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Assessment of Groundwater Contamination by Textile Effluent Discharges in Ikorodu, Nigeria

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Abstract

This paper assessed physicochemical properties (temperature, pH, acidity, alkalinity, colour, odour, taste, EC, TDS, TH, turbidity, bicarbonate, phosphate, nitrate, Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^- & SO_4^{2-} as well as heavy metal concentrations heavy metals (Cd, Cr, Cu, Fe, Pb and Zn) of selected wells and borehole near textile industries in Ikorodu, Nigeria. The physicochemical parameters were analysed using standard methods by APHA, while heavy metals were analysed using atomic absorption spectrometer (AAS). The pH of water from the boreholes and hand-dug wells ranged from 5.90 to 6.70. The well water had higher total hardness, calcium, magnesium, sulphate and chloride compared to the boreholes. Alkalinity in the boreholes ranged from 740.2 to 820.4 mg L^{-1} compared to wells that ranged from 144.4 to 670.2 mg L^{-1}. EC for the boreholes ranged from 124.5-182.3 µS cm^{-1} compared to EC of wells that ranged from 216.2-385.6 µS cm^{-1}. TDS ranged from 48.6-60.3 mg L^{-1} in the borehole compared to 62.5-120 mg L^{-1} in the wells. Concentration of Fe ranged from 0.12 to 1.2 mg L^{-1} in the boreholes compared to 1.2 to 1.60 mg L^{-1} found in the well water. Zn, Pb, and Cu ranged from 0.60 to 1.20 mg L^{-1}, 0.02 to 0.03 mg L^{-1} and 0.04 to 0.06 mg L^{-1} respectively. Concentrations of Fe and Pb were above the permissible limits of WHO and NIS. A possible source of pollution is seepage of effluent discharge through the porous soil into the groundwater and this poses great danger to the health of the people who consume the water.

Keywords: Effluents; Groundwater; Heavy metals; Pollution; Textile industry; Water quality

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Introduction

Ikorodu Township is one of the fastest growing industrial axes of Lagos State, Nigeria. This is coupled with rapid population growth and urbanization that brings about increasing demand for safe water. In view of the inadequacy of the public water supply, the majority depend on self-supplied water through hand-dug wells and boreholes. These groundwater sources are frequently harnessed indiscriminately and can be potentially polluted due to proximity to the industries established in the area. Several industries, including textiles, paint, breweries and bottling, and plastic contribute substantially to the economy through employment and income generation, and there is rapid urban growth in the area. However, inadequate management of wastes generated from these industries poses a substantial threat to the environment and public health [1]. These industries go through several processes in making textiles such as bleaching of wools, scouring, dyeing, weaving and use of synthetic dyes [2]. These activities have resulted in serious environmental problems such as the contamination of both surface and groundwater sources [3-5]. In most cases, the untreated wastewater effluents from these industries are released in water sources [6-8]. It is important to note that textile effluent is the most polluting among all industrial sectors considering both volume and composition of effluents in both developed and developing countries [9]. These effluents, with their high biological oxygen demand (BOD) and chemical oxygen demand (COD) and suspended solids are very toxic in nature [10-11] and may contaminate ground and surface water sources and alter the water quality. They have considerable effects on both the surface and ground water in the region and consequently on the health of the inhabitants [12]. The toxic waste often accumulates through tropic level causing a deleterious biological effect [13-14] due to their non-degradable nature and long time persistence in the environment. They contain a diverse range of chemicals, many of which have known hazardous properties [15-17] and which have great effects on water quality in the immediate environs. Toxic effluents from textile industries have received a lot of attention in developed countries mainly because they affect human health directly [18]. The main objective of this work is to investigate and evaluate the influence of textile effluent on the pollution of ground water (well and borehole) with heavy metals (Fe, Zn, Cu, Pb, Cd, Cr and As) in Odogunyan, Ikorodu, Nigeria. These metals were chosen because they occur naturally and can also be released through effluent discharge from industries. Some of these metals are found in the dye and other chemicals used in the textile industry. These pollutants can be transported by surface runoff and seep into these wells via available openings and percolation.

Materials and methods

1) Study area

The study area is Odogunyan, Ikorodu in Lagos State, Nigeria. It is located between longitudes 3º 28′ and 3º 32′ and latitudes 6º 36′ and 6º 42′ (Figure 1). Several industries are located in this area, which constitute the Ikorodu Industrial area due to its proximity to Lagos metropolis, which is the most populated metropolis and commercial nerve centre of Nigeria. Activities of the textile industries in the area go back three decades and these industries contributed in no small measure to the growth and development of the area. Textile industries in the Ikorodu area that often release untreated effluents into the environment, which eventually pollute both surface and groundwater sources in the area.

The study area is located on almost plain land with average elevation of 10 m to 25 m above sea level. The geology of the area makes it suitable for groundwater potential. There is the predominance of hand-dug wells in the area and these wells are shallow, ranging from five to fifteen metres. They are made at low cost especially because the water table is high enough that water can be readily found at such depths. The boreholes are few but have deeper depth and constructed with casing or pipes which prevent the small diameter hole from caving in, and protect the water source from infiltration by runoff water.

2) Sample collection and laboratory procedures

A detailed reconnaissance of the study area was conducted to ascertain the sampling points. Groundwater samples were taken from selected well and boreholes close to two prominent textile industries named Textile Mill A and B (Figure 1), every week for two months (spanning both dry and wet seasons). In each sampling site, triplicate water samples were collected in one litre double cap pre-acid washed polythene bottles. Water samples were collected during the daytime between 9 a.m to 4 p.m. Prior to collection of samples, the plastic bottles were cleaned thoroughly to remove all surface contamination, rinsed with double distilled water and dried. Temperature was determined using a thermometer. The samples were then taken immediately to the laboratory without adding any preservative. Suspended matter in the samples, if any, were removed by filtering through Whatman filter No.41. Samples were then stored in the refrigerator at 4°C until the analysis was complete. Table 1 below shows the coordinates of areas and type of groundwater samples collected for the study.

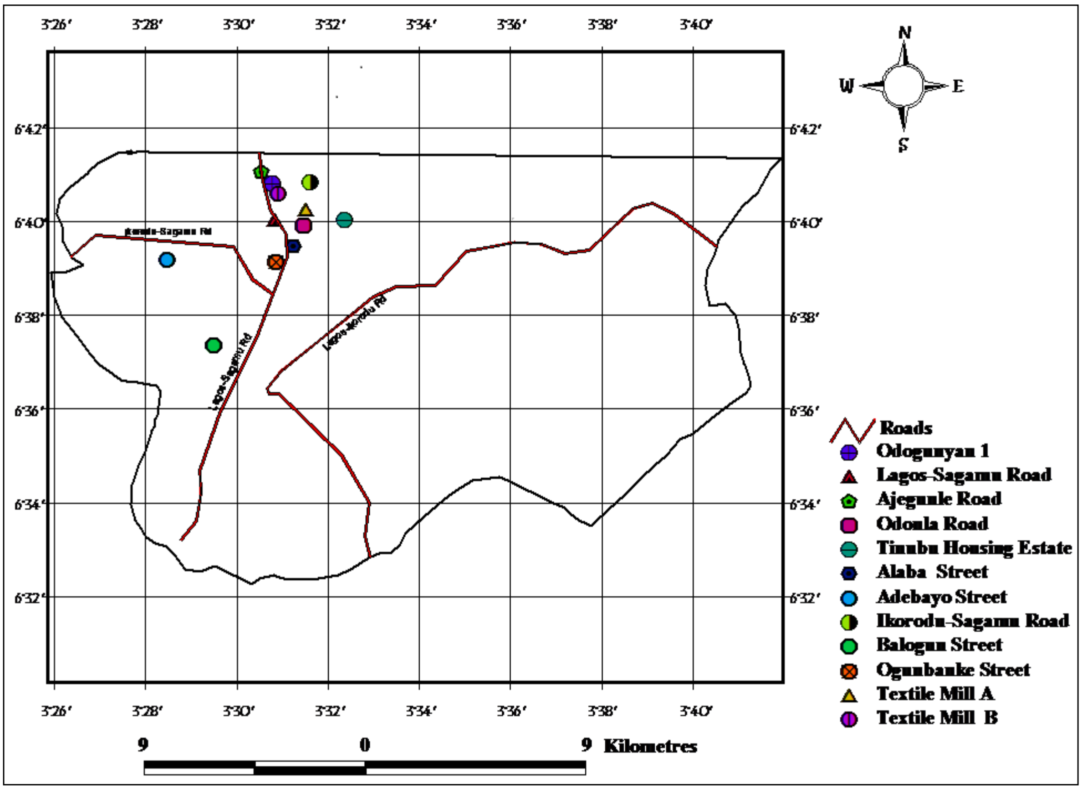

Figure 1 Map of Odogunyan (Ikorodu) in Ikorodu LGA showing sampling sites.

The analyses were carried out systematically both volumetrically and by instrumental techniques [19]. In the laboratory, the following physico-chemical parameters of temperature, pH, odour, taste, acidity, alkalinity, turbidity, electrical conductivity (EC), total dissolved solid (TDS), total hardness, bicarbonate, phosphate, sulphate, calcium, sodium, magnesium, potassium, nitrate, chloride were determined by standard methods [20]. The temperature was determined on site using thermometer. The pH of the samples was determined using digital pH meter (model Jenway 3310). The pH meter was standardized using pH buffer of 4.0 and 9.2, while electrical conductivity was measured using conductivity meter (Hach model C0150). The turbidity of the water was determined with the aid of a turbidimeter (ORION Portable Turbidimeter, Thermo Scientific, USA). Nitrate (NO_3^-) was determined by colorimetric methods, chloride (Cl^-) by titration of the sample with silver nitrate, and total hardness (TH) by titrimetric methods. Phosphate (PO_4^{3-}) was also obtained by standard method. Carbonates and Bicarbonates were determined by titrating 10 ml samples water against standard 0.1N H_2SO_4. The end for carbonates was pink colour while for Bicarbonates was red colour. The method used phenolphthalein and methyl orange as an indicator [21]. The BOD tests were carried out using standard procedure using a five-day BOD (BOD_5) test while COD was deter- mined by the Dichromate Reflux Method [20]. Water samples were digested using 10 mls of concentrated perchloric acid and 10mls of concentrated Nitric acid (i.e. ratio 1:1), and trace metals (Fe, Zn, Cu, Pb, Cd, and Cr) in the digested water samples were analyzed using the Atomic Absorption spectrophotometer (AAS) after standardizing the machine and checking the sensitivity.

3) Quality assurance (QA) and quality control (QC)

In order to achieve quality assurance and control, the study maintained a definable and acceptable level, in both field sampling and laboratory analysis. In addition, precautions were taken to avoid contamination of samples during sampling and cleaning procedures by employing a system of field blank samples (distilled water). Blank samples were also analysed with the same procedure as the collected samples.

4) Statistical analysis

One-way ANOVA using the SPSS version 18.0 package was performed to investigate whether there is significant variation among physicochemical parameters in both well and borehole water samples close to the textile mills in the study area.

Table 1 Location and source of water samples

No.	Water source	Sample Location
1	Well 4	Odogunyan 1
2	Borehole 1	Lagos-Sagamu Rd, Odogunyan
3	Well 2	Ajegunle Road, Odogunyan
4	Well 3	Odonla, Odogunyan
5	Bore hole 4	Tinubu Housing Estate
6	Bore hole 5	Alaba Street, Odogunyan
7	Borehole 3	Adebayo Street
8	Well 1	Ikorodu-Sagamu Road
9	Borehole 2	Balogun Street
10	Well 5	Ogunbanke Street, Odogunyan
11	Textile Mill A	Odogunyan
12	Textile Mill B	Odogunyan

Results and discussion

Textile effluents are generally not treated in the study area before they are discharged into the surrounding surface water such as streams and lagoons. The effluent flow overland before getting to the streams and may seep into the groundwater due to the porous soil characteristically found in the area. Physical properties such as temperature, pH, acidity, alkalinity, total hardness (TH), colour, taste and turbidity of the water samples gotten from bore hole and hand-dug wells from ten different locations in the study area vary from one another (Tables 2 and 3). Temperature of the borehole water samples ranges from 27.2ºC to 28.1ºC while temperature for well water ranges between 27.5 ºC to 28.7ºC. The range of temperature for both the well and borehole samples are similar and do not have any effect on water quality. The degree of acidity and alkalinity was measured by the pH. The pH of water from the hand-dug wells ranged from 5.9 to 6.7 with a mean of 6.0 while the pH of the borehole water ranged from 6.0 to 6.6 with a mean of 6.21. However, pH values of borehole and well samples obtained in this study were within the WHO limit of 6.5 to 8.5 [22]. Low pH values may be due to leaching of organic acids from decaying vegetation or may be because of the presence of dissolved carbon dioxide generated by bacteriological oxidation [23]. In a similar study, Efe et al. [24] observed low pH in groundwater samples from the Niger-Delta of Nigeria. The implications of the low pH include corrosion, solubility of heavy metals and impartation of bitter and metallic taste in water [25]. Water pH has an indirect effect on human health as it can affect water treatment processes [26].

Table 2 Physical and chemical parameters of borehole water samples

Parameters		**Bore Hole**				
		1	**2**	**3**	**4**	**5**
Temperature	ºC	27.3	27.2	28.1	27.6	27.3
pH		6.4	6.0	6.5	6.6	6.3
Acidity	mg/L	0.03	0.03	0.03	0.03	0.03
Alkalinity	mg/L	830.3	794.2	740.2	820.4	830.4
Chloride	mg/L	177.5	177.5	160.4	174.2	170.4
Turbidity	(NTU)	4.76	3.01	5.56	6.1	4.7
TDS	mg/L	50.8	48.6	60.3	56.5	52.6
EC	µS/cm	143.6	124.5	182.3	163.5	139.6
BOD	mg/L	21	29	23	20	22
COD	mg/L	104	110	108	123	120
Colour		Colourless	Colourless	Colourless	Colourless	Colourless
Odour		Odourless	Odourless	Odourless	Odourless	Odourless
Taste		Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Bicarbonate	mg/L	1660.6	1588.4	1480.4	1640.8	1660.6
Total Hardness	mg/L	630.2	620.2	500.2	470.2	530.1
Phosphate	mg/L	5.2	3.2	6.4	7.8	6.2
Sulphate	mg/L	20.2	13.5	14.8	21.4	18.5
Calcium	mg/L	630	620	500	470	530
Sodium	mg/L	750	670	700	690	600
Potassium	mg/L	670	650	710	710	590
Iron	mg/L	0.12	1	0.9	0.9	1.2
Zinc	mg/L	0.1	0.07	0.06	0.07	0.1
Copper	mg/L	0.02	0.03	0.03	0.01	0.01
Lead	mg/L	0.01	0.01	ND	ND	0.01
Cadmium	mg/L	0.01	0.01	0.01	ND	ND
Magnesium	mg/L	0.18	0.16	0.18	0.16	0.12
Chromium	mg/L	ND	ND	ND	ND	ND
Nitrate	mg/L	7.4	6.4	6.4	5.4	6.7

ND means Not Detected

Alkalinity in the borehole water around the textile mills in the study area ranged from 740.2 to 830.4 mg/L, while alkalinity of well water ranged from 144.4 to 685.9 mg/L. These values were higher than 10.0 to 44.0 mg/L, obtained by Afolabi et al. [27] in some boreholes within Ikorodu Township due to the effect of textile effluent discharges. Alkalinity of water is the capacity to neutralize acidic nature. George et al. [28] reported that alkalinity leads to corrosion, and influences chemical, and biochemical reactions. High value of total hardness may be due the presence of mixture of dissolved polyvalent metallic ions such as calcium and magnesium cations in the rocks of the area. The high alkalinity and bicarbonate values compared to the EC and TDS may be due to appearance the intrusion of run-off into the groundwater. In fact a majority of the wells are shallow and an absence of casings or presence of fractures on these well structures may allow salt water intrusion into the well.

The turbidity values of borehole water samples ranged between 3.01 and 6.10 NTU. Turbidity in Boreholes 3 and 4 (Table 2) and all the wells (Table 3) sampled was higher than the desirable limit of 5 NTU for drinking water set by WHO [29]. Turbidity should ideally be below 1 (one) NTU. Total hardness of water is approximately the amount of calcium ion and magnesium ion dissolved in water. For the hand-dug wells, the total hardness ranged from 470.16 mg/L to 630.18 mg/L, while for bore hole water total hardness was from 660.16 mg/L to 850.16 mg/L with mean values of 85.88 mg/L and 60.5 mg/L for hand-dug well water and borehole water respectively. It is worth mentioning that high water hardness in groundwater might reduce the dissolution of metals against metal toxicity [30]. Electrical Conductivity, which relates to electrical conductance of substances dissolved in water also vary. Electrical conductivity of water is a direct function of its total dissolved salts [31]. The range of conductivity of the well water was from 192.5 to 385.6 µS/cm, with a mean of 275.5 µS/cm, while the range of EC for the borehole sample is from 124.5 to 182.2 µS/cm, with a mean of 150.6 µS/cm. In a similar study also conducted in the Ikorodu area, Afolabi et al. [27] obtained conductivity measurement data with a mean of 332.5 µS/cm for borehole water.

The maximum permissible standard for conductivity of drinking water is 250 µS/cm [32] and values exceeding 1000 µS/cm limit are indicative of saline intrusions into the groundwater [33]. This may be due to continuous discharge of the chemicals and salts used along with dyes from the textile industries. Higher value of electrical conductivity shows higher concentrations of dissolved ions [34]. Total dissolved solid (TDS) which is a measure of the total concentration of dissolved minerals in water, ranged from 62.5 to 120 mg/L in well water, while TDS for borehole water ranged from 48.6 to 60.3 mg/L. In general, total dissolved solids in the hand-dug wells were higher than that of the boreholes in the study area. However, the values obtained were within the permissible limit set by WHO.

Maximum permissible standards for TDS of drinking water are between 20-1000 µS/cm [29, 35]. The geology of the area may influence the levels of total solids in the groundwater; however, excess TDS values could be due to the dissolved solid waste originating from the discharge of the effluent from the textile industries [19]. Total dissolved solid (TDS) found in the water was mainly due to carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates, nitrogen, calcium, sodium, potassium and iron [13]. High concentration of these may affect humans, especially those suffering from kidney and heart disease [35]. Excess TDS in drinking water may also result in widespread effects on the gastric system, produce undesirable taste, cause gastrointestinal irritation and corrosion [36]. Studies have reported a significant linear relationship between EC and TDS [37-38]. Therefore, high values obtained for EC in the water samples may be attributed to higher concentration of TDS [26]. Furthermore, EC of water is a direct function of its total dissolved salts and, hence, is an index of total concentration of soluble salts in water [19]. Similarly, Govindaradjane et al. [39] reported that a high positive correlation exists between EC and chloride content of water. BOD ranged from 39 mg/L to 94 mg/L in well water samples compared to 20 mg/L to 29 mg/L for the borehole water samples. The COD for the well water ranged from 276 mg/L to 306 mg/L while it ranged from 104 mg/L to 12 mg/L for the borehole water samples.

Table 3 Physical and chemical parameters of well water samples

Parameters		Well				
		1	2	3	4	5
Temperature	ºC	28.1	27.5	28.7	28.2	28.1
pH		5.90	5.90	6.70	5.95	6.30
Acidity	mg/L	0.018	0.054	0.018	0.050	0.060
Alkalinity	mg/L	144.40	685.90	144.40	650.60	670.20
Chloride	mg/L	142.00	142.00	145.40	240.40	240.60
Turbidity	(NTU)	6.30	6.40	5.90	7.90	6.90
TDS	mg/L	70	73.8	120	83.5	62.5
EC	µS/cm	216.2	243.0	385.6	340.7	192.5
BOD	mg/L	94	67	55	68	49
COD	mg/L	306	362	276	301	297
Colour		Colourless	Colourless	Colourless	Colourless	Colourless
Odour		Odourless	Odourless	Odourless	Odourless	Odourless
Taste		Tasteless	Tasteless	Tasteless	Tasteless	Tasteless
Bicarbonate	mg/L	288.80	1371.80	288.80	1301.20	1340.40
Total Hardness	mg/L	850.16	670.14	850.13	740.16	660.16
Phosphate	mg/L	10.80	11.20	10.20	8.90	7.80
Sulphate	mg/L	23.63	26.78	24.80	24.60	25.60
Calcium	mg/L	850	670	850	740	660
Sodium	mg/L	770	775	950	970	990
Potassium	mg/L	760	650	650	720	750
Iron	mg/L	1.40	1.60	1.50	1.60	1.20
Zinc	mg/L	1.20	0.90	0.75	0.60	0.70
Copper	mg/L	0.06	0.06	0.05	0.05	0.04
Lead	mg/L	0.02	0.02	0.03	0.02	0.03
Cadmium	mg/L	0.03	0.01	0.02	0.02	0.01
Magnesium	mg/L	0.16	0.14	0.13	0.16	0.16
Chromium	mg/L	ND	ND	ND	ND	ND
Nitrate	mg/L	8.10	8.40	10.20	10.40	7.80

ND means Not Detected

1) Groundwater ionic species

The functions of groundwater ionic species such as Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^- , NO_3^-, SO_4^{2-}, and Cl^- determine the quality of any groundwater resource in terms of physical and chemical compositions and its fitness for human consumption and diverse usage [40].

Sodium (Na^+) ion ranged from 770 to 990 mg/L in samples collected from hand-dug wells while that of borehole water was between 600 to 750 mg/L. Mean Na^+ value of the hand-dug well water was 891 mg/l and that of boreholes was 682 mg/L. Sodium concentration above 50 mg/L makes the water unsuitable for domestic use [19]. Calcium (Ca^{2+}) ion for the borehole water ranged from 470 to 630 mg/L, with a mean of 436.6 mg/L (Table 2), while that of hand-dug well water ranged from 660 to 850 mg/L with a mean of 754 mg/L (Table 3). Sodium, chloride, sulphate, carbonate, and bicarbonate ions formed the bulk of the dissolved solid contents in the water samples in the study area. This is corroborated by a similar study by Rathore [14] in an assessment of water quality of the River Bandi, which was affected by textile dyeing and printing effluents in Pali, Western Rajasthan, India. Cations such as magnesium and potassium were higher in the hand-dug well water compared to the boreholes. This may be because textile mills use a lot of salts and acids like sodium carbonate, sodium bicarbonate, sodium hydroxide, sodium silicate, sodium peroxide, sodium bisulphite and bleaching powder, which may easily seep into hand-dug wells compared to the boreholes.

The sulphate ion concentration for hand-dug well water ranged from 24.6 to 26.78 mg/L while those collected from boreholes ranged from 13.48 to 21.4 mg/L. The source of sulphate ion may be attributed to chemicals used in the textile Industries. Both hand-dug wells and boreholes had low nitrates suggesting that there is no pollution from surface sources such as septic tanks in the studied groundwater sources in the sampled wells and boreholes. The chloride ion concentration ranges from 142.0 to 240.6 mg/L in the hand-dug well compared to a range of 160.4 to 177.5 mg/L in the borehole water. In unpolluted waters, chloride concentrations are usually lower than 10 mg/L [41], however high amounts of chloride and sulphate may result in hardness of water [13]. Sodium chloride, which is used as a dehydrating and antiseptic agent, is also a source of chloride in groundwater [42]. In addition, soil porosity and permeability according to Chanda [43] has a key role in building up the chloride concentration. The range values of 1480.4 to 1660.0 mg/L obtained for bicarbonates in this study were well above the permissible limit of 100mg/L for water [44]. The presence of carbonates, bicarbonates and hydroxides are the main cause of alkalinity in natural waters [19]. The bicarbonate contamination results from the salt, which is mixed with the dyes from the textile industries, and have been found to increase the EC of the water. The study revealed no significant variation in the physicochemical parameters in the water samples of well and boreholes (Table 4).

2) Heavy metals

Concentration of iron (Fe) in the different groundwater samples varied from 0.12 mg/L to 1.20 mg/L in the borehole water compared 1.20 mg/L to 1.60 mg/L found in the well water. Concentration of iron in the well water samples was generally above the 0.3 mg/L limit (Table 5) set by NIS [44] and WHO [29, 35]. This is an indication of high iron content of textile effluent in the area, which was corroborated by Siyanbola et al. [45] who reported 5.25 mg/L of Fe in industrial effluent in the same area. Iron has an effect on the usability of water when it is more than 0.1 mg/L. It precipitates after exposure to air thereby causing turbidity, staining plumbing fixtures and plastic tanks, laundry and drinks. The ingestion of large quantities of iron can result in haemochromatosis, a condition in which normal regulatory mechanisms do not operate effecttively, leading to tissue damage because of the accumulation of iron [46]. In addition to this, when the iron concentration in the domestic water supplies exceeds 0.3 mg/L limit it becomes objectionable for a number of reasons, which are indirectly related to health [35]. In this study, high iron content in the well water samples may be attributed to effluent discharge from the textile mills.

Cd was not detected in water samples taken from Boreholes 4 and 5, while Cd concentrations of 0.01 obtained in Boreholes 1, 2 and 3 were accurate with the USEPA standard (Table 5) 0.003 mg/L limit set by NIS [44] and WHO [35]. Cd concentration in Wells 1, 3, and 4 exceeded the USEPA [25] standard except for Wells 2 and 5 which were within the limit. Cadmium is a very toxic heavy metal, which can devastate a child's immune system within a short period of exposure, and the risks of Cd in Well Water 1, 3, 4 can be amplified by its ability to increase in concentration as it moves up the food chain [47].

Table 4: One-way analysis of physicochemical parameter in well and borehole water near the textile industries in Ikorodu, Nigeria

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	49.558	1	49.558	0.0003	0.985	4.113
Within Groups	5370235	36	149173.2			
Total	5370285	37				

Table 5 WHO, USEPA and NIS (Nigerian Industrial Standards) permissible limits for trace metals in drinking water

Metal	Concentration (mg/L)				
	WHO Limits[a]	US EPA[a]	NIS Limits[a]	Present Study	
				Well	Borehole
Cd	0.003	0.01	0.003	0.01	0.01
Cr	0.05	-	0.05	0.00	0.00
Cu	2.0	-	1.0	0.05	0.02
Fe	0.3	0.3	0.3	1.29	0.82
Pb	0.01	0.05	0.01	0.02	0.006
Zn	3.0	5.0	3.0	0.07	0.08

Concentration of Pb in borehole water samples in the study area ranged between 0 to 0.01 mg/L which is within the limits set by NIS and WHO [29, 35, 44]. However, concentrations of Pb in the well water were slightly above the 0.01 mg/L limit. In a related study in Ikorodu, concentration of Pb was found to be 0.14 mg/L [27] reflecting the presence of a large number of industries in Ikorodu area that may affect the groundwater resources through their effluent discharges. High Pb concentration in humans may lead to anaemia, kidney disease, cancer, interference with vitamin D metabolism, adverse effects on mental development in infants, and toxicity to the central and peripheral nervous systems [44, 48-49]. Chromium (Cr) concentrations were not detected in all the water samples. However, care should be taken to prevent Cr pollution of groundwater as industrial activities may lead to increase in the Cr level in the environment. Ingestion of water with Cr concentration above 0.05 mg/L can lead to cancer or allergic dermatitis [44]. Concentrations of Zn in the well water near the textile industries ranged between 0.60 to 1.20 mg/L and these were below the 3.0 mg/L set by NIS and WHO [35,44] and 5.0 mg/L set by USEPA [25] (Table 5). Copper concentrations in the water samples ranged from 0.01 to 0.03 mg/L in the borehole water compared to concentration ranging from 0.04 to 0.06 mg/L in the hand-dug wells. The values obtained for copper in the well water in this study were similar to the 0.064 mg/L obtained by [25] for some boreholes in the Ikorodu area. Cu concentrations in all the water samples were below the permissible limits of between 1.0 to 2.0 mg/L set by NIS and WHO (Table 4). Concentrations above the permissible limits can cause gastrointestinal disorders [44]. Concentrations of zinc in the water samples were all below the 3.0 mg/L limit set by WHO and NIS (Table 5). Concentration of zinc in the borehole water ranged between 0.06 to 0.1 mg/L, while it ranged between 0.06 to 1.20 mg/L in the well water. Generally, studies have reported direct and indirect toxic impacts of dyes and metals commonly used in textile industry on human health in the form of tumours, cancers and allergies, including growth inhibitions on different trophic levels on bacteria, protozoans, algae, plants and different animals [50-51]. There is an urgent need for the treatment of textile waste water at the source because if it is not done, these dye impurities can enter into the biogeochemical cycle and cause various problems to consumers [52].

In order to have a comparative evaluation of ground water pollution with heavy metals in the study area, we calculated their coefficients of concentration using the formula [52]:

$$K_k = C_i/C_j, \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where C_i is the chemical element, determined in a specific place and C_j is its background concentration. Potable water considered unpolluted and with lesser heavy metal concentration was used as background concentrations of heavy metals. Coefficients of concentration (K_k) give an idea of how the groundwater is perceptibly polluted by effluents that seep through the porous soil.

The values of concentration coefficients of the most prominent heavy metals, i.e., Zn, Pb, Fe and Cu showed that that ground water in the study area, especially the wells, are clearly polluted by effluent seeping through the porous soil in the area. This is possible because most of the wells are shallow and do not have well-laid inner rings. Figure 2 below showed that Fe, Pb and Zn are the most polluting metals especially in the well water in the study area. This is corroborated by Orebiyi et al. [53] in a study of shallow wells in Abeokuta Metropolis in Nigeria. The presence of heavy metals may be influenced by water pH [53].

Figure 2 Coefficients KK of heavy metals in groundwater (boreholes and wells near textile mills in Ikorodu, Nigeria).

Conclusion

The study has shown that groundwater sources, i.e., wells and boreholes near textile mills in the Ikorodu areas are polluted by effluent discharge from the industries. The well water is mostly affected by pollution from the textile industries because they are shallow and porous which allow the seepage of effluent into the groundwater. Levels of physicochemical parameters in the well and borehole water samples examined were not significantly different. However, concentrations of Fe, Cu and Pb in the well water were above the international standards, while Cd and Cr were not detected in most of the groundwater sampled. Sulphate, magnesium and potassium were higher in the hand-dug well water compared to the bore holes, which subsequently increase the water total dissolved solids and EC. Using the polluter concentration coefficients (K_k) to evaluate heavy metal pollution in the groundwater near the textile industries, it was found that Fe had the highest value of 27.47 while Cu had the lowest value of 2.00. Chemical synthetic dyes used in the textile pose serious threats to the health of aquatic organisms, humans and the general environment. It is important to enforce policies to eliminate the use of hazardous substances, and promote their substitution with safer alternatives. This can be done through construction of proper drainage systems to reduce the leakage and overflow of the effluents, and the addition of solid materials like paper and plastic bags to the effluent drains which reduces the flow velocity and increasing the percolation chances to ground water causing ground water contamination.

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