World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Effect of waste dumpsite on the surface and groundwater supplies using water quality index in Afikpo south local government area, Ebonyi state

J. A. Ibiam [1,*], A. N. Oko [1], C. C. Amaechi [1], C. O. Apie [1], U. I. Nwali [1] and H. E. Isu [2]

[1] *Department of Science Laboratory Technology, Akanu Ibiam Federal Polytechnic, Unwana, PMB 1007 Afikpo, Ebonyi State Nigeria.*
[2] *Department of Urban and Regional Planning, Akanu Ibiam Federal Polytechnic, Unwana, PMB 1007 Afikpo, Ebonyi State Nigeria.*

World Journal of Advanced Research and Reviews, 2024, 21(02), 1343–1352

Publication history: Received on 07 January 2024; revised on 14 February 2024; accepted on 17 February 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.21.2.0547

Abstract

The research examined the effect of waste dumpsite on the surface and groundwater supplies using water quality index (WQI) in Afikpo South Local Government Area of Ebonyi State. Fifteen samples were drawn from fifteen locations. The samples were analyzed using standard methods. The results of the analyses were compared with the World Health Organization (WHO) drinking water standard. The WQI of the water samples were calculated and compared with the classification of water quality status. The results showed that the pH of the water samples ranged 4.6 ± 0.047 – 6.70 ± 0.090, EC 7.26 ± 1.63 – 2450 ± 4.32, Turbidity 0.50 ± 0.082 – 2.00 ± 0.094, TDS 23.10 ± 0.047 - 1830 ± 17.00, Alkalinity 45 ± 0.47 - 2080 ± 4.71, Total Hardness 4 ± 0.47 – 170 ± 0.94, DO 5.07 ± 0.012 – 7.72 ± 0.016, BOD 0.4 ± 0.047 – 12.8 ± 0.082, NO_3^- 1.14 ± 0.009 – 32.69 ± 0.047 and 0.09 ± 0.00 – 15.6 ± 0.028. The results showed that the pH, Turbidity, Total Hardness, NO_3^- were all below the WHO drinking water standard. All the locations of the water samples showed some levels of acidity. Apart from location MB that recorded high levels of TDS and Alkalinity every other location was below the WHO permissible limit of drinking water standard. The results of the analysis also revealed that the WQI value of the water was 57.92 and this was below the critical value of 100. From the findings, all the water samples need to be treated with alkali to reduce the low pH while the water samples generally need to be given comprehensive treatment before usage.

Keywords: Water Quality Index; Waste dumpsites; Borehole; Ebonyi State; Turbidity

1. Introduction

Water is the most abundant resource on earth and about 70 percent of the human body and 60 – 70 percent of plant cells is made up of water [1]. It is very vital for the survival of any form of life. On the average, a human being consumes about 2 litres of water every day. About 80 percent of the earth's surface is covered by water [2]. Out of the estimated 1,011 million Km^3 of the total water present on earth, only 33,400 m^3 of water is available for drinking, agriculture, domestic and industrial use.

Availability of water is one of the determinants of human settlement, existence and activities on the earth. Its quality is of all the environmental concerns that developing countries face. The lack of adequate, good quality water remains the most serious [3].

Water, whether from underground or surface sources, found in nature is polluted [4]. The pollution of these water sources would render them unwholesome for consumption and may be costly and difficult to treat [5]. Pollution could

* Corresponding author: J. A. Ibiam

increase as a result of increase in industrialization. On one hand and population explosion which have resulted to rise in demands of water.

Handling of solid waste is a major issue in several countries, especially in developing countries with high population growth [5]. In most developing countries, solid wastes are the major input of dumpsites. With respect to the hydrological analysis of groundwater, it flows from areas of higher topography towards areas of lower topography thereby bringing about the examination of the degradable material which form leachate and pollute the groundwater and surface water of the study areas.

Dumpsites is a common practice in developing countries and one of the cheapest methods for organized waste management in many parts of the world [6],[7]. Dumpsites pose serious threat to the quality of surface and groundwater if improperly managed and secured [8]. This threat to the surface and groundwater could be dangerous and harmful. The level of this threat depends on the composition and quantity of leachate and the distance of a dumpsite from the water source.

In Ebonyi State, Nigeria, the commonest means of disposal of solid wastes, whether urban or rural settings is through dumpsites/landfills. The massive population growth has put pressure on the available dumpsites and landfill which dotted the landscape of these areas. Waste generated from households, markets, schools, farms and industries etc. are deposited to the dumpsites since it is the cheapest form of disposal [9].

Wastes deposited at the dumpsites are subject to erosion onto the surface water or infiltrate into the groundwater. By percolation of water through the waste substances, variety of organic and inorganic substances and microorganisms [10] which are termed leachate permeate through the soil, surface and groundwater in the vicinity of the dumpsites and in turn pollutes both the surface and groundwater with the immediate surroundings in the subsoil [11] through a combination of physical, chemical and microbial processes of the dumpsites.

The aim of this study is to investigate the effects of waste dumpsites on the surface and groundwater supplies using water quality index (WQI) in Local Government Area, Ebonyi State. The study will investigate the physical and chemical water quality parameters to determine if they meet the drinking quality standard of WHO.

1.1. Water Quality Index (WQI)

WQI is a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water for human consumption [12]. This is also known as water pollution index and is a number that expresses water quality by aggregating the measurements of water quality parameters such as dissolved oxygen (DO), pH, NO_3^-, PO_4^{3-}, NH_3, Cl, hardness, metals etc). It is regarded as one of the most effective way to communicate water quality. Water quality is assessed on the basis of calculated water quality indices [12]. The water quality index was developed by the [13]. The concept of WQI is based on the comparison of the water quality parameter with respective regulatory standards. It is proximity – to – target composite of water quality, adjusted for the density of monitoring stations in each country, with a maximum score of 100. In the classification of water quality status based on water quality index [14], water with WQI in the range of 0 – 25 is excellent, between 25 - 50 as good, 51 - 70 as poor, 76 – 100 very poor and above 100 as unsuitable for drinking. Usually the lower score alludes to better water quality (excellent, good) and higher score to degraded quality (bad, poor).

1.2. Calculation of Water Quality Index

The standards for drinking purposes as recommended by [15] have been considered for the calculation of WQI. There are three steps for computing WQI. The weighted Arithmetic method [16] was used for the calculation of WQI. Further, quality rating or sub-index (Equation 10) was calculated using the following expression:

$$Qn = 100[Vn - Vi] / [Sn - Vi] \qquad \text{.............................. Equationn 10}$$

Where,

n = is a number reflecting relative value of this parameter in the polluted water with respect to its standard permissible value Sn

Q_n = quality rating for the n^{th} water quality parameter

V_n = estimated value of the n^{th} parameter at a given water sampling station

S_n = standard permissible value of the n^{th} parameter

V_i = ideal value of nth parameter in pure water (i.e., 0 for all other parameters except the parameters pH and Dissolve oxygen *[7.00 and 14.60 mg/l, respectively]*)

The unit weight (Equation 11) was calculated by a value inversely proportional to the recommended standard value Sn of the corresponding parameter.

$$W_n = k/S_n \qquad \text{.................................. Equation 11}$$

Where

Wn	=	unit weight for nth parameter
S_n	=	standard permissible value for nth parameter
K	=	proportionality constant.

The overall WQI (Equation 12) is calculated by the following equation

$$WQI = \sum_{n=1}^{n} \left(\frac{Q_n W_n}{W_n} \right) \qquad \text{................................. Equation 12}$$

The investigation will include the heavy metals in the water sources. The water quality index mode will be used to quantify and evaluate the quality of the water [6] Table 1.

Table 1 Classification of Water Quality based on Weighted Arithmetic WQI Method

WQI	Rating of Water Quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
>100	Unsuitable for drinking	E

Source: [6]

Various statistical packages will be deployed in this work.

2. Material and methods

2.1. The Study Area

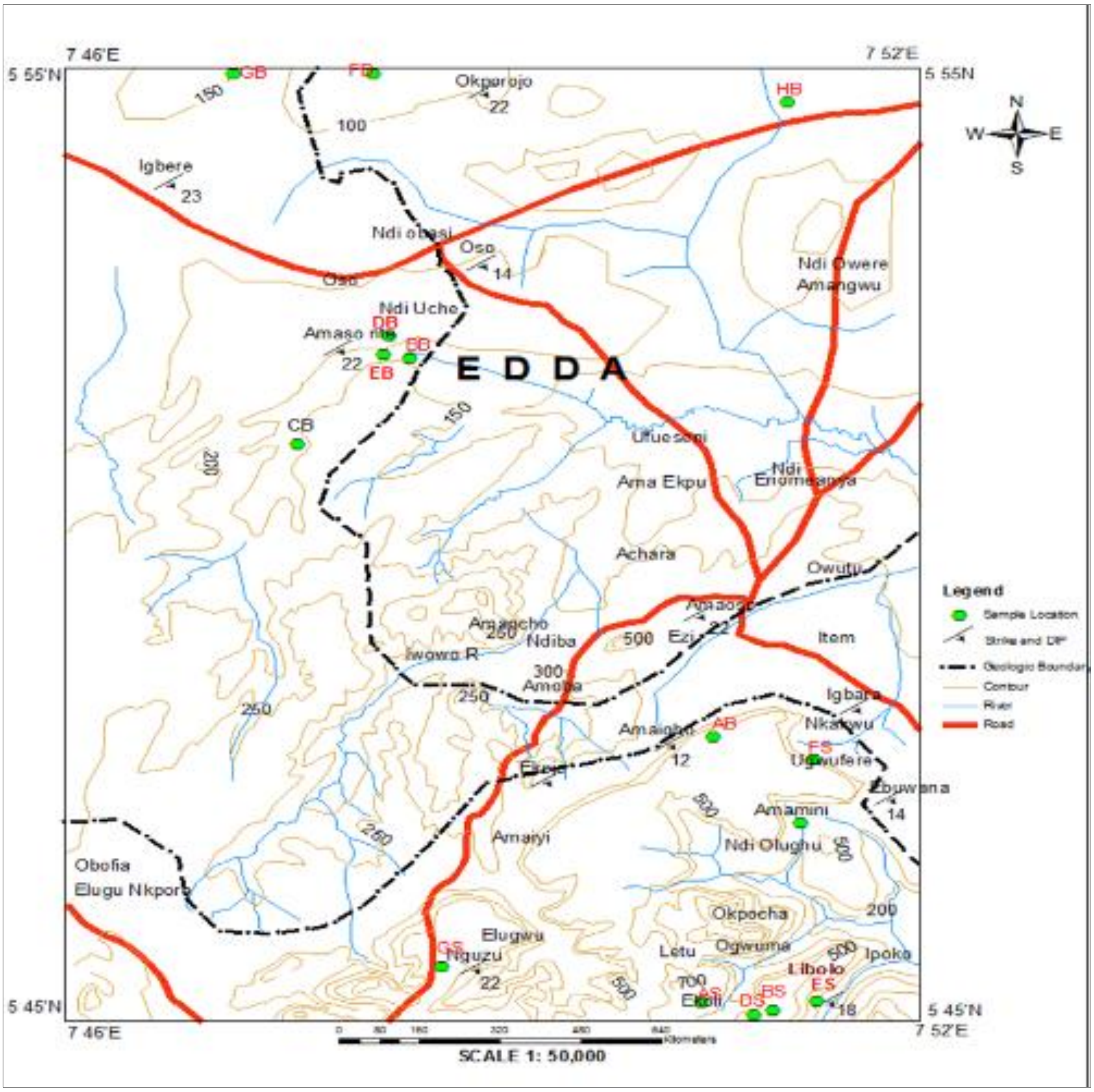
The study area was Edda Local Government Area, located in the Southern Zone of Ebonyi State, Nigeria. Geographically, Edda Local Government Area situate between 70.45 and 50.58 latitudes north of the equator and lies about 90 miles (144.873 km) north of the Atlantic coast. Her surface land area is about 86.14 square miles (223.1 square kilometres) [17]. Edda has boundaries on the North with Ohaozara; on the South by Ohafia Local Government Area; on the East by Unwana/Afikpo and by the West with Akaeze/Nkporo. The local government area occupies about 378 square kilometers with population of about 240,000 according to the 2006 national demography (Ebonyi State).

The main occupation of the people is largely farming. Edda Local Government Area is richly blessed with large mineral deposits such as: lead, zinc, copper, gypsum, coal, crude oil and gas, as well as kaolin, laterite and igneous rocks [18].

2.2. Sample Locations and Codes

Samples were collected at Ekoli, Nguzu, Ebunwana, Owutu, Etiti, Amangwu and Oso, Autonomous Communities in Edda Local Government Area. These seven autonomous communities covered the two major geological divisions of Edda Local Government Area with Ekoli, Nguzu and Ebunwana representing the upper division of Edda Local Government Area, while Owutu, Etiti, Amangwu and Oso represent the lower part of Edda Local Government Area. A total of 21 sample stations (Figure 1) were mapped out in the locality and coded as Anyoji(ASp), Eme-Udu (BSp), Nne-Oji (CSp), Achi-Ogba (DSp), Iminika spring (ESp), Mgbogho Libolo (FS), Olo Ekoli (GS), Ofoiyi Owutu (HS), Oghuekpe Amangwu

(IS), Iyere Ogwuma (JS) while the borehole samples included, Amaukabi (KB), Nde Okpo (LB), Okporojo Sec School (MB) and Julius Awa (NB). The control water sample was drawn from a borehole at Ninth Mile corner in Enugu State and was .coded OB and serves as the Control. Electronic Hand-held GPS instrument was used to record the co-ordinates of each sampling point (Table 2).



Source: Cartograhic Unit, Department of Geology, Ebonyi State University

Figure 1 Map of Edda LGA showing sample locations

Table 2 Locations, Codes and GPS Co-ordinates of the sample sites

Sample locations	Codes	Elevation (m)	Latitude (N)	Latitude (E)
Spring				
Anyoji	Asp	167.50	05°45'10.20"	007°50'25.10"
Eme-Udu	BSp	155.20	05°45'07.50"	007°50'35.14"
Nne-Oji	CSp	135.80	05°45'08.50"	007°50'40.40"
Achi-Ogba	DSp	148.00	05°45'09.40"	007°50'43.50"
Iminika	ESp	116.00	05°45'10.50"	007°46'59.80"
Streams				
Mgbogho Libolo	FS	116.00	05°56'10.50"	007°46'59.80"
Olo Ekoli	GS	115.2	05°50'10.40"	007°46'35.200"
,Ofoiyi Owutu	HS	81.60	05°45’43.90”	007°49’00.40”
Oghuekpe Amangwu	IS	76.32	05°46'30.10"	007°44'45.20”
Iyere Ogwuma	JS	79.60	05°45'30.10"	007°46'30.10"
Boreholes				
Amaukabi	KB	58.00	05°48'37.10"	05°48'37.10"
Nde-Okpo	LB	70.70	05°52'01.700"	007°48'50.30"
Okporojo Sec Tech	MB	44.30	05°54'55.80"	007°51'04.60"
Julius Awa	NB	135.80	05°44'08.50"	007°50'40.40"
Ninth Mile (OB)	OB	ND	ND	ND

2.3. Sampling and Laboratory Analyses

The plastic containers used for sample collection were thoroughly washed with detergent, rinsed with distilled water to remove any trace of contaminant which may remain in the containers and dried. It was further rinsed with 0.1M HNO_3 and preserved with the acid prior to sampling. Composite samples were collected in one litre polyethylene containers. The containers were labeled according to sample source using masking tape and a permanent marker for easy identification. At the point of sampling, the sample bottles were emptied and rinsed three times with the very sample water. The hand held borehole was pumped for 3 mins to homogenize the mix before filling the container to the brim and capped. In order to prevent some metal loss through surface adsorption and to immobilize the metals in solution 4 cm^3 of concentrated HNO_3 was added into the 1-litre of the water sample to preserve the metals prior to laboratory analysis. The same procedure was followed for the spring and stream water samples. For quality assurance, batch samples were collected twice in a day (morning, 7.30 – 10.00 am and evening 5.00 – 7.30 pm) and mixed to obtain the composite sample used in the study. Triplicate determinations of each parameter were carried out in each sample. Physicochemical parameters such as Temperature, Turbidity, pH were taken in-situ with the aid of Multiparameter Datalogger (Hanna Model No.11 1991300), EC and TDS were determined using conductivity/TDS/Sal/Res. Meter, Model SX 713. The heavy metals were carried out using atomic absorption spectrophotometer (AAS), the Na and K were tested with flame photometer. The acid radicals and total hardness were analyzed titrimetrically.

3. Results

The results of the evaluation of surface and groundwater quality are presented in Table 2. The summary of the statistical description of the groundwater quality are presented in Table 3. Data are presented as means, standard deviation, standard error, coefficient of variation (CV) and percentage relative standard deviation (% RSD).

Table 3 Mean ±SE of Physicochemical Parameters of Water Samples

Sampling Point	pH	EC ($\mu S/cm$)	Turbidity NTU	TDS (mg/l)	Alkalinity (mg/l)	TH (mg/l)	DO (mg/l)	BOD (mg/l)	NO_3^- (mg/l)	PO_4^{3-} (mg/l)
ASp	4.60±0.047	69.30±0.082	1.50±0.082	45.70±0.24	75± 0.47	4±0.47	5.14±0.019	3.2±0.047	1.14±0.009	0.96±0.028
BSp	6.10±0.047	82.60±0.094	1.50±0.047	54.50±0.13	70±0.94	30±1.25	5.29±0.012	7.6±0.094	2.02±0.016	0.09±0.00
CSp	5.90±0.047	53.10±0.047	2.00±0.047	33.90±0.16	45±0.94	16±0.82	5.84±0.019	6.8±0.16	1.71±0.054	0.44±0.019
DSp	5.20±9.98	67.80±0.130	1.50±0.13	50.50±0.082	50±0.47	18±0.82	5.07±0.012	6±0.47	1.2±0.082	0.27±0.009
ESp	5.20±0.082	84.20±0.094	2.00±0.094	55.80±0.13	45±0.47	22±0.94	5.64±0.019	0.4±0.047	1.45±0.024	1.30±0.094
FS	5.10±0.047	365.00±0.69	2.00±0.094	23.10±0.047	45±0.94	12±0.47	6.22±0.009	7.6±0.083	3.15±0.024	2.16±0.009
GS	6.20±0.094	268.00±0.047	1.00±0.047	177±2.87	200±0.94	96±1.25	5.80±0.041	4.4±0.094	18.82±0.47	0.87±0.014
HS	5.80±0.047	543.00±0.047	1.00±0.082	363±5.56	275±2.36	136±2.83	5.37±0.009	4±0.24	1.58±0.047	15.76±0.028
IS	6.20±0.820	434.00±1.89	1.00±0.082	293±1.41	475±7.07	144±1.63	6.47±0.009	12.8±0.082	21.49±0.042	0.96±0.028
JS	5.90±0.047	266.00±2.83	1.50±0.082	178±3.40	150±2.36	92±0.82	7.72±0.016	4±0.47	2.58±0.074	0.78±0.014
KB	6.10±0.047	805.00±2.36	1.00±0.047	353±5.56	495±2.36	158±1.25	6.47±0.014	2.8±0.047	32.69±0.047	0.61±0.008
LB	6.10±0.047	336.00±0.94	1.00±0.047	229±3.68	700±7.07	86±0.47	6.46±0.024	2.4±0.047	1.83±0.024	2.33±0.024
MB	6.70±0.090	2450±4.32	0.50±0.047	1830±17.00	2080±4.71	18±0.82	6.91±0.005	4.4±0.047	1.57±0.033	0.70±0.00
NB	5.90±0.130	653±1.70	1.00±0.082	461±4.71	940±2.34	146±1.25	7.04±0.019	0.8±0.82	1.58±0.047	0.09±0.005
OB	6.20±0.047	7.26±1.63	1.00±0.082	488±3.77	215±7.07	170±0.94	7.41±0.005	0.4±0.13	2.36±0.023	0.35±0.024
[30]	6.5-8.5	250	5	500	500	500	4	10	50	10

Table 4 Results of the Water Quality Index (WQI) of the water samples

Samples	Experimental value	Standard value (Sn)	1/Sn	Unit Weight Wn	Quality rating (Qn)	WnQn
pH	5.79	6.5	0.14	0.173	242	41.87
EC	443.83	1000	0.001	0.002	44.38	0.09
Turbidity	1.29	5	0.2	0.775	25.8	20.00
TDS	296.25	500	0.002	0.003	59.25	0.18
Alkalinity	403	500	0.002	0.002	80.6	0.16
Total Hardness	70	500	0.002	0.014	14	0.20
Dissolve Oxygen	6.10	4	0.25	0.164	212.5	34.85
BOD	4.80	10	0.1	0.208	48	9.98
NO_3^-	19.57	50	0.02	0.051	39.14	2.00
PO_4^{-3}	1.95	10	0.1	0.513	1.95	1.00
Σ				1.905		110.33

$$\mathrm{WQI} = \frac{\mathrm{WnQn}}{\mathrm{Qn}} = 57.92$$

4. Discussion

The pH in Table 3 ranged from 4.60 to 6.7 with a mean value of 5.76, indicating a moderately acidity to near neutral nature of water sources. Except location MB with a pH of 6.7$\pm$0.094, all other locations have pH lower than the WHO (6.5-8.5) standard for drinking water quality. This compares well with the mean values of 5.70 and 6.12 findings of [17], respectively. The low pH has the capacity to attack geological materials and leach toxic metals into the water. Metals tend to be more toxic at lower pH because they are more soluble [14]. The mean and range of Electrical Conductivity (EC) as shown in Table 3 were 480.20 and 53.1 - 2450μs/cm, respectively. Apart from Location MB that recorded the highest EC of 2450μs/cm other locations were below [15], [16] permissible limit of 1000 μs/cm for drinking water. EC is related to the concentrations of total dissolved solids and major ions. The results of the findings agree with [19] in the literature. This high value is an indication that the water is not fresh and potable. The mean Turbidity values as shown in Table 3 ranged from 0.5$\pm$0.047 - 2$\pm$0.094NTU. Turbidity values in all the water samples were generally low when compared with [1] drinking water standard of 5 NTU. The appearance of water with turbidity less than 5 NTU is usually acceptable to consumers [19]. Turbidity in water samples is a function of total suspended solids (TSS) as well as Total dissolved solids (TDS). Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern. The results of the analysis in Table 3 showed that Total Dissolved Solids (TDS) values ranged from 23.1$\pm$0.047 - 1830$\pm$16.997mg/l with mean concentrations of 342.71 mg/l. Apart from Location MB with TDS mean concentration of 1830$\pm$16.997mg/l which was above the WHO (500mg/l) permissible limit of drinking water, all other locations were within the WHO limits. It is reported in that water with a TDS above 500 mg/l is not recommended for use as drinking water and other sophisticated applications as a result of excessive scaling in water pipes and heating wares. The results in Table 3 showed that the spring water recorded Alkalinity that were below WHO [19] permissible limit of 100mg/l for drinking water while the stream and the borehole waters recorded values greater than the WHO permissible limit. The high alkalinity in stream and boreholes may be due to the dissolution of crystalline limestone which is abundant in the study area. The alkalinity of water is caused mainly due to OH^-, CO_3^{2-} and HCO_3^- ions. [16] also reported similar results in groundwater analysis in Ikere which was above the maximum allowable contamination value of 100 mg/l. The concentration of Total Hardness in Table 3 range from 4 - 170 mg/l with a mean value of 76.33 mg/l and all the locations recorded values below the [30] drinking water standard of 500mg/l. Water total hardness is imparted mainly by the calcium and magnesium ions, which apart from sulphate, chloride and nitrates are found in combination with carbonates [20]. Table 3 shows that the Dissolved Oxygen (DO) ranged 5.07$\pm$0.012 - 7.72$\pm$0.016 mg/l with a mean value of 6.19 mg/l. This value is high when compared with literature [20]. Out of the 15 locations, 47% of the samples analyzed contain dissolved oxygen less than 6 mg/l while 53% of the samples contained more than 6mg/l, which represents that groundwater was not contaminated by organic matter and non-polluted with respect to biological parameters[16]. Low DO may result an anaerobic conditions that result obnoxious odour. Depletion of dissolved oxygen in water supplies can encourage the microbial reduction of nitrate to nitrite and sulphate to sulphide [19]. The value of Biochemical Oxygen Demand (BOD) was in the range 0.4$\pm$0.047mg/l to 12.80$\pm$0.082mg/l with a mean concentration of 4.8mg/l. These values are consistent with the findings of [17]. A low level of this BOD is an indication of little pollution which implies low aerobic activity. The results in Table 2 show that all the NO_3^- concentrations recorded in all the locations ranged 1.14 ± 0.009 - 1.73 ± 0.024 mg/l respectively with a mean concentration of 1.87 mg/l they were below the [35] drinking water standard of 10mg/l of nitrate. This low level is an indication that there is low infiltration of nitrate into the water bodies from the dumpsites. It is reported that NO_3^- level above the WHO limit is dangerous to children below the age of 6 and pregnant women as it has the potential of causing metheglobenamia [21]. Excessive nitrate exposure can result in acute acquired methemoglobinemia, a serious health condition [21]. The results of the analysis in Table 3 showed that the Phosphate concentration ranged from 0.09$\pm$0.00 to 15.76$\pm$0.028 mg/l with a mean concentration of 1.85mg/l. With exception of location AB with a mean concentration of 15.76$\pm$0.028, exceeding the WHO stipulated tolerance level of 5.0mg/l for potable water, other locations were within the WHO threshold of drinking water standard. It is stipulated in literature that traces of PO_4^{-3} at 0.1mg/l in water has deleterious effect on water quality by promoting the development of slimes and algal growth. It is reported that the presence of phosphate in the groundwater body emanates from sources such as sewage, detergents, industrial effluents and agricultural drainage [7].

4.1. Water Quality Index

The results of the calculation of water quality index (WQI) of the spring, stream and borehole waters are shown in Table 4. The WQI of the water sample was 57.92 was below the critical water quality index value of 100. Any water with a record of WQI of 57.92 according to the grading of water quality [4] is very poor water quality and the finding was not in accord with the submission of [22] which was 83.05. This very grade of WQI in the samples could be linked to the higher values of dissolved solids, turbidity and the ions in the samples. It is reported in [14] that any water with a WQI greater than 100 was unsuitable for drinking and to other domestic uses. Such water needs treatment for its quality to be enhanced. Generally, the results of the analysis showed that the spring water has a low water quality index than that of the stream and borehole water thereby making the spring water being better quality water than the borehole water as there were low pollution indicators that impacted on the spring.

5. Conclusion

The physicochemical assay of the spring water samples in all the locations showed that phosphate concentration were below the WHO drinking water standards except Ofoiyi Owutu (HS) that recorded 15.76$\pm$0.028 which was above WHO drinking water standard. The boreholes and streams showed the same trend with the exception of Okporojo Secondary School (MB) that recorded higher values for EC (2450.00 ± 4.32 mg/L), TDS (1830.00 ± 17.00 mg/L), total alkalinity (2080.00 ± 4.71 mg/L) total dissolved solids (1830.00 ± 2.36 mg/L), total alkalinity (2080.00 ± 4.71 mg/L

Recommendations

Consumers of spring water especially the people of Ekoli Edda where only spring water exist should be properly and regularly educated on simple domestic or household treatment of the water using the $CaOCI_2$;

Studies on the soil chemistry of the spring water source should be carried out to identify the specific cause of the acidity; in general, the spring water in the study area should be treated to enhance the pH and hardness to make it safe for drinking.

Compliance with ethical standards

Acknowledgments

We wish to acknowledge the management of Akanu Ibiam Federal Polytechnic, Unwana and that of Tertiary Education Trust Fund (TetFund) for given the team the financial enablement to carry out this study. We are very appreciative.

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Smith, B. & Edger, E. (2006). Environmental Science: A Study of Interrelationships (10th Ed.). New York: McGraw-Hill Higher Education.

[2] Dara, S. S. & Umare, S.S (2010). A Text book of Engineering Chemistry. S. Chand & Company Ltd, 7367, Kan Nagar, New Delhi – 110 055

[3] Markandiya, A. (2004). Water quality issues in developing countries. World Bank and University of Bath. Contribution to a volume on essays in Environment and Development.

[4] Bhatia, S. C. (2011). Environmental Chemistry. CBS Publishers & Distributors, Pvt Ltd, 24 Ansari Road, Daryaganj, New Delhi-11002, India

[5] Amano, K.O.A, Danso-Boateng, E. Adom, E., Nkansah, D. K., Amoamah, E. S. & Appiah-Danquah, E. (2021). Effect of waste landfill site on surface and groundwater drinking quality. Water and Environmental Journal, pp. 1-15

[6] Jhamnani, B. & Singh, S. K. (2009). "Groundwater due to Bhalaswa Landfill Site in New Delhi". Department of Civil and Environmental Engineering, Delhi College of Engineering, Delhi, India, Journal of Environmental Science and Engineering, 1(3): 121-125

[7] Longe, E. O. & Balogun, M. R. (2010). "Groundwater Quality Assessment near a Municipal Landfill", Lagos, Nigeria, Department of Civil and Environmental Engineering, University of Lagos, Nigeria, Research Journal of Applied Sciences, Engineering and Technology, 2(1): 39-44

[8] WHO (1995). Guideline for Drinking Water Quality, Set-up in Geneva, 1994, p.4

[9] Kusi, E., Nyarko, A.K., Boamah, L. A. & Nyamekye, C. (2016). Landfills: Investigating its operational practices in Ghana. International Journal of Energy and Environmental Science, 1(1): 19-28

[10] Lone, I. U. H., Kumar, A., Khan, F., Saxena, S. & Dar, A. I. (2012). Evaluating the effect of landfill on groundwater quality in relation to physicochemical and bacteriological characteristics. Journal of Chemical and Pharmaceutical Research, 4(12): 5202-5214

[11] Bhalla, G., Swamee, P. K., Kumar, A. & Bansal, A. (2012). Assessment of groundwater quality near municipal solid waste landfill by an aggregate index method. International Journal of Environmental Science, 2(2):1492-1503

[12] Omoboriowo, A.O., Okengwu, K.O., Ugwueze, C.u., Soronnadi-Ononiwu, G.C., Acra, E.J, Chiaghanam, O.I. & Chiadikobi, K.C. (2012). Geochemical characterization of Afikpo Basin, Arochukwu Area, South East, Nigeria. Advances in Applied Science Research, 3(6): 3652-3657

[13] Emerson, J. W., Esty, D. C. and Hsu, A. (2012). Yale Center for Environmental Law and Policy, Yale University (Center for International Earth Information Network, Columbia University), p. 38

[14] Asuquo, J. E. and Etim, E. E. (2012). Water Quality Index for assessment of borehole water quality in Uyo Metropolis, Akwa Ibom State, Nigeria. International Journal of Modern Chemistry, 1(3: 102 - 108)

[15] Longe, E. O. & Balogun, M. R. (2010). "Groundwater Quality Assessment near a Municipal Landfill", Lagos, Nigeria, Department of Civil and Environmental Engineering, University of Lagos, Nigeria, Research Journal of Applied Sciences, Engineering and Technology, 2(1): 39-44

[16] Brown, R. M,, McCleilland, N. J., Deininger, R. A. AND O'Connor, M. F. (1972). A Water Quality Index-Crossing the Psychological Barrier. Proceedings of the International Conference on Water Pollution Research, Jerusalem, 18-24

[17] Boah, D. K, Twum, S. B. & Pelig-Ba, K. B. (2015). Mathematical Computation of Water Quality Index of Vea Dam in Upper East Region of Ghana. Environ. Sci. 3(1): 11-16

[18] Ebonyi State Government of Nigeria (2006). A Publication of the Ministry of Information and State Orientation, Abakaliki, Ebonyi State, pp. 1- 30.

[19] Ebonyi State Government of Nigeria (2010). A Publication of the Ministry of Information and State Orientation, Abakaliki, Ebonyi State, pp. 1-22.

[20] Omoboriowo, A.O., Okengwu, K.O., Ugwueze, C.u., Soronnadi-Ononiwu, G.C., Acra, E.J, Chiaghanam, O.I. & Chiadikobi, K.C. (2012). Geochemical characterization of Afikpo Basin, Arochukwu Area, South East, Nigeria. Advances in Applied Science Research, 3(6): 3652-3657

[21] USGS (2012). U.S. Geological Survey. Science for a changing World. http://ga.water.usgs.gov//edu/earthgwquality.html. Last modified: Friday, 21-12-2007.

[22] BIS Tolerance limits for Inland surface water IS: 2296-1982 and BIS Standard 2006

[23] Taiwo, A.M., Adeogun, A.O., Olatunde, K.A. & Adegbite, K.I. (2011). Analysis of groundwater quality of hand-dug wells in peri-urban area of Obantoko, Abeokuta, Nigeria for selected physicochemical parameters, Pac. J. Sci. Technol., 12, 527-534.

[24] WHO (2006). Guidelines for Drinking-Water Quality. First Addendum to Third Edition. Volume 1, Geneva.

[25] Lorraine, C.B. (2000). Assessing the acute gastro intestinal effects of ingesting naturally occurring high levels of sulphate in drinking water. Crit. Rev. Clin. Lab. Sci. 37, 389-400.

[26] Ibrahim, Y.M.; Agbendeh, Z.M. & Wyasu, G. (2013). Physicochemical and Potential Toxic Metals Level in Surface Water around Yauri Abattoir, North Western Nigeria. Annual International Conference of Chemical Society of Nigeria, pp. 56-63.

[27] Lawal, A.O., Aliand, Z.N. & Haruna, H.M.S. (2013). Water Quality Assessment of Hand-Dug Wells in Kakuri and its Industrial Area Using Physicochemical Parameters. Annual International Conference of Chemical Society of Nigeria, pp. 56-63.

[28] Lahl, U.; Zeschmar, B.; Gabel, B.; kozicki, R.; Podbielski, A.; Stachel, B. & Strauss, S. (1983). Groundwater Pollution by nitrate. Groundwater in water resources planning, proceeding, International Association of Hydrological Sciences (IAHS) publication, 142: 1159-1168.

[29] Razowska-Jaworek, L. (2012). Calcium and Magnesium in ground water-distribution and significance. International seminar organized by the Upper Silesian Branch of the Polish Geological Institute.

[30] World Health Organization (2011). Guidelines for drinking water quality.