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Groundwater Suitability for Domestic Use in an Industrial Area of Ilorin, Kwara State, Nigeria

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Abstract

This study examines the effect of some industrial effluents on the quality of groundwater in shallow wells. Three industries located around Ilorin, central Nigeria were used for the study. Groundwater contamination was evaluated in water samples from six wells. Effluent samples were collected from the outfalls of the study industries and at four locations along a stream that receives effluent from the industries. Both physico-chemical characteristics and heavy metal concentrations were evaluated. The results were compared with the WHO [20] and NIS [21] standards in order to establish its suitability for human consumption. The results revealed that some of wells are contaminated by industrial effluents which renders them unsuitable for human consumption. This follows from the fact that some harmful chemicals were discovered at levels in excess of the WHO permissible values.

Keywords

Contamination, effluent, pollutant, groundwater.

1. Introduction

An adequate supply of potable water plays an important role in sustaining human life and achieving sustainable development [1]. Water quality is now an important global issue, especially with respect to domestic use. Despite the essential role of water in human life, it has a great potential for transmitting a wide variety of diseases and illnesses once it is polluted. The cause of such pollution includes discharge of untreated or partially treated industrial wastewater, pollution from households due to open disposal of domestic sewage, and agricultural runoff containing residues of fertilizers, pesticide and other chemicals [2]. The pollution of water sources is of great concern to every community because of its health hazard to people who use the water for washing, cooking, bathing and drinking. There are several diseases such as cholera, dysentery, typhoid fever, ring worms, skin irritation, and many other illnesses associated with the consumption and use of polluted and contaminated water [3].

Access to drinking water has thus become a vital and persistent environmental health challenge in developing countries and all over the globe ([4] [5] [6]). For most communities, the most secure source of safe drinking water is insufficient pipe-borne water from municipal water treatment plants. Over years, residents of Ilorin, an urban city in central Nigeria, adopted other means of supplementing the inadequate pipe borne water supply from the public service provider, the Kwara State Water Corporation [7]. Other sources of water supply within Ilorin metropolis includes boreholes, hand dug wells, water tankers, bottled and sachet water, and water vendors ([8] [9]). Hand dug wells (a category of groundwater) among aforementioned sources has been found to be readily explored to meet community water requirement or make up the short fall within the metropolis ([10] [9]).

Groundwater quality is threatened mainly by human activities, although harmful substances are sometimes introduced by natural processes [11]. Ground water and contaminants can move rapidly through fractures in rocks. Fractured rock presents a unique problem in locating and controlling contaminants because the fractures are randomly spaced and do not follow the contours of the land surface or the hydraulic gradient. Contaminants can also move into the ground water system through macro-pores—root systems, animal burrows, abandoned wells, and other systems of holes and cracks that supply pathways for contaminants [12]. [13] has observed that the present method of transportation and ultimate disposal of industrial effluents is unsafe. Industrial waste-water originates from the wet nature of the largest industries which require large quantities of water for processing and disposal of wastes. Most industries are therefore located near water sources which make the pollution potential of industrial wastewater far greater than that of domestic waste-water [14]. Some wells rely on artificial recharge to increase the amount of water infiltrating an aquifer, often using water from storm runoff, irrigation, industrial processes, or treated sewage. Despite the fact that various devastating ecological and human disasters which have continuously occurred over the years implicate industries as major contributor, it does not rule out the importance of industrialization. According to [15], the urge for industrialization has been the major want for most developing countries of the world. Industrial waste and emissions contain toxic and hazardous substance most of which can be detrimental to human health [16]. Apart from industries, other serious source of pollution of well water include: human waste from latrines and septic tanks; runoffs water and; agrochemicals such as pesticides and nitrates ([2] [17]).

As earlier mentioned, wells are a vital and common source of water in Ilorin and some of these are located along the course of Otin stream. This local waterway receives industrial effluent from some notable Industries in the city. This study investigates the effect of the effluent discharge into the stream on the quality of well water within the immediate catchment of the stream. The study will be helpful in assessing the impact of the industrial effluent on the groundwater of the surrounding wells and determine their suitability for human consumption. Water samples from wells within the area were subjected to physicochemical investigations in order to achieve the set aim and objectives.

2. Materials and Methods

2.1 The Study Area

Figure 1. Modified google earth imagery showing the study location

The study was carried out on wells located within the catchment of the Otin stream located in Ilorin central Nigeria. Otin stream runs from western part of the metropolis and it discharges directly into the Asa River channel. The sampling point along the stream lies between Latitude 8^{O} 28^{I} 20^{II} N; Longitude 4^{O} 31^{I} 34^{II} E and Latitude 8^{O} 28^{I} 36^{II} N; Longitude 4^{O} 33^{I} 15^{II} E (Figure 1).

2.2 Sampling and Laboratory Analysis

A preliminary survey was carried out to identify the location and selection of suitable representative sources. A total of six wells surrounding three industries were selected. The effluent point of these three industrial locations were evaluated in other to confirm their relationship in terms of properties with the surrounding wells. Samples were also taken at both upstream and downstream of the river relative to the discharge points. The layout of the sample area is as shown in Figure 2. The rationale behind the sampling point is the preliminary investigation which shows a possibility of groundwater pollution from industrial effluents discharged into the river channels. The sampling points were of three categories and they are: 6 samples of well water; 4 samples of stream water; and 3 samples of industrial effluents (Figure 1 and Table 1). The well water is the principal target in order to evaluate the groundwater quality in the study area while the stream and effluent water samples served as control points.

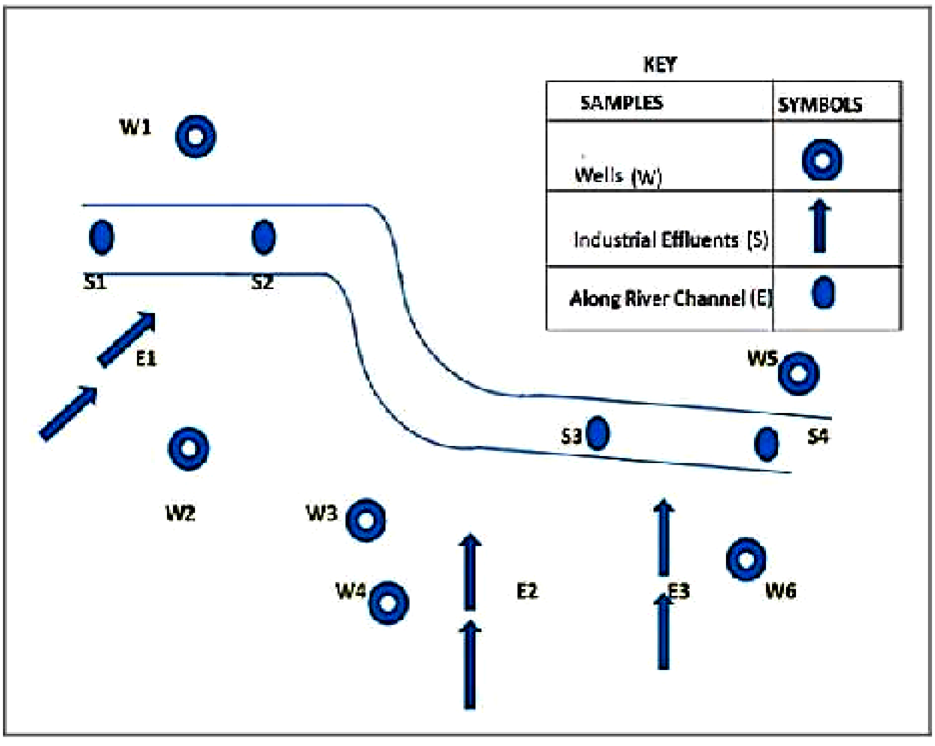

Figure 2. Layout of the sampling area (not to scale)

Table 1. Location and Coordinates of Samples Stations

S/No	Samples	Longitude (E)	Latitude (N)	Sampling Area
1	S1	04 31' 34"E	08 28' 20"	Saw Mill (Upstream)
2	S2	04 31' 36"E	08 27' 20"	Saw Mill (Downstream)
3	E1	04 31'40"E	08 28' 20"	Saw Mill (Effluents)
4	W1	04 31'42"E	08 28' 20"	Saw Mill (Well 1)
5	W2	04 31' 37"E	08 28' 19"	Sawmill (Well 2)
6	E2	04 32' 14"E	08 27' 22"	Global Industry (Effluent)
7	W3	04 32'18"E	08 27' 25"	Global Industry (Well 3)
8	W4	04 33' 28"E	08 27' 30"	Global Industry (Well 4)
9	E3	04 33' 08 "E	08 28' 32"	Tuyil Pharmacy (Effluent)
10	S3	04 33' 07"E	08 28' 33"	Tuyil Pharmacy (Upstream)
11	S4	04 33' 09"E	08 28' 34"	Tuyil Pharmacy (Downstream)
12	W5	04 33' 12"E	08 28' 33"	Tuyil Pharmacy (Well 5)
13	W6	04 33' 15"E	08 28' 36"	Tuyil Pharmacy (Well 6)

The samples were taken during the dry season of March 2016 to ensure that the effluent from surface run-off did not contribute to the contamination of the groundwater. Dilution of the effluents is also low because of the little flow in the stream at this time. Samples were taken in white plastic water bottles which were rinsed properly as recommended by [18] before labelling, storage and quality evaluation at laboratory. A total number of 21 parameters were tested. These are Temperature, *p*H, Turbidity, Conductivity, Total Dissolved Solid (TDS), Colour, Total Hardness, Alkalinity, Nitrate, Sulphate, Zinc, Aluminium, Barium, Chromium, Chloride, Copper, Fluoride, Iron, Manganese, Calcium and Ammonia. Some of the parameters were recorded in-situ at the point of sampling while the analyses of other various water quality parameters were conducted following standard analytical methods as described by [19] and [20].

2.3 Analytical Method

Results of the laboratory analysis were subjected to data evaluation by standard statistical methods and the results were compared with International standards for drinking water and Nigerian Standards of Water Quality Guidelines as specified by [21] and [22] respectively.

3. Results

The detail results of both the physical and the laboratory test conducted are as shown in Tables 2 and 3. Seven physico-chemical parameters were evaluated and they are temperature, total hardness, TDS, pH, colour, turbidity and conductivity (Table 2). For heavy metal evaluation, 14 parameters were considered as discussed in section 4 and these include: Calcium, Alkalinity, Nitrate, Sulphate, Zinc, Aluminium, Barium, Chromium, Chloride, Copper, Fluoride, Iron, Manganese and Ammonia (Table 3).

4. Discussion

From the global summary of all the tested parameters of the samples, considering the mean values, only the pH has value greater than the permissible value specified by NIS/WHO as shown in Table 4. For the physico-chemical parameters assessment of all the wells, most of the parameters were found to be within the permissible level specified by NIS/WHO. However, on individual analysis as fully described in section 4.2, many of the parameters were found to make most of the wells unsuitable for human consumption.

Table 2. Results of Physico-Chemical Characteristics of the Samples

Samples		Temp (^{O}C)	pH	Turbidity (NTU)	Conductivity (micro ohms/cm)	TDS (mg/l)	Colour (HU)	Total Hardness (m/l)
Well	W1	26.10	8.29	3.43	783	392	2.67	8.45
	W2	26.00	7.63	1.35	324	163	6.2	15.1
	W3	26.40	8.52	15.40	495	245	0.12	25.0
	W4	26.20	11.86	29.50	2199	1099	0.53	32.0
	W5	26.20	8.6	2.33	567	283	2.43	440
	W6	26.00	8.4	2.06	554	277	1.65	590
Stream	S1	26.20	8.05	130	381	190	4.3	15.0
	S2	26.30	7.95	12.40	391	195	0.23	10.4
	S3	26.00	8.3	12.30	429	215	2.5	282
	S4	26.00	7.9	15.60	442	221	8.9	340
Effluent	E1	26.30	7.79	1.75	472	236	0.41	6.8
	E2	26.40	11.02	22.60	1334	667	0.32	10.8
	E3	26.70	6.41	56.1	429	215	5.72	380
NIS/WHO		Ambient	6-8.5	1-5	1000	500	5	150

Table 3. Results of Heavy Metal Concentration of the Samples

Samples		Alkalinity (mg/l)	Nitrate (mg/l)	Sulphate (mg/l)	Zinc (mg/l)	Aluminium(mg/l)	Barium (mg/l)	Chromium (mg/l)	Chloride (mg/l)	Copper (mg/l)	Fluoride (mg/l)	Iron (mg/l)	Manganese (mg/l)	Calcium (mg/l)	Ammonia (mg/l)
Well	W1	20	30	8	2.05	0.02	0.02	0.053	18.9	0.05	0.53	0.08	0.12	4.4	0.38
	W2	25	21	4	1.68	0.04	0.06	0.04	17.1	1.8	0.3	0.06	0.15	7.5	0.4
	W3	60	10	5	0.05	0.02	0.07	0.079	15.8	0.64	0.35	0.19	0.11	12.5	0.38
	W4	52	8	6	0.23	0.06	0.08	0.082	26.0	0.25	0.24	007	0.14	16	0.03
	W5	240	49	35	0.07	0.06	0.25	0.023	4.30	0.73	0.01	0.13	0.95	220	0.01
	W6	244	36	38	1.53	0.05	0.10	0.035	17	1.1	0.41	0.09	0.75	295	0.0
Stream	S1	15	4	28	0.02	0.01	0.13	0.010	3.5	0.85	7.56	0.03	0.01	7.5	0.38
	S2	18	9	31	0.21	0.03	0.03	0.03	6.7	0.22	0.81	0.05	0.03	5.2	0.45
	S3	140	38	42	0.06	0.04	0.05	0.063	16.7	0.52	0.28	0.17	0.10	141	0.01
	S4	130	34	53	3.7	0.08	0.09	0.012	8.21	2.10	0.75	0.28	0.08	170	0.01
Effluent	E1	24	28	15	2.6	0.05	0.08	0.012	15	0.14	0.12	0.13	0.09	3.4	0.92
	E2	38	23.1	26	1.8	0.05	0.04	0.04	17.2	0.79	0.04	0.04	0.04	5.4	0.39
	E3	40	45	30	1.95	0.09	001	0.08	25.0	0.59	0.09	0.21	0.03	190	0.42

NIS/WHO	200	45	100	3	0.2	0.70	0.05	100	1	1.5	0.3	0.1	150	5

Table 4. Global Summary of the Samples

Parameters	Samples									
	Well Water			Stream Water			Effluent			NIS/WHO
	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	
Temp (^{O}C)	26.15	26	26.4	26.13	26	26.3	26.47	26.3	26.7	Ambient
pH	8.88	7.63	11.86	8.05	7.9	8.3	8.41	6.41	11.02	6-8.5
Turbidity (NTU)	9.01	1.35	29.5	42.58	12.3	130	26.82	1.75	56.1	1-5
Conductivity (micro ohms/cm)	820.33	324	2199	410.75	381	442	745	429	1334	1000
TDS (mg/l)	409.83	163	1099	205.25	190	221	372.67	215	667	500
Colour (HU)	2.27	0.12	6.2	3.98	0.23	8.9	2.15	0.32	5.72	5
Total Hardness (m/l)	185.09	8.45	590	161.85	10.4	340	132.53	6.8	380	150
Alkalinity (mg/l)	106.83	20	244	75.75	15	140	34	24	40	200
Nitrate (mg/l)	25.67	8	49	21.25	4	38	32.03	23.1	45	45
Sulphate (mg/l)	16	4	38	38.5	28	53	23.67	15	30	100
Zinc (mg/l)	0.94	0.05	2.05	1	0.02	3.7	2.12	1.8	2.6	3
Aluminium (mg/l)	0.04	0.02	0.06	0.04	0.01	0.08	0.06	0.05	0.09	0.2
Barium (mg/l)	0.1	0.02	0.25	0.08	0.03	0.13	0.37	0.04	1	0.7
Chromium (mg/l)	0.052	0.04	23	0.03	0.01	0.06	0.04	0.01	0.08	0.05
Chloride (mg/l)	16.52	4.3	26	8.78	3.5	16.7	19.07	15	25	100
Copper (mg/l)	0.76	0.05	1.8	0.92	0.22	2.1	0.51	0.14	0.79	1
Fluoride (mg/l)	0.31	0.01	0.53	2.35	0.28	7.56	0.08	0.04	0.12	1.5
Iron (mg/l)	1.26	0.06	7	0.13	0.03	0.28	0.13	0.04	0.21	0.3
Manganese (mg/l)	0.37	0.11	0.95	0.06	0.01	0.1	0.05	0.03	0.09	0.1
Calcium (mg/l)	92.57	4.4	295	80.93	5.2	170	66.27	3.4	190	150
Ammonia (mg/l)	0.2	0	0.4	0.21	0.01	0.45	0.58	0.39	0.92	5

4.1 Physico-chemical Parameters

Temperature values for various samples ranged from 26.0 ^{O}C to 26.4 ^{O}C. The values obtained for the streams and the effluents were also in the range of the values obtained for the well. All these values were within the permissible limits of NIS standard (Table 2). It is noteworthy that high water temperature enhances the growth of microorganisms that can aid the increase taste, odour, colour and corrosion problems. Moreover, cool water is generally more palatable than warm water [16].

Total hardness expresses the concentration of both calcium and magnesium and its result is presented in Table 2. The samples from wells W1, W2, W3 and W4 fell within the permissible standard of NIS/WHO while the samples from wells W5 and W6 have values higher than the NIS/WHO standard. The higher value of wells W5 and W6 can be attributed to the effluent from Tuyil Pharmaceutical Industry, (sample E3) which was relatively higher. Though, there is a specified limit, but no health-based guideline value is proposed for hardness [16]. However, the degree of hardness in water may affect its acceptability to the consumer in terms of taste and scale deposition.

TDS comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and small amounts of organic matter that are dissolved in water. TDS in drinking-water originate from natural sources, sewage, urban runoff and industrial wastewater. [23] reported that high TDS values have the tendency to absorb heat from the sun thereby raising the temperature and increasing the turbidity of water, hence, its high level presence in drinking-water may be objectionable to consumers. The result as presented in Table 2 shows that the samples from wells W1, W2, W3, W5 and W6 fell below the highest permissible value of 500mg/l specified by NIS/WHO. The sample from well W4 has a higher value than the standard. This can be attributed to the effluent source in the area (Sample E2).

A ***p*H** value higher than 8.5 indicates that a significant amount of sodium bicarbonate may be present in the water. The test results for *p*H shows that the sample from wells W1, W2, and W6 were within the recommended value of 6-8.5 as shown in Table 3. Wells W3, W4 and W5 had values greater than the permissible *p*H values recommended by NIS/WHO (Table 2). It was discovered that the high *p*H of wells W3 and W4 were attributable to the major effluent source in the area (i.e. sample E2). Low *p*H of water results in corrosion of metallic buckets and household utensils, a *p*H of 6.0 is not too acidic to cause serious corrosion problems.

Colour in drinking-water is usually due to the presence of coloured organic matter (primarily humic and fulvic acids) associated with the humus fraction of soil. It can also be strongly influenced by the presence of iron and other metals, either as natural impurities or as corrosion products. It may also result from the contamination of the water source with industrial effluents and may be the first indication of a hazardous situation [16]. All the wells except well W2 samples fell below the recommended value of 5-50 Hu by NIS/WHO for water colour (Table 2). The high value recorded in well W2 cannot be traced to the industrial wastewater since this well, by proximity is not close to the effluent sample with high values (i.e. E3). The lower values of the stream samples that serve as control also attest to this.

Turbidity may be an indication of presence of inorganic particulate matter in some groundwater and can adversely affect the efficiency of disinfection. The samples from wells W3 and W4 had turbidity values higher than the permissible value recommended by NIS/WHO (Table 2). Their high values can be linked with the effluent in the area (since E2 and E3 has higher values). Other samples had values below the permissible 5 NTU. The high value of turbidity may aid water borne diseases because it affects the efficiency of disinfectants.

Conductivity is a measure of free ions in a water sample and its high value indicates the presence of metals. All the well samples except W4 had values below the permissible limit recommended by NIS/WHO as shown in Table 2. The high value of well W4 can be attributed to the effluents from sample E2 which was also high. However, the control samples obtained from the receiving stream does not show any significant correlation.

4.2 Heavy Metal Concentrations

Chloride in drinking-water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. Excessive chloride concentrations increase rates of corrosion of metals in the distribution system, depending on the alkalinity of the water. Excessive concentration of chloride can make water distasteful and, therefore, unfit for drinking [24] and cause corrosion in the water supply system and its removal method is expensive [25]. The study shows that its concentration in each of the wells is within the NIS/WHO recommended standard (Table 3). The samples from the industrial effluents and the streams were also within the limit, which is a clear indication that industrial wastewater has not contributed excessive chloride ion to the groundwater in the area.

Nitrate in excess of 45mg/l is of health significance especially to pregnant women and infants under six months, although its content is apparently tolerated by most adults [16]. The *Nitrate* concentrations in well samples W1, W2, W3 W4 and W6 were found to be within the permissible level specified by NIS/WHO standards. Only sample W5 had higher values of nitrate concentration above permissible value as shown in Table 3. However, the high values of samples W5 and W6 can be traced to the higher value of nitrate concentration found in the effluent sample E3 and control stream samples S3 and S4.

Excessive ***Sulphate*** concentration in water tends to produce a bitter taste. High *sulphate* concentration can cause intestinal irritation and have a laxative effect on people in accordance to [16]. The concentrations of *Sulphate* for all the well samples were found to be lower than the highest permissible level of 100 mg/l specified by NIS/WHO standard (Table 3).

According to [16], a total ***alkalinity*** that is naturally up to 400mg/l is not a health hazard while very low alkalinity is associated with low *p*H values and may indicate potential for problems due to corrosion. *Alkalinity* is the measure of the hydroxyl ions in a sample. Well water from samples W5 and W6 had alkalinity values greater than the permissible limit specified by the NIS/WHO. The high values in the two well samples are traceable to the stream around the wells while there is no correlation with the effluent samples. Other four well samples (W1, W2, W3 and W4) as shown in Table 3 were within the permissible level of alkalinity as specified by the standard.

It has been hypothesized that ***aluminium*** exposure is a risk factor for the development or acceleration of onset of Alzheimer disease in humans [16]. Aluminium is the most abundant metallic element and constitutes about 8% of the Earth's crust. In this study, all the well samples had values lesser than the permissible limit specified by NIS/WHO standard as shown in Table 3. Samples from the stream and industrial effluents were also within the specification. This is an indication that the groundwater from the wells in the area under study is not contaminated by Aluminium presence.

Chromium is widely distributed in the Earth's crust. According to WHO [16], the guideline value which was first proposed in 1958 for hexavalent chromium, based on health concerns, but was later changed to a guideline for total chromium because of difficulties in analyzing for the hexavalent form only. For this study, the presence of *chromium* in well samples W1, W3 and W4 were found to be higher than the permissible limit specified by NIS/WHO standard. This can be traced to the effluent sources from sample E3 as it equally showed a high presence of this metal (Table 3). This indicates that the water from this source is not safe for human consumption because of the excessive presence of the chromium as shown by the analysis.

Copper is both an essential nutrient and a drinking-water contaminant. Samples W1 and W6 had values greater than the permissible limit specified by NIS/WHO standard and both are traceable to the streams around the wells. The other 4 wells has the copper level within the permissible limit as shown in Table 3. This is an indication that the water from wells W1 and W2 are unfit for human consumption in order to guide against Gastro-intestinal disorder as a result of presence of *Copper*.

Levels of ***zinc*** in surface water and groundwater normally do not exceed 0.01 and 0.05 mg/l, respectively. However, drinking-water containing zinc at levels above 3mg/l may not be acceptable to consumers. Zinc presence in the groundwater of the study area was found to have values lesser than the permissible limits as specified by NIS/WHO, although, sample S4 from the stream water show an appreciable level of zinc which may be as result of combined effect of the effluent discharge from all the industries along the stream. Table 3 shows the detail level of zinc concentration for all the tested samples.

Barium is present as a trace element in both igneous and sedimentary rocks, and barium compounds are used in a variety of industrial applications. However, barium in water comes primarily from natural sources. There is no evidence that barium is carcinogenic or mutagenic. Barium has been shown to cause nephropathy in laboratory animals, but the toxicological endpoint of greatest concern to humans appears to be its potential to cause hypertension [16]. In all the well samples, the value of barium concentration was found to be less than the permissible limits specified by NIS/WHO. In the case of effluent samples, E3 shows a high level of barium even though its effect is not reflected in the groundwater samples. Levels of barium for the samples are shown in Table 3.

Iron is one of the most abundant metals in the Earth's crust. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/l [21]. Iron stains laundry and plumbing fixtures at levels above 0.3 mg/l; there is usually no noticeable taste at iron concentrations below 0.3 mg/l, and concentrations of 1–3 mg/l can be acceptable for people drinking anaerobic well water [16]. In this study, the iron concentration in all the sampled wells with exception of sample W4 was found to be less than the permissible limits specified by the NIS/WHO standard. The level of iron in sample well W4 was very high and cannot be linked to neither the effluent samples nor the control samples of stream water as shown in Table 3. The high presence of iron W4 could be as a result of the natural deposit or the elements presents in that aquifer and this has rendered the water from W4 unsuitable for human consumption.

Manganese is naturally occurring in many surface water and groundwater sources, particularly in anaerobic or low oxidation conditions, and this is the most important source for drinking-water. According to [22], ***manganese*** is a nuisance chemical that causes neurological disorder in human and causes troublesome stains and deposits on light coloured clothes and plumbing fixtures. Its concentrations below 0.05–0.1 mg/litre are usually acceptable to consumers but may sometimes still give rise to the deposition of black deposits in water mains over an extended period; this may vary with local circumstances [21]. All the wells samples had *manganese* concentration greater than the permissible limits specified by NIS/WHO standard. This is neither attributable to the industrial effluents nor stream water samples as shown in Table 3. The higher concentration of this metal in these wells makes them unsuitable for human consumption.

Ammonia in the environment originates from metabolic, agricultural and industrial processes and from disinfection with chloramine. Natural levels in groundwater and surface water are usually below 0.2 mg/l and anaerobic groundwater may contain up to 3mg/l [16]. Ammonia can compromise disinfection efficiency, result in nitrite formation in distribution systems, cause the failure of filters for the removal of manganese and cause taste and odor problems. *Ammonium* presence in the entire well, stream and effluent water samples were found to be at value lower than the maximum permissible limit specified by NIS/WHO standard. It is an indication that the groundwater in the area is free from ammonia contamination. Table 3 shows the value for each of the tested samples.

Fluoride occurrences in groundwater, concentrations vary with the type of rock the water flows through but do not usually exceed 10 mg/l. Epidemiological evidence show that concentrations above this value carry on an increasing risk of dental fluorosis, and progressively higher concentrations lead to increasing risks of skeletal fluorosis [16]. *Fluoride* presence in all the well samples was found to be within the permissible level specified by NIS/WHO standard. All samples from the effluents were also found to be adequate. For the stream samples, only one of the samples was found to have excessive presence of this metal as shown in Table 3.

Calcium cause water hardness and result from limestone type materials in underground soil layers. The presence of high calcium level shows consistence of water hardness in such sources of water. Hardness of water causes greasy rings on the bathtubs, film on dishes or hair after washing and poor laundry results. *Calcium* presence as shown in Table 3 were found to be adequate in well samples W1, W2, W3 and W4, while samples in W5 and W6 had their values higher than the maximum permissible specified by the NIS/WHO. The high values in these two wells are traceable to effluents from the industries and can be linked to high value of presence of this metal found in effluent sample E3 and control stream samples S3 and S4.

Conclusion

Groundwater quality assessment helps to determine its suitability for human consumption. However, this work has also sought to examine the effects of the industrial discharge effluents on the quality of groundwater in the study area. The parameters evaluated includes the quantitative measurement of; Temperature, pH, Turbidity, Conductivity, Total Dissolved Solids, Odour, Colour, Total Hardness, Calcium, Alkalinity, Nitrate, Sulphate, Zinc, Aluminium, Barium, Chromium, Chloride, Copper, Fluoride, Iron, Manganese, and Ammonia in the samples. The results reveal the presence of pollutants in the groundwater of the study area. It can also be deduced that samples E2 and E3 presents the greatest dangers to groundwater quality in the study area. Sample from W4 indicates that the well is the most affected of the wells sampled. Wells W1 and W5 to a lesser extent also requires some attention. The consequence of this may result in water borne diseases if the situation is not controlled. The Federal Ministry of Health, Division of Water Resources and the Federal Ministry of Water Resources, Federal Environmental Protection Agency and other appropriate authorities should be empowered, not only to set guidelines, but also to enforce compliance to the guidelines. There is the need for the government to ensure that the industries have some form of wastewater treatment before their effluents is discharged into streams and rivers.

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