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Profiling the Contamination Level and Pollution Load Index of Borehole Water from Esako West LGA, Edo State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Fresh water has continued to decrease both in quality and quantity with a wide variety of pollutants entering into fresh water resources. In this research the quality of fresh water was being accessed using standard method of analysis of water. Physiochemical parameters and heavy metal content were determined and data was assessed using contamination factors, degree of contamination and pollution load index result revealed that borehole water at Esako west LGA was slightly contaminated by phosphate (0.16 mg/l) and over 5 times the WHO standard. The acidic water (pH

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6) was observed over 200 mg/l of carbon dioxide the contamination factor for zinc were generally greater than 1, while other parameter had values of contamination factors less than 1. In conclusion, borehole water at Esako west contaminated and slightly polluted through the locals continued to consume this water, there is a need for treatment to remove phosphate whose source may be from phosphate rocks in the area or sipping from phosphate fertilizer in farms.

Keywords: Anthropogenic; chemometrics; Index models ground water; pollutants; physicochemical; water quality.

1. INTRODUCTION

Water is one of the most abundant gifts of nature. It is an indispensable resource for the continued existence of all living things including man and adequate supply of fresh and clean drinking water is a basic need for all human beings [1]. In nature, all water contains impurities; as water flows in streams, accumulates in lakes and filters through layers of soil and rock in the ground, it dissolves or absorbs substances it come in contact with, which may be harmful or harmless [2]. One of the major and critical problems in most developing countries today is the provision of an adequate and safe drinking water to its populace [3]. Drinking water that is safe and aesthetically acceptable is a matter of high priority to National Agency for Foods and Drugs Administration and Control (NAFDAC) and other regulatory agencies in Nigeria and is expected to meet the Nigerian Industrial Standard. Furthermore, drinking water that is fit for human consumption is expected to meet the World Health Organization and be free from physical and chemical substances and microorganisms in an amount that can be hazardous to health [4]. It is a known fact that no single method of purification can eliminate 100% contaminants from drinking water. However, water can be and should be made safe for consumption within acceptable limits [5].

Sachet water is any commercially treated water, manufactured, packaged and distributed for sale in sealed food grade containers and is intended for human consumption while bole hole water is a non-treated water that is readily consumed by humans [6-10]. Water consumers are frequently unaware of the potential health risks associated with exposure to water borne contaminants which have often led to diseases like diarrhea, cholera, dysentery, typhoid fever, legionnaire's disease and parasitic diseases [11]. The continuous increase in the sale and indiscriminate consumption of both bole hole and packaged drinking water in Nigeria is of public health significance, as the prevalence of water related diseases in developing countries is determined by the quality of their drinking water [12,13].

The safety of drinking water in poor and deprived communities has in the last decade been in jeopardy as a result of the introduction of refuse and sewage into sources of water supply. The intake of unwholesome water could have devastating effects on our health as unsafe drinking water is a key determinant of many microbial diseases with serious complications in immune-competent and immune-compromised individuals. The introduction of sachet water was aimed at providing safe, hygienic and affordable instant drinking water to the public and to curb the magnitude of water related infections in the country [14-16,11,17].

Pure water is colorless, odorless and tasteless with high boiling and melting points as well as high heat of vaporization. Pure water can be slightly ionized reversibly to yield hydrogen and hydroxyl ions [18-21]. Therefore, water is not just a solvent in which the chemical reactions of the living cell occur. It is very considered often in direct participation in those reactions. Quality of drinking water is evaluated on the basis of its chemical components [22-25]. This is done by assessing the pH, hardness, total alkalinity, dissolved oxygen, carbon dioxide, heavy metals and organic constituents [17].

Consumption of sachet water in Nigeria is on the increase irrespective of whether they have NAFDAC Certification or not. However, despite the strong effort by NAFDAC in the regulation and quality assessment of sachet water, there are a growing number of reported public illnesses after drinking sachet water [26-28]. There are a number of reported cases of typhoid, diarrhea and other water borne diseases arising from consumption of sachet water [29]. Sachet water serves as a major source of potable/drinking water to communities around Imo State.

Borehole water is readily available water these days for human consumption, and the quality and source of the water are questionable. Anthropogenic activities such as the use of pesticides, fertilizers and the release of contaminated waste material could pollute the water aquifer. This borehole water is consumed by humans with the believe that it is coming directly from its source, hence it is clean. This research therefore was conducted to evaluate the quality of borehole water samples collected from Esako West LGA in Edo State.

Some of these bole hole and sachet water are contaminated, either chemically or microbial, and are toxic to man. When these contaminants accumulate beyond the recognized and recommended limits, they become toxic to living organism. The consumption or use of contaminated bole hole or poorly treated sachet water is capable of causing water or chemical related diseases. It is on these bases that an attempt is being made to determine the quality of both treated and untreated water in Esako west area of Edo State [30].

The aim of this research work was to carry out quality assessment of bole hole water in Esako West area of Edo State. The specific objectives for achieving the aim were: to analyze borehole and water samples collected from Esako West area of Edo State LGA; to compare the result of the analysis with those of WHO acceptable standard for drinking quality water; to evaluate contamination factors and pollution load. This research work was limited to the following analysis; pH, conductivity, total dissolved solid, chloride ion, phosphate, nitrate, copper, iron, zinc, manganese and copper and CO_2 concentrations.

2. MATERIALS AND METHODS

2.1 Preparation of Reagent

1 gram of phenolphthalein salt was weighed with a weighing balance and dissolved in 100ml of ethanol to obtain 1 % phenolphthalein indicator.

0.02 N sodium hydroxide solution was prepared by dissolving 0.8 grams of sodium hydroxide pellet in 1000 ml of distilled water in a 1000 ml volumetric flask.

2.2 Sample Collection

The water samples used for this research were collected from Esakowest Local government area of Edo State Nigeria according to standard methods for water analysis.

2.2.1 Determination of pH

The pH values of the water samples were determined by the method of national agency for food and drug, administration and control (NAFDAC), using (Standard operating procedure for water analysis). 200 ml beaker was washed, rinsed dried in an oven at 105 ^oC and allowed to cool in a desiccator. 100ml of the water sample was introduced into the beaker and a pH meter of the model JENWAY 3510 pH meter previously calibrated with buffer 7.0 is used to determine the pH of the water samples.

2.2.2 Determination of conductivity

The method of NAFDAC for determination of pH of water samples was followed and the conductivity was determined using Lasany microprocessor conductivity meter.

2.2.3 Determination of total dissolved solid

The total dissolved solid for the water samples was estimated from the values obtained from the conductivity using a mathematical manipulation as shown below
1000 μs/cm = 500 mg/L

2.2.4 Determination of the CO_2 content

The carbon dioxide content of the water samples was determined by the method of NAFDAC as stated in the standard operating procedure for water analysis. The maximum acceptable limit for NAFDAC is 50 mg/L. 100 ml of the water samples was measured using a measuring cylinder and introduced into a previously washed, rinsed and oven dried conical flask. 2-3 drops of phenolphthalein indicator was added to the sample and the resulting mixture was titrated using 0.02 N sodium hydroxide solution until a faint permanent pink colour was observed. Agitation must be done to avoid dissolving more carbon dioxide in the samples from the atmosphere.

The titre value is recorded and the concentration of the CO_2 in the water samples is calculated using the relation 1ml of 0.02 N NaOH = 10 mg/L of CO_2

2.2.5 Mineral analysis of water sample

The mineral analysis of water samples was determined by the method used and described by Verla et al., 2022 using Atomic Absorption Spectrometer. The concentration of each of the minerals was obtained in mg/L following the procedures described by the instrument manual [31].

3. RESULTS

The results from 8 different borehole water samples collected in Esako West LGA of Edo state are as shown in the Tables 1 and 2.

3.1 Contamination and Pollution Index Models

The C_f is an indicator used to assess the presence and intensity of anthropogenic contaminants in groundwater. The C_f was determined mathematically using equation 1

$$C_F = \frac{C_m}{C_b}. \quad (1)$$

where C_m is the concentration of a particular parameter in the water and C_b is the reference concentration of that parameter. WHO standards for drinking water were taken as the reference concentrations. The degree of contamination degree (CD), is simply the summation of contamination factors and is employed in comparing sites

$$\mathrm{CD} = \sum C_F \quad (2)$$

The PLI is a potent tool that provides a simple and comparative means for assessing the level of pollution. The PLI gives a summative indication of the overall level of toxicity in a sample. The PLI value greater than 1 is polluted, less than 1indicates no pollution whereas values equal to 1 indicates contaminant loads close to the reference concentration. The pollution load index was determined mathematically using Equation 2.

Generally, PLI is estimated using the following equation;

$$\mathrm{PLI} = [Cf_1 \times Cf_2 \times Cf_3 \times Cf_4 \ldots Cf_n]^{1/n} \quad (3)$$

where n is the number of parameters considered in the study and $Cf_n$is the contamination factor for each individual parameter. This PLI provides a comparative means for assessing a site quality.

4. DISCUSSION

Table 1 shows the results obtained for the physicochemical analysis and statistical evaluations of bore hole water samples collected from Esako west local Government area of Edo State.

4.1 Phosphate

The presence and concentration of phosphorus is waters could be an important pollutant. Phosphates are retained by some complex system of biological uptake, absorption, and mineralization [32]. Phosphates are not toxic to people or animals unless present in very high concentrations in which case the interfere with digestion. In this study the phosphate level in the range was 0.08-0.24 mg/L. These levels of phosphates were not within the permissible limit of NAFDAC and WHO for all the samples. Hence, the bore hole water samples were contaminated with about five times the WHO standard. Sources of phosphates could be adjourning farmlands in which phosphate fertilizers have been used.

4.2 Nitrate

Values of nitrate range was in the range of 7.0-59.0 mg/L while mean nitrate levels (30 mg/l) obtained in this study were less than WHO standard of 50 mg/l. Nitrate concentrations in samples 3 (59.0 mg/L) and 5 (55.0 mg/L), were slightly higher than threshold values for both NAFDAC and WHO standards. Usually, high nitrate levels are attributed to anthropogenic activities such as the indiscriminate dumping of waste [33]. Nitrates are known to interfere with the oxygen transport ability of the red blood cells with this effect felt more in the popular blue baby illness. Infants who drink water high in nitrates may turn “bluish” and appear to have difficulty in breathing since their bodies are not receiving enough oxygen [34].

4.3 Chloride (Cl)

Chloride is invariably present in small amounts in almost all natural waters and its contents go up appreciably with increasing salinity [35]. High concentration of chlorides is considered an indicator of pollution due to organic wastes of animal or industrial origin. Chlorides are troublesome in water and also harmful to aquatic life. The chlorine content of the bore hole water samples range is within 2.0-10.0 mg/L and were generally lower than the standard limit of WHO and NAFDAC except for sample 3,4 and 5 that showed very high concentration with values of

9.0 mg/L, 10.0mg/L and 5.0mg/L. It has no adverse health impact, but excess of it impacts bad taste to the drinking water [32].

Heavy metals studied here include iron, zinc, manganese and copper. These were selected because of their link to cancer and organ damage [36,37]. These metals react with oxygen to form reactive oxygen species that damage cells [38].

4.4 Iron (Fe)

Iron is an important mineral element required by human in trace quantity. It is one of the most abundant elements in the soil, hence its concentration in ground water abounds. High concentration of iron in drinking water is deleterious due to its health hazard [38], because excessive ingestion can cause anemia and even death in chronic exposure. In this study, the concentration of iron the water samples are below permissible limit of NAFDAC and WHO and the range obtained in this study were 0.09-0.41 mg/L although sample 3 gave a higher value of 0.4 mg/L.

4.5 Zinc (Zn)

The Zn concentrations in the studied bore hole water samples had mean values range of 0.57-3.5 mg/L. The observed values were reportedly higher than the common world range for WHO standard. Environmental contamination of Zn is mainly related to anthropogenic activities. The anthropogenic sources of Zn are related to industries and the use of liquid manure, composted materials and agrochemicals such as fertilizers and pesticides in agriculture [39].

4.6 Manganese (Mn)

The sources of manganese in water may include metal alloys, batteries, glass and ceramic materials. This is not unusual for disposal of waste on water channels that finds their way into streams, especially wasted from auto mechanic workshops. The result obtained for the bore hole water samples showed that manganese was within the range of 0.01-0.03 mg/L. This range of values were within the permissible limit of the WHO and NAFDAC.

4.7 Copper (Cu)

Ingestion of metals such as copper (Cu) may pose great risks to human health. It may also cause small increases in blood pressure, particularly in middle-aged and older people and can cause anemia. Contribution of Cu maybeenvisagefrom dumping of solidwastes, application of fungicides, live stock manures, sludges and atmospheric deposition [38]. The présence of Copper in the water sampleswerewithin the range of 0.001-0.80 mg/L and below the WHO permissible limit of 3 mg/L.

4.8 pH

The pH of water is an important parameter that determines the quality of drinking water. It is the measure of the acidity and alkalinity of the water [38,39]. The pH of quality water according to national agency for food and drug, administration and control (NAFDAC) and world health organization (WHO) standard should be within the range of 6.8-9.0. Hence below or above this limit, the water is termed unfit for human consumption. In this study, it was revealed that the pH of the majority of the water samples were below NAFDAC and WHO limit with. The results obtained were in the range of 4.36-6.88.

4.9 Electrical Conductivity (EC)

Mean value of electrical conductivity of borehole water was 47.83, much lower than 100 the standard value for NAFDAC and WHO. It is known that acidic pH encourages high EC, but this was not so for borehole water at Esako west. EC is a measure of dissolved salts and can affect taste of water [40,31].

4.10 Total Dissolved Solids

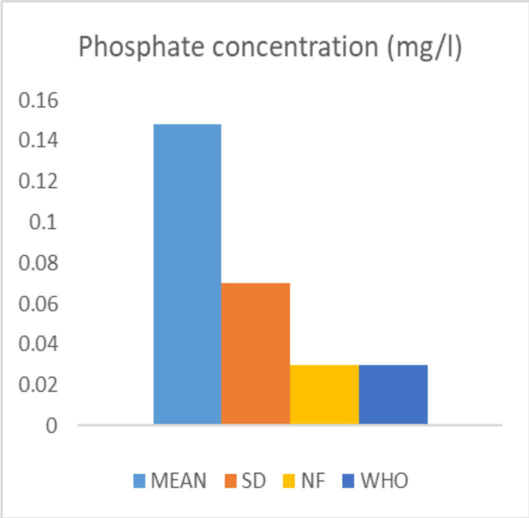
Total dissolved solids of the water samples range from 13.87-276 mg/L in which sample 1,2,4,6-8 were within the acceptable range of WHO and NAFDAC while samples 3 and 5 were above the limit with values of 256 and 276 mg/L respectively. However, sample 3 has the highest TDS with 276 mg/L and sample 1 have the lowest with 13.87 mg/L. TDS may cause water to be corrosive and the consumption of water with high dissolved solids could lead to gastrointestinal diseases. These solids which can be suspended can cause damage to human if the concentration is too high [41].

Table 1. Results of physicochemical analysis of the bore hole water samples

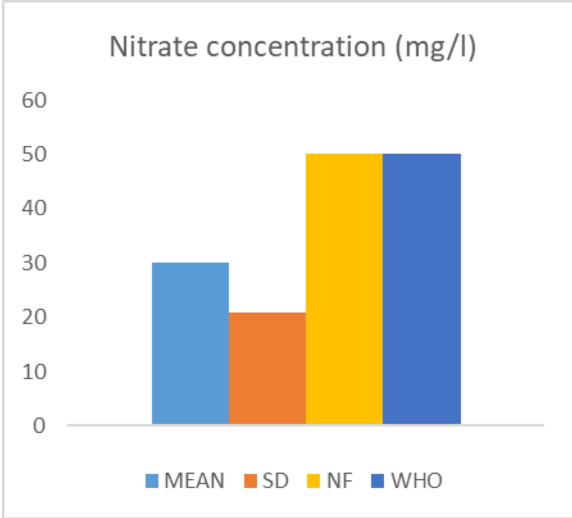
S/N	Parameter	S1	S2	S3	S4	S5	S6	S7	S8	M	SD	Range	WHO
a	PO_4^{3-}(mg/l)	0.08	0.10	0.18	0.05	0.21	0.20	0.24	0.12	0.15	0.07	0.08-0.24	0.03
b	NO_3^-(mg/l)	29	7	59	32	55	41	12	05	30	20.94	7-59	50
c	Cl^-(mg/l)	4	3	9	10	5	2	3	0.10	4.51	3.40	2-10	5
d	Fe (mg/l)	0.10	0.12	0.41	0.21	0.27	0.09	0.12	0.13	0.18	0.11	0.09-0.41	0.3
E	Zn (mg/l)	3.5	2	4	0.57	3.2	1.10	2.1	0.96	2.18	1.27	0.57-3.5	2
F	Mn(mg/l)	0.02	0.03	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01-0.03	0.4
g	Cu (mg/l)	0.02	0.001	0.80	0.03	0.01	0.02	0.01	0.01	0.11	0.27	0.001-0.80	3
h	Ph	6.08	6.83	5.19	6.29	4.36	6.40	5.97	5.99	5.89	0.77	4.36-6.83	6.5- 9.0
i	EC (µS/cm)	27.75	29.50	124	23.5	105	34.55	20.30	18.10	47.83	41.7	18.1-104.5	100
j	TDS (mg/l)	13.87	14.65	276	20.0	256	17.27	17.15	17.05	79.02	115.61	13.87-276	250
11	CO_2 mg/L	280	175	125	75	270	116	200	153	174.25	72.83	75-280	50

Table 2. Contamination factor

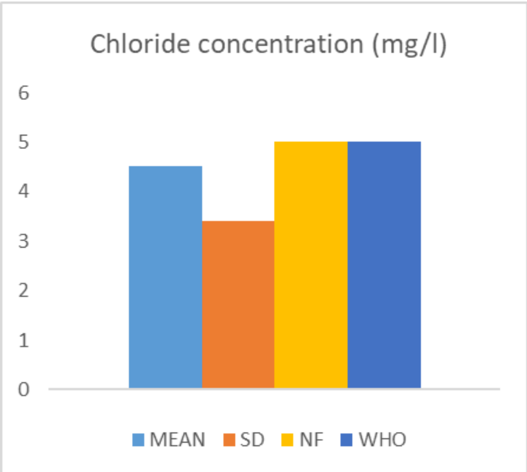
Parameters	1	2	3	4	5	6	7	8	ΣCF
PO_4^{3-}	2.66	3.33	6.00	1.66	7.00	6.66	8	4.00	39.31
NO_3^-	0.58	0.14	1.18	0.64	1.10	0.82	0.24	0.10	4.8
Cl^-	0.80	0.60	1.80	2.00	1.00	0.40	0.60	0.02	7.22
Fe	0.33	0.024	1.36	0.70	0.90	0.30	0.40	0.03	4.044
Zn	1.75	1.00	2.00	0.28	1.60	0.55	1.05	0.48	8.71
Mn	0.05	0.08	0.03	0.05	0.03	0.03	0.03	0.05	0.35
Cu	0.01	0.001	0.04	0.02	0.01	0.01	0.01	0.01	0.111
Ph	0.42	1.05	0.03	0.97	0.67	0.92	0.92	0.92	5.9
EC	0.28	0.30	1.24	0.24	1.05	0.35	0.20	0.18	3.84
TDS	0.06	0.06	1.10	0.08	1.03	0.07	0.07	0.07	2.54
CO_2	5.65	3.5	2.5	1.5	5.4	2.32	4.0	3.06	27.93
PLI	1.09	0.89	1.57	0.74	1.80	1.13	1.41	0.81	
ΣCF	12.59	10.085	17.28	8.14	19.79	12.43	15.52	8.92	


Phosphate concentration (mg/l)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
MEAN SD NF WHO

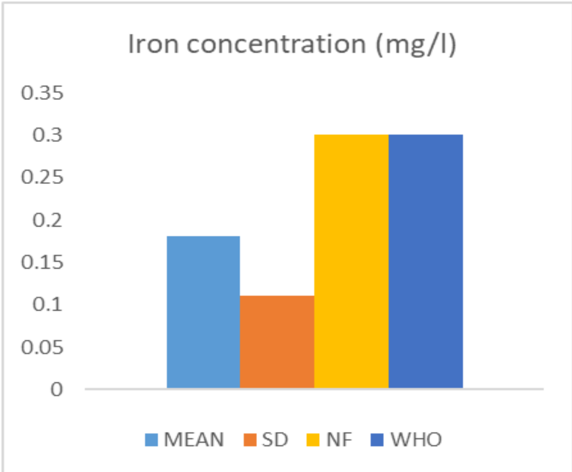
a


Nitrate concentration (mg/l)
60
50
40
30
20
10
0
MEAN SD NF WHO

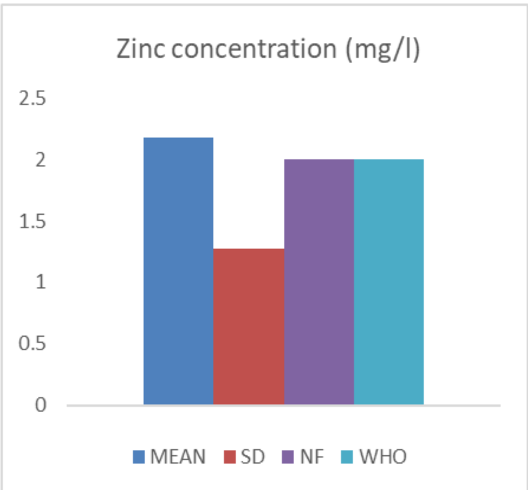
b


Chloride concentration (mg/l)
6
5
4
3
2
1
0
MEAN SD NF WHO

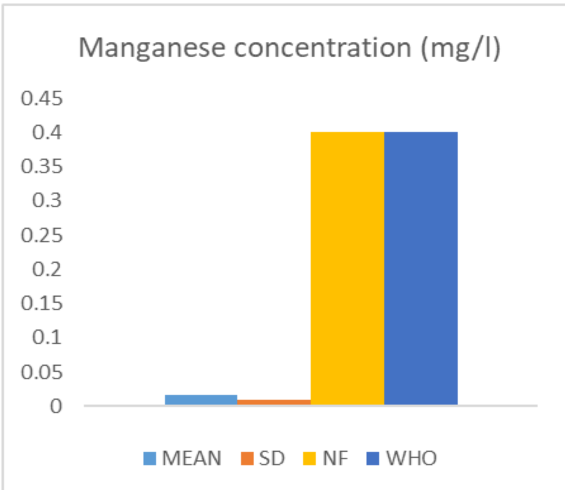
c


Iron concentration (mg/l)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
MEAN SD NF WHO

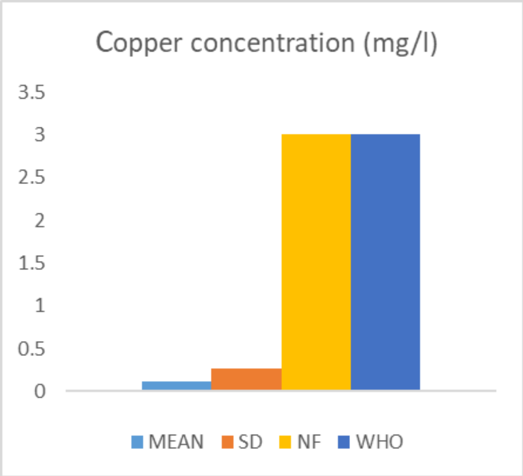
d


Zinc concentration (mg/l)
2.5
2
1.5
1
0.5
0
MEAN SD NF WHO

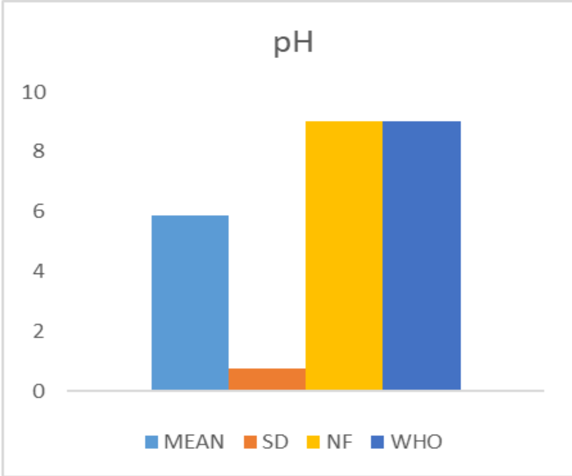
e


Manganese concentration (mg/l)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
MEAN SD NF WHO

f



g



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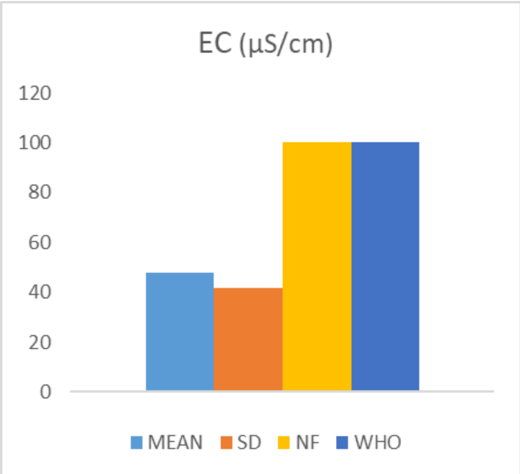

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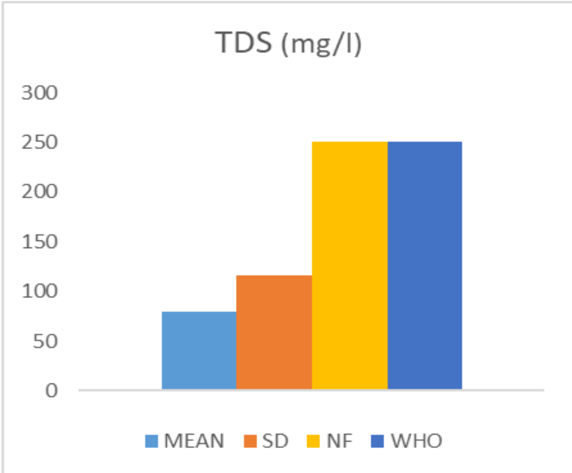

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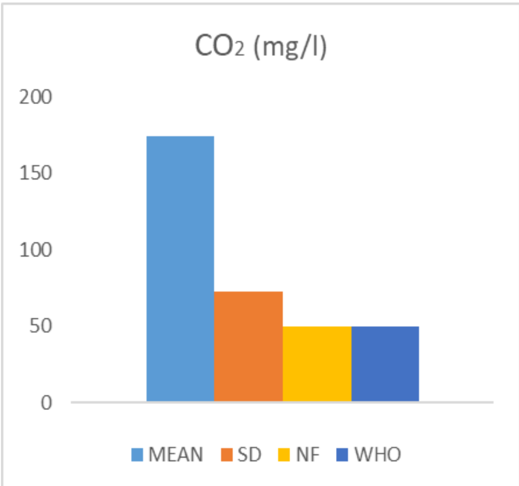

k

Fig. 1. (a to k) Charts for Comparisons of mean values of physicochemical parameters with NAFDAC and WHO standard values and Standard deviation

4.11 Carbon Dioxide Content (CO_2)

Carbon dioxide content in water is a very important parameter for defining water quality. The source of carbon dioxide in water is usually from the atmosphere. High concentration of carbon dioxide in water will increase the CO_2 content of the human when ingested constantly. In this study, the carbon dioxide content of the water sample exceeded the recommended limit for quality water set by NAFDAC having a range of 75-280 mg/L

4.12 Contamination and Pollution Indices

Table 2 shows the results obtained for the contamination factor. The results obtained for the contamination factors shows moderate contamination of metals. The results also showed that there is a very high contamination of phosphate in the water samples collected from the area. This pollution could be attributed to the continues uses of phosphate containing materials like NPK fertilizers which increases the level of phosphate in the soil which could percolate into the soil or be washed away by runoff during rainfall into water bodies.

5. CONCLUSION

It can be concluded that high phosphate and CO_2 content in the bore hole water made the water not fit for consumption. The overall results showed that the bore hole water samples collected from Esako west LGA of Edo State are considerably contaminated and unhealthy for human consumption without any form of treatment. The quality of available water has implication on the health status of a community. Polluted water is the major reason for the spread of many endemic diseases.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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