NS	NS
O & G (mg/L)	0.02 ± 0.02	NS	ND	NS	NS	NS	NS	5.0	NS
Fe (µg/L)	120 ± 3.3	NS	NS	NS	300	300	1000	NS	NS
Zn (µg/L)	20 ± 21	NS	NS	*50	5000	NS	5000	NS	NS
SO_4^{2-} (mg/L)	99 ± 13	NS	175	NS	NS	NS	NS	NS	NS
Cu (µg/L)	11.0 ± 5.3	400	200	NS	50	50	50	NS	50
Cd (µg/L)	0	NS	NS	NS	NS	NS	NS	NS	50
Zn(µg/L)	20 ± 21	NS	NS	NS	NS	NS	NS	NS	25
Pb (µg/L)	87 ± 18	NS	NS	NS		NS	NS	NS	100

FWPCA = Federal Water Pollution Control Administration CSWQCB = California State Watter Quality Control Administration
NS = not specified ND = no detected

Table 6a: Comparison of levels of physicochemical parameters of Asaba textile Mill effluents with results obtained for textile mills elsewhere.

River/Textile mill	Country	Temp. ^{0}C	TS (mg/L)	TSS (mg/L)	TDS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	O & G (mg/L	NH_3-N (mg/L)	SO_4^{2-}	$PO_\$^{3-}$	TR Cl	References
Kaduna Mill 4 (KADTEX)	Nigeria	26.7	-	1200	848	242	2190	ND	0.05	-	0.74	1.06	[5]
Kabul River (KABRIVTEX)	Pakistan	32 - 130	460 - 18080	100 - 3020	220 - 13430	-	1500 - 4160	-	-	-	-	-	[4]
Raca paper Industry (RACAIND)	Egypt	-	1690	99.4	1080	-	1790	-	-	-	-	-	[32]
Kohinoor Text. Mill (KOHITEX)	Pakistan	40	-	5496	2512	548	1632	-	-	-	-	-	[7]
Asaba Text. Mill (ASABATEX)	Nigeria	47.8± 3.5	1430±95	132±50	1280±87	153±30	340±230	6.9±2.6	1.9±1.1	110±180	1.9±1.3		Present Study

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Table 6b: Comparison of values of pH, physical parameters and the heavy metals of Asaba textile mill effluents with results obtained for textile/paper mils elsewhere.

River/Textile Mill	Country	pH	Elect. Conductivity (μscm^{-1})	Mn (µg/L)	Pb (µg/L)	Cu (µg/L)	Fe (µg/L)	Cd (µg/L)	Cr (µg/L)	Ni (µg/L)	Zn (µg/L	References
Kaduna Mill 4 (KADTEX 4)	Nigeria	11.53	-	300	-	5140	ND	-	ND	-	190	[5]
Raca paper industry (RACAIND)	Egypt	8.77	-	-	110	344	1960	-	140	152	-	[32]
Kohinoon Textile Mill (:KOHITEX)*	Pakistan	9.50	3.57	4340	280	6360	6000	510	1670	670	3230	[7]
Asaba Textile Mill (ASABATEX)*	Nigeria	7.30±0.60	57.9±8.6	0.20±0.60	38±42	12.6±7.9	270±250	ND	0.08±0.30	ND	150±62	Present Study

Table 7a: Comparison of levels of physicochemical parameters of waters of river Niger (at Asaba) with results obtained for rivers elsewhere.

Country	Temp. ^0C	TS (mg/L)	TSS (mg/L)	TDS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	O & G (mg/L	NH_3-N (mg/L)	SO_4^{2-}	PO_5^{3-}	TR Cl	References
Nigeria	-	-	-	-	68±23 - 656±35	3440±160 - 234±17	-	-	-	-	-	[6]
Nigeria	27.0 – 34.0	715 - 23984	10 - 1513	673 - 45216	-	10 - 1703	-	-	50 - 690	1.00 - 6.02	-	[8]
Nigeria	26 - 32	160 - 1480	10 - 270	0.10 – 5.90	13.0 - 560	11.9 - 224	-	-	-	-	-	[9]
Nigeria	26±0.7	1190±530	180±21	1010±520	89±11	110±9.6	0.02±0.02	1.00±0.05	99±13	2.10±0.90	ND	Present Study

Table 7b: Comparison of values of pH, physical parameters and the heavy metals of waters of River Niger with results obtained for rivers elsewhere.

River/Textile Mill	Country	pH	Elect. Conductivity (μscm^{-1})	Turbidity (NTU)	Mn (µg/L)	Pb (µg/L)	Cu (µg/L)	Fe (µg/L)	Cd (µg/L)	Cr (µg/L)	Ni (µg/L)	Zn (µg/L	References
Challawa River points S_4, S_6, S_7 and S_8 (rainy season)	Nigeria	-	-	-	630 - 1110	1220 - 2340	126 - 230	220 - 1330	70 - 1000	2540 - 5250	2110 – 12000	910 – 4210	[6]
Ibeshe Stream	Nigeria	1.96 - 8.23	1570 - 43200	0 - 144	-	ND – 70.0	-	-	-	ND – 10.0	-	10.0 – 100	[8]

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Tinto River	Spain	2.60±0.21	-	-	-	-	15200±1400	-	120±97	-	160000±110000	34400±33000	[33]
Odiel River	Spain	6.2±2.1	-	-	-	-	2100±2900	-	40±29	-	68400±88000	6270±3300	[33]
Ogunpa/Ona	Nigeria	6.6 – 8.1	-	-	-	<10.0 – 8600	<1.00 – 39.0	-	<1.00 – 23.0	2.00 – 19.0	<1.00 – 27.0	<1.00 – 35.0	[9]
Niger River	Nigeria	7.00±0.70	41.9±3.9	54.4±9.3	ND	87±18	11.0±5.3	120±33	ND	ND	ND	20±21	Present Study

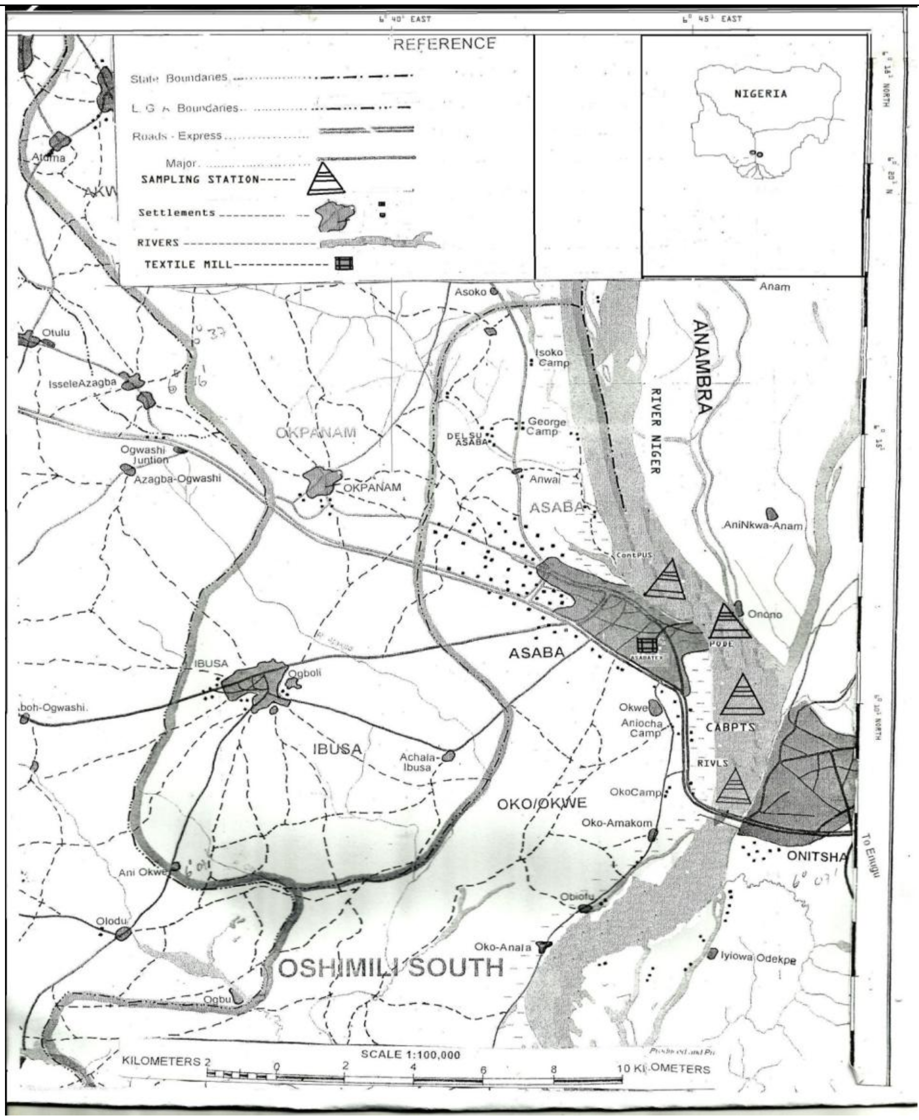

FIG. 1: Map of Study Area Showing a Section of Niger River and the Sampling Stations

CONCLUSION

Effluent and receiving water of the Niger River were sampled for four seasons consecutively (i.e. two dry and two rainy seasons). Thes samples were analyzed for selected physicochemical parameters of water

and selected heavy metals. Results showed that effluent quality was low and thus have ability to pollute any receiving water body. The water quality of the receiving water was also found to be low with high concentration of Pb and dissolved solids. The water of the study area has been classified to be very polluted and need to be rigorously treated before use for drinking and other non-drinking uses of water. Use of water in the stretch of the Niger river for drinking purpose can lead to some adverse health effect for the users. Environmental protection authorities such as the National Environmental Standards and Regulations enforcement Agency (NESREA) (of Nigeria) should make sure rigorous inspections of effluents are carried out before their discharged into surface waters to ensure that environmental parameters do not exceed set limits.

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