FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 No. 2, February, 2025, pp 312 - 319
DOI: https://doi.org/10.33003/fjs-2025-0902-1486

COMPARATIVE METAL AND PHYSICO-CHEMICAL ANALYSIS OF WELL WATER SAMPLES FROM ZAI AREA OF DUTSE, JIGAWA STATE

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ABSTRACT

Water, the best drink ever is a basic necessity of life for humans, plants and animals as such the need to maintain its quality and freshness are everyone's business. Through anthropogenic activities a number of pollutants reach both surface and underground water bodies decreasing the quality and freshness and sometimes rendering it unsafe for drinking purpose. This research presents a comparative metal and physico-chemical analysis of well water samples from Zai area of Dutse, Jigawa State using various analytical methods and AAS analysis. The results revealed that the water samples studied are hard with average values ranging between 938.32 mg/L and 35.54 mg/L. The results also showed that the water samples contain a lot of dissolved salts thereby increasing the conductivity. The pH of the water samples were within the WHO range of 6.5-8.5. The average turbidity of the water ranged from 0.45 NTU TO 46.65 NTU. The results also showed the total dissolved solid to be between 36.5 mg/L and 597.5 mg/L. The water quality index analysis revealed the WQI values for all the samples to be ≥ 50 which means the water samples are unsafe for drinking purpose. Again the heavy metal pollution index value showed most of the water samples to be free from heavy metal pollution. Based on the results above, taking water from these wells for drinking purpose without the appropriate treatment could put one at health risk.

Keywords: Well water, Physico-chemical, WQI, HPI, Metals, Zai area

INTRODUCTION

It is worthy of note that adequate supply of fresh and clean drinking water is a basic necessity of all human beings. However, millions of people are deprived of this basic need especially those in the developing countries such as Nigeria due to poor management and ecological degradation by man's activities. Anthropogenic activities have led to a steady release of pollutants into the water bodies leading to degradation in quality of surface and groundwater bodies, affecting their basic uses, and therefore becoming a problem for both human health and the environment. (Zhao, Kuo, & Chen, 2021; Onate & Cortez, 2020. The degradation of the water quality is further worsened by excessive use of chemical products in day to day activities such as fertilizers, herbicides, pesticides etc. The purpose of water for man in his daily activities include for washing, drinking, cooking etc (Akpoborie *et al*, 2008). Due to the unreliable nature of surface waters in terms of pollution levels for drinking purpose, ground waters have become the major source of drinking water in both urban and rural areas because they are more reliable for domestic and other human needs (Okeola *et al*, 2010; Haruna *et al*, 2008, Shymala *et al*, 2008).

In recent years, there has been an increased rate in the use of metal- based fertilizers this could result in continued rise in concentration of metal pollutants in fresh water reservoir due to water run-off. There is no doubt that unfavourable change in the concentrations of quality parameters of water sample render the water incapable of performing its major functions such as cooking, washing, drinking etc optimally. It is therefore necessary that the quality of drinking water should be checked at regular interval. The objective of this research work is therefore to carry out extensive analysis on well water sample which was conceived to be mysterious by residents due to its inability to cook foods.

The water quality index, developed by Horton (1965) and modified by Brown *et al* (1965) is a tool to determine the status of water quality. It integrates all the parameters while comparing with the standards recommended by the government authorities to safeguard human health (Barti and Kartyal, 2011). Numerous methods have been used to obtain the water quality index but by far the most widely used is the Weighted Arithmetic Index (WAI) method. Again heavy metal pollution index (HPI), developed by Mohan *et al*, (1996) is an index method used to determine whether water sample is polluted with heavy metals or not by assessing the level of heavy metals presence in the sample. Therefore this research work is aimed at investigating the possible causes of loss of quality of well water sample and suggests how this quality could be restored.

MATERIALS AND METHODS

Description of the study area

Samples for the study were collected from twenty-two wells located in Zai area of Dutse JIgawa State Nigeria for two seasons (wet and dry seasons) in 2024. Zai area of Dutse is located on latitude 9º10'30" N to 9º21'10" N and longitude 11º40'30" E to 11º51'o" E. The area is surrounded by rocky mountains.

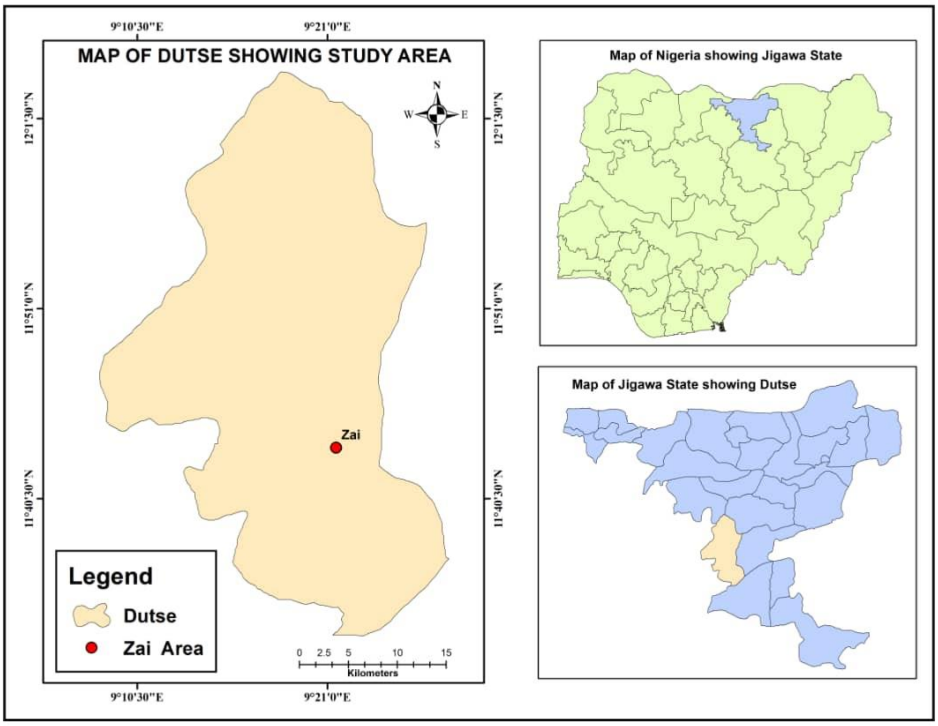

Figure 1: Map of study area

Methods

Some of the physico-chemical parameters of the water samples (temperature and pH) were determined onsite using Hanna hand pH meter S358236 and LCD portable digital multi – system thermometer KT 201271041 (Sesugh *et al.*, 2021), while dissolved oxygen (DO), total dissolved solids (TDS) and electrical conductivity (EC) were determined immediately in the laboratory using hand held TDS-3 meter (TDS meter hold) and conductivity meter (multi-parameter PCS Tester™ 35. Other parameters such as chloride, sulphate, iron, chemical oxygen demand (COD), carbon dioxide (CO_2), total hardness, alkalinity, calcium, sodium, potassium and magnesium ions, turbidity, CO_3^{2-} , HCO_3^{-}, BOD and phosphate were estimated using standard methods described in APHA 23rd edition and Sadhana & Anad, 2014. Heavy metals were determined by atomic absorption spectrometry (AAS).

WQI was calculated for the two seasons to ascertain the suitability of the well water for drinking and domestic purposes. This was achieved by using nine important physico-chemical properties. These parameters are: pH, HCO_3, turbidity, total hardness, total dissolved solids (TDS), magnesium (Mg) ions, electrical conductivity (EC), calcium (Ca) ions, and total alkalinity. These parameters were chosen for their maximum contribution on the quality of well water for domestic use.

The equation for the calculation of water quality index WQI is given as

$WQI = \sum WiQi$ (Brown *et al*.,1972) (1)

Where $Wi = \frac{wi}{\sum_{i=1}^{n} wi}$ (2)

$Qi = 100(Vi/Si)$ (3)

Qi is sub index of i^{th} parameter, wi is unit weight, Si is recommended standard for i^{th} parameter, Vi is the measured value of the i^{th} parameter.

$wi = \frac{k}{Si}$ (4)

Where $k = \frac{1}{\sum 1/Si}$ (5)

Based on this equation, the water is classified as:

WQI between 0-25 excellent for drinking, 25-50 slightly polluted but good for drinking, 50-75 moderately polluted (poor for drinking), 75-100 polluted (very poor for drinking) and above 100 excessively polluted (unsuitable for drinking).

The heavy metal pollution level of the well water samples was also estimated using the heavy metal pollution index formula (Mohan *et al*., 1996). The equation for the calculation of heavy metal pollution index (HPI) is given as follows:

$HPI = \sum_{i=1}^{n} \frac{WiQi}{Wi}$ (6)

Wi $=\frac{K}{Si}$, where Wi is unit weight, Si is standard permissible limit value of the i^{th} parameter (ppb), K is a constant; Qi is sub-index value of the i^{th} parameter

$Qi = \sum_{i=1}^{n} \left(\frac{Mi}{Si}\right) * 100$ (7)

Where, Mi is the measured value of the i^{th} parameter in part per billion (ppb).

If HPI <100, it means the water sample is not polluted with the heavy metals.

If HPI >100, it means the water sample is polluted by the heavy metals.

Results and Discussion

The results of the physico-chemical analysis of the well water samples are as presented in Tables 1a and b. From the Tables, it is clear that the water parameters varied from site to site.

Table 1a: Average Physico-chemical properties

Site	Ca^{2+} mg/L	Conc. mg/L chloride	SO_4^{2} mg/L^{-}	Fe^{2+} mg/L	E c µS/ cm	COD mg/L	CO_2 PPM	Turbidity NTU	Mg^{2+} mg/L	CO_3^{2-} mg/L	HCO_3^{-} mg/L
1	43.20	95.41	18.76	0.42	455.00	3.10	6.00	6.75	5.57	ND	316.00
2	27.20	37.75	11.84	0.33	185.00	3.85	8.25	2.25	1.11	ND	138.00
3	36.40	21.86	14.98	0.61	130.00	2.50	3.50	1.45	3.55	ND	66.00
4	27.20	13.91	13.07	1.04	70.00	2.25	5.50	43.65	1.73	ND	105.00
5	26.40	26.81	10.10	0.74	120.00	3.80	3.00	11.95	1.63	ND	104.00
6	82.40	115.26	19.50	0.42	500.00	2.35	5.25	1.50	36.38	ND	200.00
7	73.50	92.38	13.40	0.78	385.00	4.70	8.00	23.75	5.04	ND	162.00
8	84.60	163.83	29.04	0.39	575.00	3.10	8.50	2.55	8.55	ND	204.00
9	90.40	166.87	7.79	0.15	615.00	3.00	12.50	0.45	14.20	ND	246.00
10	156.0	308.80	5.81	0.31	1035.00	3.75	11.00	2.30	8.62	ND	472.00
11	81.20	254.26	21.77	0.37	1025.00	5.20	9.75	6.90	20.73	ND	538.00
12	116.80	303.96	4.23	0.35	1060.00	2.30	9.50	2.75	33.17	ND	298.00
13	298.60	54.55	27.59	0.31	1270.00	2.00	8.50	1.55	60.24	ND	274.00
14	229.60	418.77	26.04	0.32	1815.00	3.75	8.50	2.30	35.86	ND	568.00
`15	92.00	268.00	8.49	0.22	1100.00	8.60	5.00	0.85	14.83	ND	770.00
16	76.00	82.39	6.02	0.27	370.00	2.05	4.75	28.50	8.76	ND	198.00
17	81.60	110.14	26.25	0.30	455.00	2.40	5.25	12.05	12.31	ND	158.00
18	43.20	90.33	23.40	0.29	385.00	1.20	6.50	2.75	13.22	ND	166.00
19	13.60	16.87	21.77	0.37	80.00	1.75	6.50	46.65	8.295	ND	63.00
20	15.20	14.89	17.46	1.18	45.00	5.35	4.75	25.40	3.95	ND	56.00
21	16.80	29.78	20.45	0.46	50.00	1.50	4.50	61.05	2.84	ND	60.00
22	15.20	13.90	26.66	0.25	85.00	3.40	5.50	33.80	6.98	ND	58.00

Table 1b: Average Physico-chemical properties continue

Site	pH	Temp ^{0}C	BOD mg/L	D O mg/L	Total H mg/L	TDS mg/L	Na+ mg/L	K+ mg/L	PO_4^{2-} mg/L
1	7.70	29.75	2.95	5.95	115.25	300.00	4.13	5.14	1.34
2	7.40	30.70	3.00	6.50	55.35	112.50	ND	0.14	0.76
3	7.45	29.25	3.25	5.80	82.59	431.50	ND	0.09	0.76
4	7.15	28.80	3.15	6.35	51.49	78.50	ND	0.26	0.82
5	7.15	29.30	3.40	6.65	49.07	109.00	ND	0.14	0.82
6	7.55	28.45	4.20	7.45	232.79	212.50	3.47	1.45	0.64
7	7.65	28.55	2.85	5.80	172.72	597.50	3.52	0.22	0.71
8	7.25	29.65	4.25	7.70	152.95	411.50	2.02	0.37	0.70
9	7.70	29.75	3.05	6.25	215.20	301.50	3.60	1.24	0.68
10	7.40	30.70	3.55	6.30	263.92	288.00	4.25	1.48	0.68
11	7.80	29.10	2.60	5.75	230.58	547.00	5.56	5.58	1.58
12	7.80	29.40	3.15	5.45	362.77	530.00	4.03	4.06	1.47
13	7.95	29.60	2.65	5.35	938.32	304.50	7.27	4.03	1.54
14	7.45	30.75	3.15	6.20	248.26	210.00	6.96	6.84	1.48
15	7.70	31.20	2.15	3.70	223.15	503.50	6.23	7.20	0.70
16	7.50	31.15	4.00	6.20	171.46	322.00	0.94	2.11	0.67
17	7.55	30.45	3.30	7.45	197.81	278.50	1.56	2.66	0.57
18	7.25	31.35	4.05	5.95	130.72	348.00	1.78	2.88	0.48
19	6.80	30.70	3.55	6.85	52.55	36.50	ND	0.19	0.78
20	6.80	30.35	3.05	6.45	39.70	36.50	ND	0.09	0.84
21	6.90	31.00	3.50	6.90	35.54	42.50	ND	0.34	0.83
22	6.65	31.80	2.05	4.65	51.28	44.00	ND	0.37	0.72

Table 2: Mean metal concentration

Site	Cr (mg/L)	Cd (mg/L)	Zn (mg/L)	Fe (mg/L)	Cu (mg/L)	Ni (mg/L)	Mn(mg/L)	Pb (mg/L)
1	ND	0.0202	0.3638	0.3042	0.0734	0.0053	0.1803	ND
2	ND	0.0083	0.4409	0.1905	0.1062	0.0016	0.1404	ND
3	ND	0.004	0.3498	0.2679	0.3198	ND	0.0816	ND
4	ND	0.0058	0.4038	0.7393	0.1188	ND	0.0772	ND
5	ND	ND	0.4021	0.3211	0.3313	ND	0.0478	0.14
6	ND	ND	0.3246	0.4681	0.3017	ND	0.1509	0.1665
7	ND	ND	0.3854	0.4445	0.2048	ND	0.1067	0.0586
8	ND	ND	0.3463	0.2502	0.3599	ND	0.0775	2.4512
9	ND	0.008	0.3317	0.2650	0.3836	ND	0.0852	ND
10	ND	0.0083	0.3663	0.2285	0.3794	ND	0.1742	ND
11	ND	0.0071	0.2659	0.094	0.2417	ND	0.1364	ND
12	ND	0.0014	0.2782	0.4202	0.3043	ND	0.391	ND
13	ND	0.0001	0.2837	0.2541	0.3142	ND	0.1512	ND
14	ND	0.0044	0.3199	0.1675	0.5339	ND	0.2080	ND
15	ND	ND	0.3191	0.1662	0.1869	ND	0.2798	ND
16	ND	ND	0.3743	0.2817	0.2221	ND	0.0914	0.0851
17	ND	0.001	0.3060	0.2208	0.302	0.015	0.1035	0.1353
18	ND	0.0022	0.3366	0.1970	0.1612	ND	0.0813	0.0703
19	ND	0.0016	0.3561	0.9495	0.2135	0.0117	0.0821	ND
20	ND	ND	0.3222	1.5318	0.3186	0.0134	0.0976	ND
21	ND	ND	0.3823	0.2395	0.4991	ND	0.0664	ND
22	ND	ND	0.3315	0.6847	0.2774	ND	0.0709	ND

The pH of a water sample is a very important parameter that can affect a number of the physico-chemical properties of the water sample. For example, dissolution of salts in the water is a pH dependent process which in turn can affect the conductivity, hardness, etc of the water sample. The maximum and minimum average pH values obtained for the well water sample are 7.95 and 6.65 at sites 13 and 22 respectively (Figure 1). These values meet the WHO standard of 6.5-8.5 for drinking water. A number of researchers obtained similar pH values for well water samples in other parts of the world (Oko *et al*., 2014, Braimah *et al*., 2021).

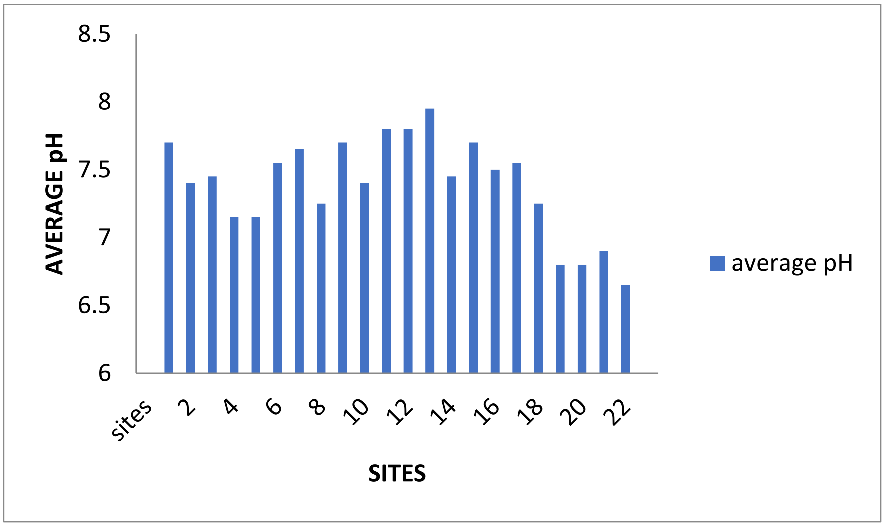

Figure 2: Average pH of samples

The conductivity of the water gives a vague idea about the water's capacity to conduct electricity. It also signifies the quantity of dissolved salts and hence, the pollution level of the water. The higher the dissolved salts the higher the conductivity of the water. The maximum and minimum average conductivity were obtained at sites 14 (1815µs/cm) and 20 (45µs/cm). Some of these values are really high which is expected considering the significant amounts of calcium and magnesium ions as well as sulphate detected in the samples. The values measured are also within the recommended WHO values.

Alkalinity is a measure of the water's ability to neutralise acid. It is usually as a result of bicarbonates, carbonates and hydroxides of calcium and magnesium. The results obtained in this research gave the maximum and minimum average alkalinity to be 522 mg/L (site15) and 56 mg/L (site 20) respectively. The alkalinity obtained in the research is likely due to bicarbonate ions in the sample. According to literature, from pH of 4.2 to 8.2, the alkalinity is solely due to bicarbonates. The maximum average (Figure 2) is outside the recommended standard by WHO which was expected owing to the fact that Zai area is a rocky and mountainous region.

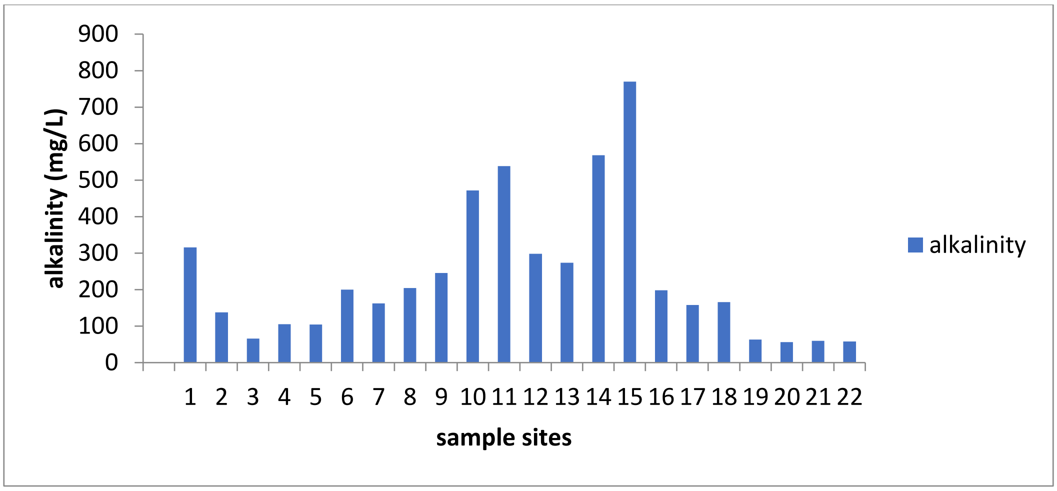

Figure 3: Average alkalinity

The desirable and permissible limits for hardness in drinking water are between 200-600 mg/L respectively. This water parameter is as a result of dissolved calcium and magnesium from soil containing limestone etc. The average values in this research are within these limits (Figure 4). Hardness is categorized as soft (0-60 mg/L), medium (60-120 mg/L); hard (120-180 mg/L) and very hard (> 180 mg/L). Most of the average values in this research fall within the medium to hard end of the category with few ones being very hard. These values are higher than those obtained by Oko *et al*. (2014).

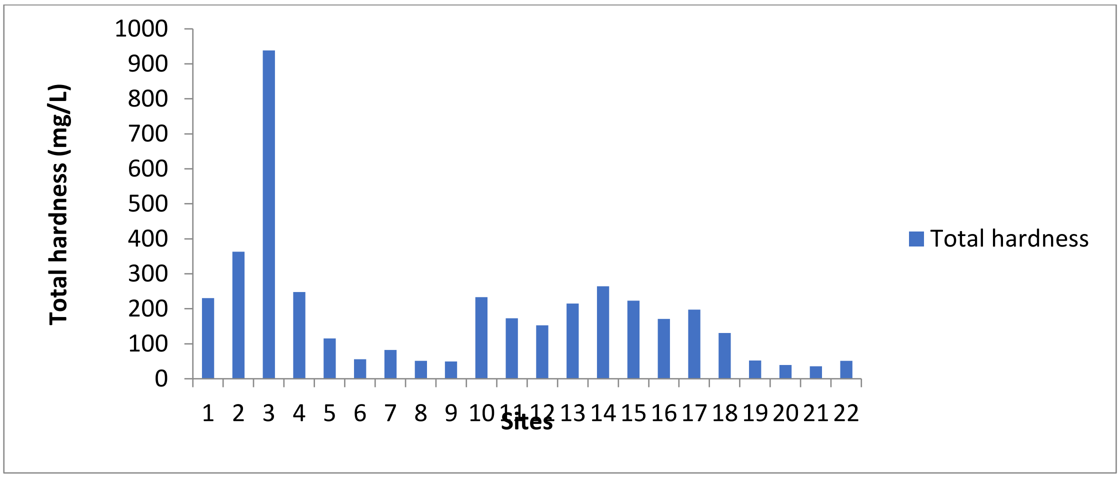

Figure 4: Average total hardness (mg/L)

Turbidity, a measure of resistance of water to allow light to pass through it, is as a result of suspended matter such as silt, plankton, clay etc. The WHO limit for turbidity in drinking water is 5 NTU. The average turbidity ranged between 0.45 NTU (site 9) and 61.05 NTU (site 21). This means that some of the well water cannot be recommended for drinking.

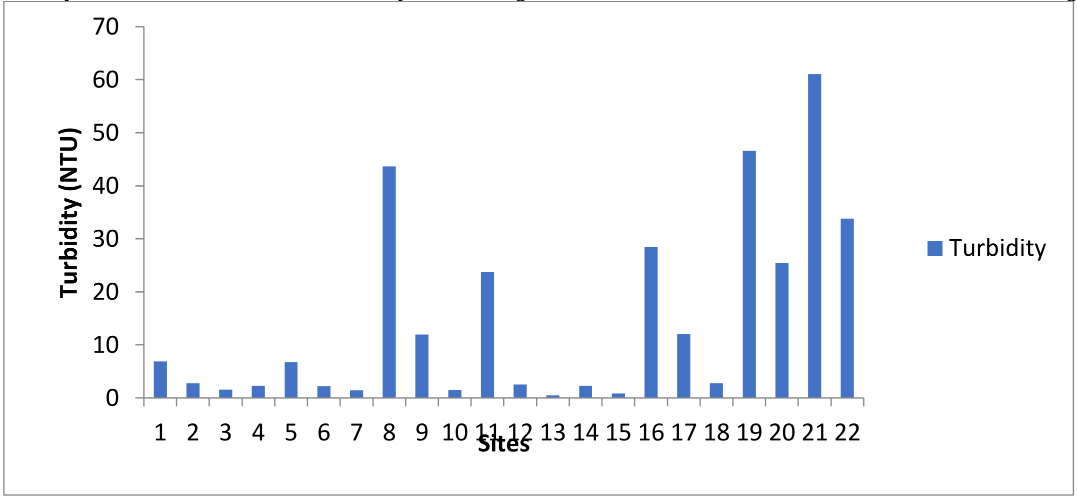

Figure 5: Average turbidity

Total dissolved solid (TDS) is one of the most important water quality parameters that can decrease significantly, the portability of the water. It comes about as a result of carbonates, chlorides and sulphates of sodium, calcium and magnesium (Edwin and Murtala, 2013). The maximum average TDS was recorded at site 7 (597.5 mg/L) which is above the WHO limit of 500mg/L for drinking water, while the minimum average of 36.5 mg/L was recorded at site 19.

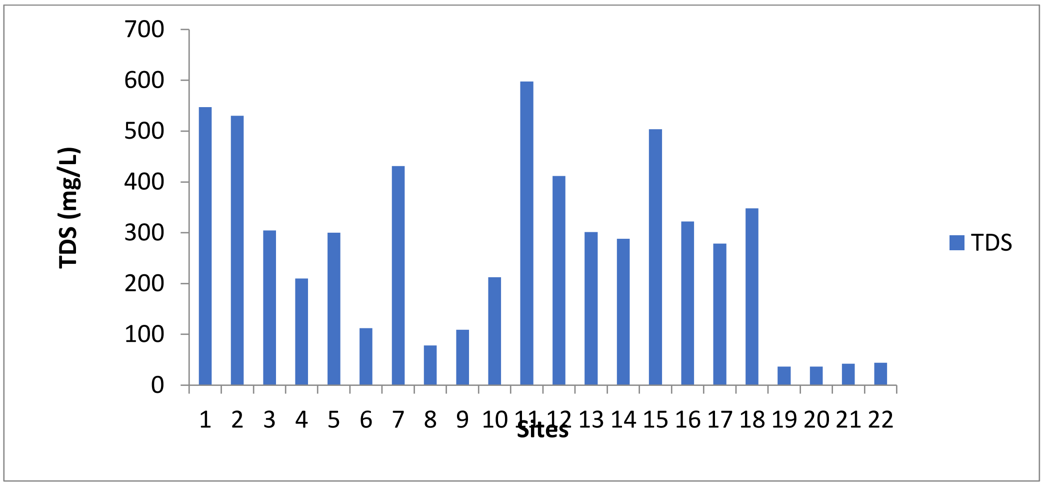

Figure 6: Total dissolved solids (mg/L).

Dissolved oxygen (DO) is also an important parameter when assessing the quality of water because its availability determines the survival of aquatic lives (Yogendra and Puttaiah, 2008). In the current research, the general dissolved oxygen content was low (Table 1b) in all the sampled water, perhaps indicating high organic matter content. The low dissolved oxygen in the samples was expected considering the high temperatures of the samples collected. According to Edwin *et al*. (2013), there is an inverse relationship between temperature and dissolved oxygen. The minimum and maximum average values of DO (3.7 mg/L and 7.7 mg/L) were recorded at sites 15 and 8 respectively which are within the permissible limit of WHO.

Chemical oxygen demand (COD) is the amount of oxygen required to oxidise both organic and inorganic compounds. The minimum and maximum average COD (1.2 mg/L and 8.6 mg/L) were recorded at stations 18 and 15 respectively (Table 1b). These values are well within the 10 mg/L limit of WHO.

Carbon dioxide level in water usually depends on the water type and for well water; its content can exceed 10 mg/L. The highest value (24 mg/L) was recorded at site 9 and the minimum value (3 mg/L) was recorded at side 5. Carbonate ions were not detected in any of the sampled well water. Perhaps it was below detection limit of the instrumentation (Table 1a).

Temperature is usually not a stringent condition when studying water quality. The measured values in this research were all above the recommended value of WHO. The highest and lowers values (32.1^oC and 28^oC) were recorded at sites 15 and 3 respectively.

The source of sulphate in water bodies are usually either by atmospheric deposition or through industrial discharge of sulphur containing effluents. The sulphate content of all the samples from the studied sites was below the recommended value of 50 mg/L by WHO (Table 1a). Similar values were obtained in literature (Haingotseheno *et al*., 2020).

Calcium and magnesium are always found in water and they are the major contributors of water hardness. Their values in water can range between zeros to several hundreds of milligrams per litre. In the current studies, the maximum and minimum average Ca^{2+} (298.6 mg/L and 13.6 mg/L)were recorded at sites 13 and 19 respectively, while 60.24 mg/L and 1.11 mg/L (Table 1a), were also recorded for Mg^{2+} at sites 13 and 2 respectively.

One of the main inorganic anions in water is the chloride in the form of chlorine. Its presence in water (in excess) always produces salty taste. The WHO limit for chloride in drinking water is 250 mg/L. The maximum and minimum average chloride in this research are 418.77 mg/L (site 14) and 13.89 mg/L (site 22) respectively.

One of the most abundant resources in the earth's crust is iron (about 5 %). This element gets into the water bodies including well water when rain water seeps through soil and thereby dissolving the element in the soil. The maximum and minimum average iron in the water samples are 1.06 mg/L (site 4) and 0.17 mg/L (site 15) respectively.

Sodium, the most abundant alkali metal is also found in drinking water but usually not exceeding 50 mg/L. In some of the well water samples studied, sodium was not detected perhaps due to its absence or being below detection limit of the instrumentation. The maximum and minimum average values are 7.77 mg/L (site 13) and 0.94 mg/L (site 16) respectively. The maximum and minimum average values of potassium in samples are 7.2 mg/L (site 15) and 0.09 mg/L (site 20 & 3) respectively.

Biochemical oxygen demand (BOD) is an indication of the amount of biodegradable organic matter in the water sample. The higher the organic matter content, the higher the BOD value due to heightened microbial activity. The maximum and minimum average BOD for the well water samples are 4.25 mg/L (site 6) and 2.05 mg/L (site 22) (Table 1b) respectively. These values are below the 5 mg/L limit set by WHO.

The alkalinity of a water sample is a measure of the presence of hydroxides, bicarbonates and carbonates. It is believed that for a sample with pH of between 4.2 -8.2, the alkalinity is due to bicarbonate alone. Going by the pH values in this research (Figure 2), the alkalinity is due to bicarbonate. The maximum and minimum average bicarbonate values are 770 mg/L (site 15) and 56 mg/L (site 20).

The maximum and minimum average phosphates in the studied sample are 1.58 mg/L (site 11) and 0.48 mg/L (site 18) respectively.

Figure 7 is the chart of water quality index (WQI) of well water samples studied. The water quality is classified into WQI ratings based on the WQI values. WQI from 0-25 is termed as excellent for drinking purpose, 25-50 as slightly polluted but good for drinking; 50-75 as poor for drinking purpose (moderately polluted), 75-100 as very poor for drinking purpose (polluted) and > 100 as unsuitable for drinking purpose (excessively polluted). From the Figure, the WQI values for samples from sites 2,3,6,8 9, 13, 15 and 18 fall within 50-75 range and can be considered as poor for drinking purpose. Again, samples from sites 10 and 12 can be considered as being very poor for drinking purpose while samples from sites 1, 4, 5,7, 11, 16, 17, 19, 20, 21 and 22 are classified as unsuitable for drinking purpose since their WQI values are all above 100. These deductions are well supported by the values of the physico-chemical parameters presented in Table 1a & b).

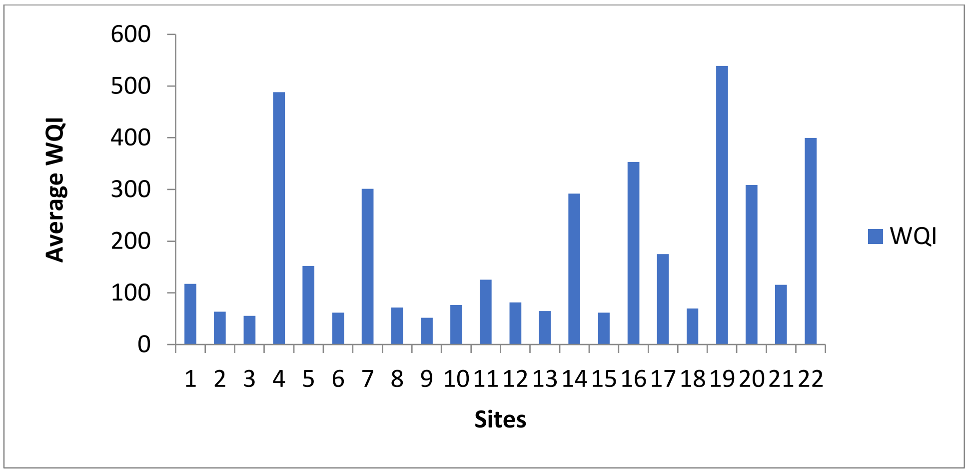

Figure 7: WQI

The result of heavy metal pollution index (HPI) of the studied samples is presented in Figure 8. This index is used to assess whether a water sample is polluted by heavy metals or not. When the calculated HPI value is < 100, it means that the water is save for drinking and is free from heavy metal pollution (Table 2). But if the calculated value is > 100, then the water is polluted with heavy metal and unsafe for drinking. From the Figure, it is clear that samples from sites 1, 2, 3, 4, 16, 17 and 18 have their HPI values > 100 and are therefore polluted with heavy metals and are unsafe for drinking. Whereas the rest of the samples have their HPI values < 100, and are considered as not polluted by heavy metals and are therefore safe for drinking.

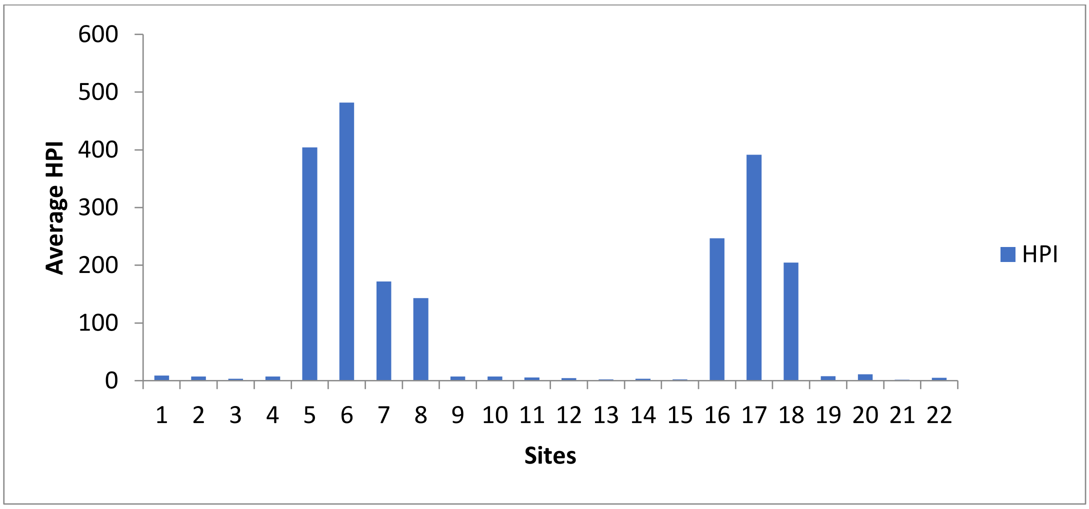

Figure 8: HPI

CONCLUSION

The comparative metal and physico-chemical analysis of well water samples from Zai area of Dutse revealed high levels of the parameters studied. The most of the well water studied were found to be either hard or very hard due to the excessive amounts of dissolved salts present.

Based on water quality index values (WQI) obtained, most of the samples studied were classified as not suitable for drinking purpose but could be used for laundry purpose if the hardness could be removed. Again, based on the heavy metal pollution index (HPI) values obtained, most of the well samples studied were found to be free from heavy metal pollution.

Furthermore, based on the parameters studied, no evidence was found on why water from some of the wells was unable to cook some food items as claimed by the residents. Perhaps if the water can be softened using treatment methods such as reverse osmosis, electro dialysis, or iron exchange to reduce the levels of calcium and magnesium in the water required for domestic purpose, the problem could be reduced; Or by demineralisation of the water by removing excessive salts and minerals. We can also reduce the alkalinity of the well water by simply adding mineral acids to neutralise the per carbonate ions.

ACKNOWLEDGEMENT
This research received funding from TETFUND through Federal University Dutse, under the institutional based research grant (IBR).

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