



Application of Statistical Technique to Assess the Impact of Sanitary Sewage on Groundwater Quality of Mando Area, Kaduna Nigeria

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ABSTRACT

This research was carried out to assess the impact of sanitary sewage on groundwater quality of Mando area using the application of statistical technique. A total of sixteen (16) samples were collected and the lateral distance from the well water sources to the septic tanks was recorded for all the sampling locations. Physicochemical parameters, microbiological parameters, anions and cations were evaluated and compared to National Standard for Drinking Water Quality (NSDWQ). Nitrate, Escherichia coli (E.coli) and turbidity are the major water quality problems associated with the sampled households hand dug well water sources. From the statistical analysis (one-way ANOVA), distance of contamination source to water source has a significant effect all parameters except E.coli.

ARTICLE INFO

Article History

Received: October, 2021

Received in revised form: October, 2021

Accepted: November, 2021

Published online: December, 2021

KEYWORDS

Contamination, Groundwater quality, physicochemical characteristics

INTRODUCTION

Groundwater is one of the most useful water resources around the world. It accounts for about ninety-five percent of all freshwater found on the earth surface (Krantz and Kifferstein, 2005). Many populations are supplied with groundwater for drinking, irrigation or industrial purposes. Urbanization leads to an increasing demand for water of adequate quality, accompanied by the discharge of large corresponding volumes of wastewater. The major challenge is to protect urban groundwater resources so that it remains available to the future population. The total of groundwater withdrawn annually is approximately estimated at about 20% of global water withdrawals (Akpordio 2000).

Ground water is most at times polluted from a lot of the daily activities carried out by man. This can be through domestic sewage, radioactive waste materials, hazardous and biomedical waste disposal, oil spills, accidental leakage of oil, industrial effluents, and run-off water containing pesticide and fertilizer residue and leachates percolating from landfills (Lalitha, 2003).

More than 60% of the Nigerian population depend on groundwater for domestic water supply (Omole, 2013). This is due to the fact that most homes rely on self-supply of water

rather than municipal water supply (Omole, 2013; Ndambuki, 2015). Self-supply of water without proper planning and regulations, however, often leads to abuse and chaos. In Nigeria, improper town planning has created situations where industries and domestic homes are close by each other thus, effluent discharges and other forms of pollution from industrial activities often impact on drinking water sources and other aspects of human life (Adewunmi *et al.*, 2011).

Groundwater has natural deposits of contamination. However, groundwater pollution can also arise from anthropogenic activities and from the surface and groundwater interactions (Quillan, 2004). Pollutants that can affect drinking water sources include heavy metal pollution from manufacturing, metallurgy, paints and chemicals and other similar industrial activities. Other pollutants such as nitrates, nitrites and sulphate can affect drinking water sources because of improperly managed wastewater effluents. Therefore, regular water quality monitoring is important to safeguard public health.

The problems associated with sewage disposal have become a major problem of the urban world due to increase in human population and urbanization (Corcoran *et al.*, 2010). Consequently, domestic wastewater discharges

are considered one of the most significant threats to human environments worldwide (GPA, 2001).

In Mando area, groundwater is one of the main sources of water used intensively for domestic and agricultural purposes. The problems of water quality are much more acute in areas that are densely populated, with unplanned construction of septic tanks and localization of industries. Importantly, groundwater can also be contaminated by naturally occurring sources.

In this study, impact of sanitary sewage on groundwater quality of Mando area was evaluated using the application of statistical technique.

Study Area

The study area is Mando of Igabi local government area. Mando is situated along Birnin-

Gwari Lagos expressway Afaka Kaduna, Nigeria. Its geographical coordinates are 10° 43' 0" North, 6° 34' 0" East. The area is seen to have gentle slope, few out crops covered by farmland, interspersed with shrubs and scattered trees. The area can be accessed by motor vehicles, motorcycles and foot traverses. The Mando area drainage pattern comprises of four main rivers, which are seasonal rivers; River Gora, Debu, Doka and Mashi. The major river is River Gora, which runs southwards at the lowest part of the general area. The total population of Mando is approximated to be 7500 (Tukur, 2006). The population over the years have increased because more people have settled in the area.



Figure 1: Study Area

MATERIALS AND METHOD

The physiochemical parameters evaluated were pH, electrical conductivity, total dissolved solids, turbidity, nitrates, total alkalinity, total hardness and iron. The microbiological evaluation was the Escherichia coli count. Cations and anions were also assessed.

PH is a measure of how acidic or basic water is. The range goes from 0 to 14 which is a scale with which pH of a substance is being measured. With 7 being neutral, pH less than 7 is acidic and greater than 7 indicate a base. The

normal pH range in water systems according to NSDWQ is 6.5 - 8.5. Electrical conductivity reflects the capacity of water to conduct electrical current and is directly related to the concentration of salts in dissolved water. The greater the total dissolved solids content is, the lower the turbidity of the water. Total dissolved solids are a measure of the dissolved combined content of all organic and inorganic substances present in a molecular ionized or micro granular suspended form. High levels of TDS can make water taste salty or brackish. Water hardness is the traditional

measure of the capacity of water to react with soap. Hard water requires a considerable amount of soap to produce lather. Total alkalinity is the measurement of the concentration of alkaline substances dissolved in water that can both attract and release hydrogen ions.

The materials used for the analysis includes:

- i. 100ml sample bottles (30 sample bottles for collecting 15 samples),
- ii. Sampler: this is tied to the sample bottle and immersed deeply into the wells,
- iii. A masking tape that was used for labelling,
- iv. Ethanol and cotton wool that were used for sterilizing ,
- v. wagtch photometer,
- vi. Membrane filtration apparatus,
- vii. Titrimetric apparatus e.g. burette ,conical flask, measuring cylinder, membrane filter etc. that would be used to carry out titrimetric analysis to analyse chloride, alkalinity, total hardness and salinity,
- viii. Flame photometer and the standards.

Samples were collected from 15 selected areas of Mando. The samples were collected through stratified random sampling to have a good representation of that area. Sanitary measures were ensured while collecting the samples. For each location, the lateral distance between the septic tanks and the sample points was measured using a measuring tape in meters (m). Two sample bottles were required: one was used for the microbiological analysis and the other

was used for physiochemical analysis and determination of cations and anions.

The EPA (Environmental Protection Agency) analytical method 1622 or 1623 was adopted in the collection of samples as follows:

- i. Gloves and eye protection were used when collecting the samples.
- ii. Sample bottles and caps were rinsed three (3) times with the sample water.
- iii. Sample bottles were filled to brim for physiochemical test and about one or two inches were left at the top for the microbiological test.
- iv. Samples were placed immediately in the cooler for delivery to the laboratory

RESULTS AND DISCUSSION

The analysis was carried out under four categories; physiochemical parameters, microbiological analysis (to determine E.coli), cations and anions with respect to the lateral distance between the septic tanks and sample points. The results obtained for each of the parameters were compared to the National Standard for Drinking Water Quality (NSDWQ) and WHO standards which is a guide to determine or ascertain if each samples collected if fit for drinking or not.

pH

From the analysis, all the hand dug wells sampled in Mando area have a pH range of 5.5 – 7.8. Ten (10) of the locations were within the 6.5 –8.5 of the NSDWQ permissible limits, while six (6) locations have less than 6.5. These locations have pH values below acceptable limits and are slightly acidic as shown in Figure 1.

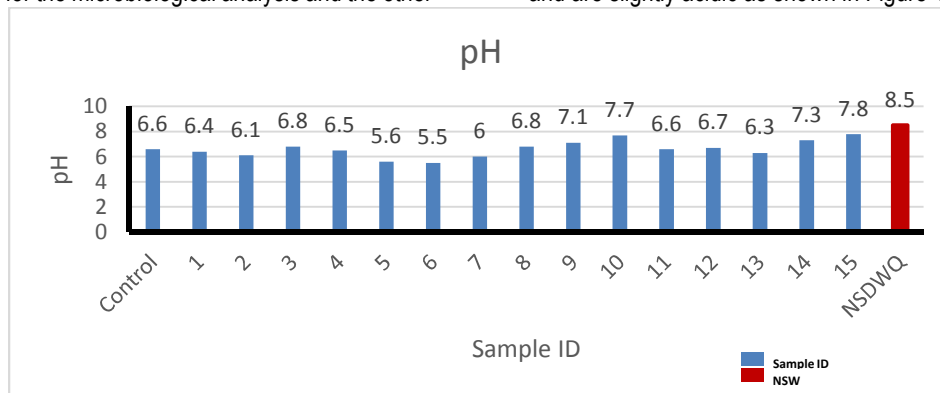


Figure 2: pH values



Electrical Conductivity

Electrical conductivity reflects the capacity of water to conduct electrical current and is directly related to the concentration of salts in dissolved water. The electrical conductivity of all

analysed water samples are within the permissible range of WHO and NSDWQ. The acceptable value for electrical conductivity is 1000u/cm and all the water samples have electrical conductivity within the permissible range as shown in figure 2.

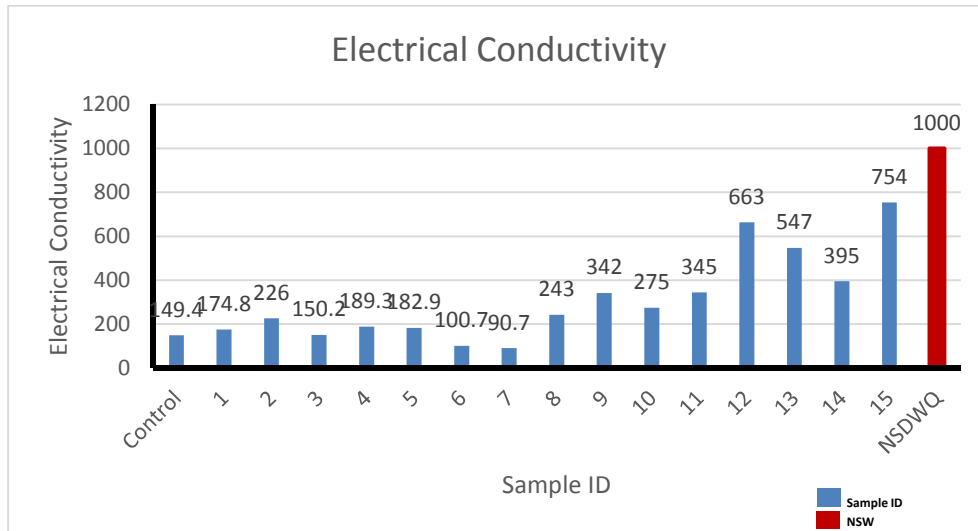


Figure 3: Electrical Conductivity values

Total Dissolved Solids (TDS)

All samples collected have low levels of Total Dissolved Solids except sample 12 and 15 with high TDS of 332ppm and 374ppm

respectively. However all samples are still within the permissible limit of WHO and NSDWQ which is 500ppm.

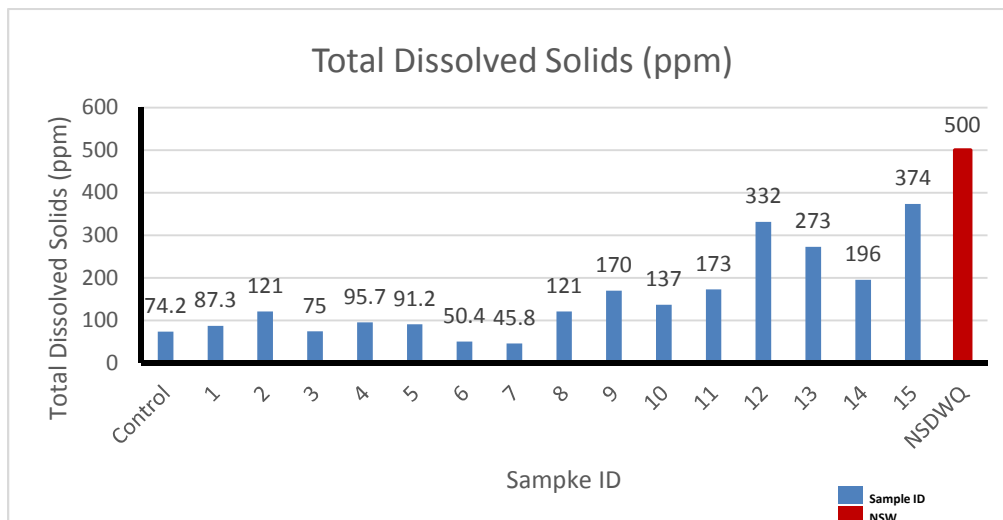


Figure 4: Total Dissolved Solids Values

Turbidity

Turbidity is the cloudiness or haziness of water. It is the degree to which water loses its transparency due to the presence of suspended particles. The more the total suspended solids in water, the higher the turbidity. Heavy rainfall affects water flow which in turn affects turbidity

and this can be seen as in Figure 4. Samples 1, 2, 10, 11 and 12 had turbidity above 5NTU which is above the permissible range of NSDWQ. This is due to increased sediments from run off as the analysis was carried out during the raining season.

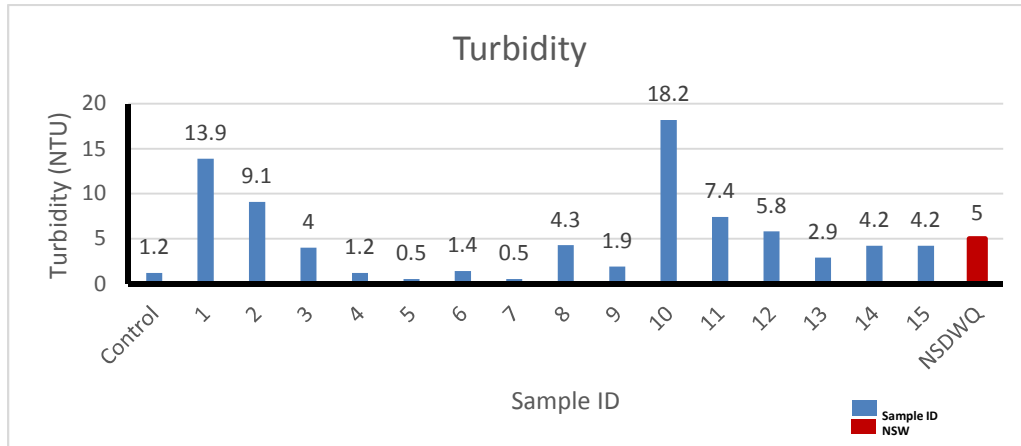


Figure 5: Turbidity Values

Nitrate

Amongst the sources of groundwater nitrate is the improper disposal of waste. This includes wastes from animal farms, use of nitrogenous fertilizer and septic systems. The nitrate levels in almost all the locations were very

high. This may be attributed to a high level of improper disposal of waste and poor sanitary sewage disposal. Only samples 1, 3 and 5 of all the sixteen (16) locations have nitrate levels within the permissible range of 50mg/l as shown in Figure 6.

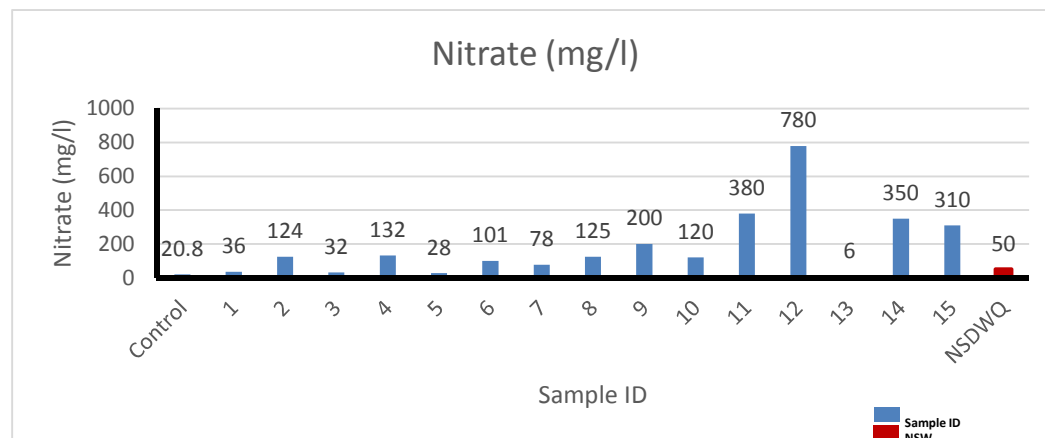


Figure 6: Nitrate Values

Total Alkalinity

Total alkalinity is the measurement of the concentration of alkaline substances dissolved in water that can both attract and release

hydrogen ions. All the sample locations analysed have total alkalinity that lies between the permissible range of WHO, which is 500mg/l as shown in the figure.

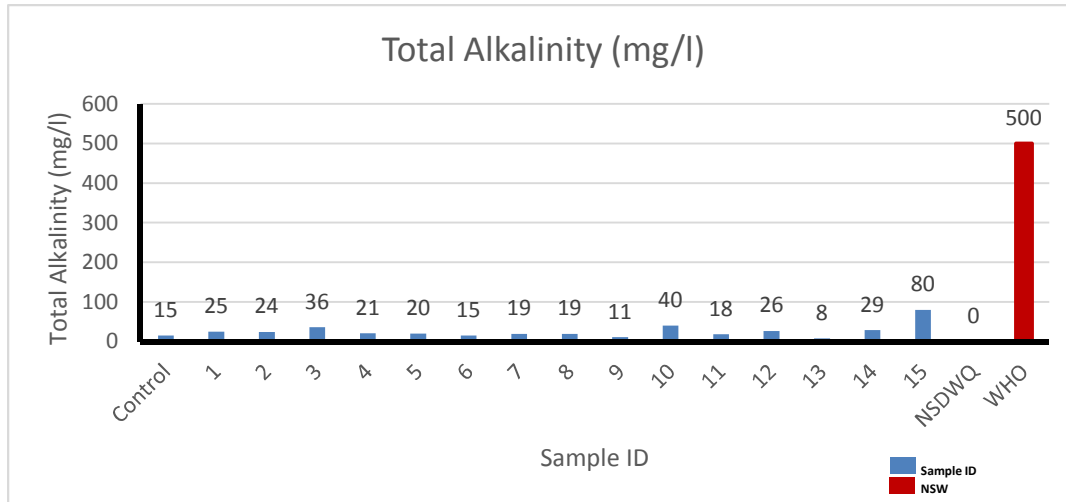


Figure 7: Total Alkalinity Values.

Total Hardness

Water hardness is the traditional measure of the capacity of water to react with soap. Hard water requires a considerable amount of soap to produce lather. Scaling of hot water pipes, boilers and other household appliances is due to hard water. A high degree of hardness can lead to cardiovascular diseases and incursion on

kitchen utensils. All the sample locations analysed in the study area have the total hardness of less than 150mg/l which is the permissible limit as stipulated by NSDWQ. Only sample 1 out of the sixteen (16) locations had a very close level of hardness to the limit having a concentration of 130mg/l.

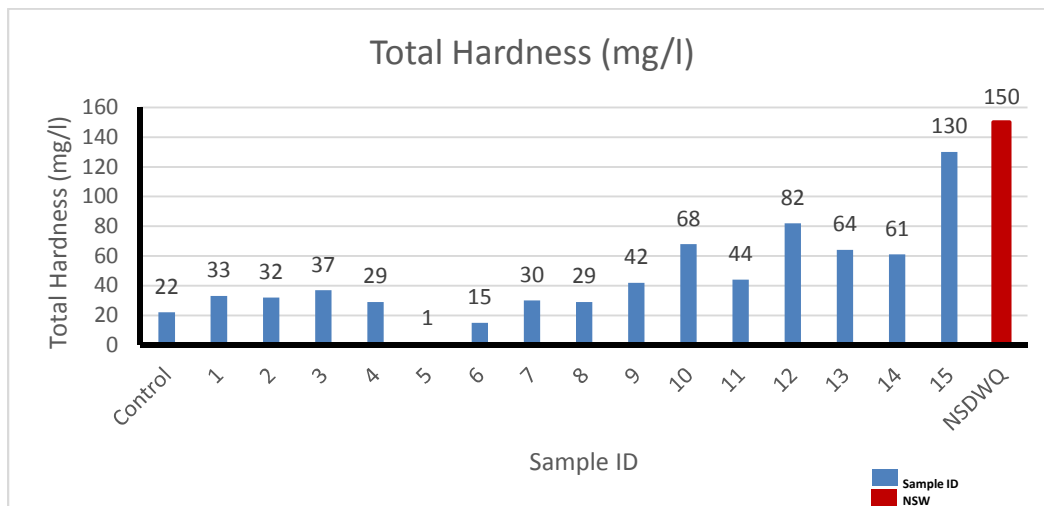


Figure 8: Total Hardness Values

Iron

Of all the sixteen locations that were sampled, the concentration of iron was either zero (0) or of a very minute concentration far below the

standard which is 0.3mg/l. No known health impact is attributed to high iron concentration in drinking water but it causes rust in metal containers.

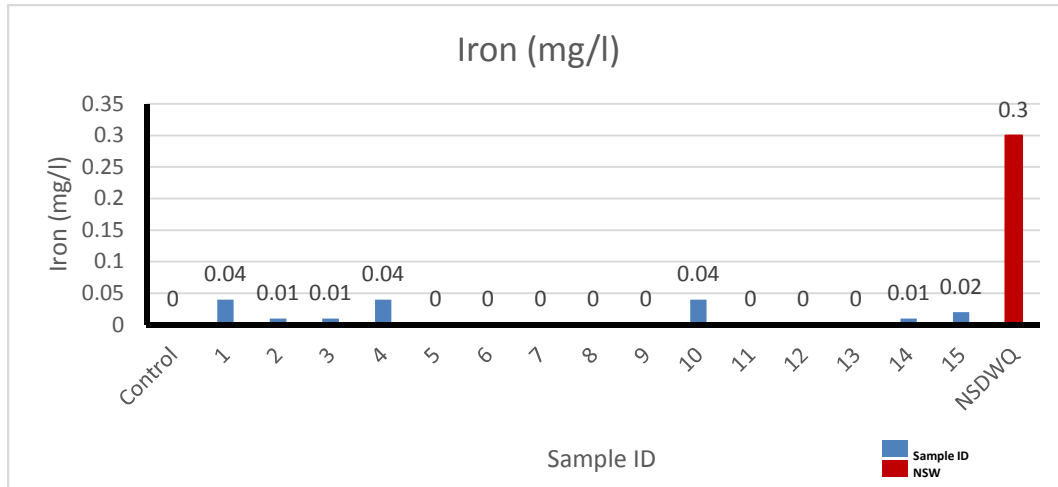


Figure 9: Iron Values

LATERAL DISTANCE BETWEEN SAMPLE POINTS AND SEPTIC TANKS

The distance between the wells and the nearest septic tanks ranged from 1.5 – 6.4m and the coliform count ranged from TNTC (too numerous to count), 463 to 0 cfu /ml. Most of the samples showed appreciable amount of coliform

count. The isolates characterized and identified in the water samples was *Escherichia coli*. Irrespective of the distance of the water wells from the nearest septic tank, the presence of coliform organism was also noticed. However, other factors like population density and environmental hygiene may also affect the quality of well water.

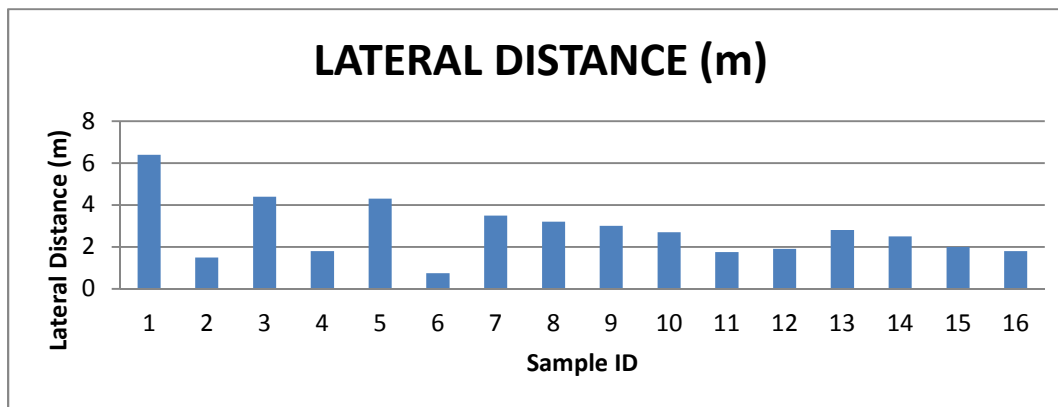


Figure 10: Lateral Distances between Water samples and Septic Tanks

MICROBIOLOGICAL CONCENTRATION (*Escherichia coli*)

Bacteriological analyses of hand dug wells in the study area showed that majority of the

underground drinking water sources were contaminated. The coliform counts were all on the very high side while worst case scenarios have TNTC value (Too Numerous To Count) except two



(2) locations with zero (0) number of coliform, which is the standard for both WHO and NSDWQ. This is a serious source of public health concern due to the assumed safety of the hand dug wells in the study area as a predominant source of

water. A health impact of bacteriological contaminated drinking water includes urinary tract infections, bacteraemia, meningitis, diarrhea, acute renal failure and haemolytic anaemia.

Table 1: Concentration of Anions

SAMPLE (mg/l)	Control	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NSDWQ
CHLORIDE	15.7	43.2	48.2	27.7	40.7	43.2	26.7	26.2	53.2	61.2	28.2	47.7	72.7	72.7	70.2	139.7	200
SULPHATE	0	0	0	2	3	0	3	4	2	4	3	1	5	2	3	0	100
BICARBONATE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-

Chloride is chlorine in solution as a compound. High concentration of chloride gives an undesirable taste to water and contribute to the deterioration of domestic plumbing and water heaters. High chloride concentrations in water may also be associated with the presence of sodium in drinking water (WHO 1984). Chloride concentrations in the study area were observed to be within the acceptable limits of 200mg/l for portable water according to WHO and NSDWQ. The only location that had a close value to the permissible range is sample 15 which had a chloride concentration of 139.70mg/l.

The Sulphate minerals can cause scale build up in water pipes similar to other minerals. It is also associated with a bitter taste in water that

can have a laxative effect on humans and young livestock when combined with calcium and magnesium. The permissible limits for sulphate according to NSDWQ and WHO are 100mg/l and 250mg/l respectively. All the hand dug well samples collected have low sulphate concentrations and therefore fall within the permissible range.

Bicarbonate is also a natural component of all mineral waters. Mineral waters that are sourced from limestone rich areas typically have high carbonate content. All the sixteen (16) locations have 0mg/l of bicarbonate present as against its permissible limit of 250mg/l by WHO specifications.

Table 2: Concentration of Cations

SAMPLE	Control	1	2	2	4	5	6	7	8	9	10	11	12	13	14	15	WHO
SODIUM(Na)	0.000	15.5	15.8	10.0	14.9	11.2	10.6	6.5	15.284	17.2	14.8	14.7	18.1	17.1	15.7	17.7	200
CALCIUM(Ca)	0.000	0.4	2.6	1.6	23.0	4.1	0.7	0.7	2.1	6.0	7.8	4.4	7.9	5.4	3.3	14.3	75
MAGNESIUM(Mg)	0.000	0.01	2.2	2.3	4.3	1.7	0.3	0.7	1.1	2.9	3.6	4.5	5.1	4.8	4.6	6.5	30
POTASSIUM(K)	0.000	3.0	8.8	7.8	12.0	10.2	3.0	4.0	9.5	9.4	10.1	12.3	8.8	10.9	11.0	17.1	12

Sodium in drinking water is essential for normal body functioning of the human body. It can be found in all body tissues and fluids and it is not generally considered harmful at normal intake from combined food and drinking water. Sodium is an essential nutrient, but high quantities increase the risk of hypertension (high blood pressure). The WHO standard permissible limit for sodium is 200ppm. All the hand dug well locations sampled in Mando area had sodium values within the permissible limit and is therefore acceptable.

Calcium is an important determinant of water hardness and it also functions as a pH stabilizer because of its buffering qualities. It also gives water a bitter taste. High quantities or concentrations in the body can cause stomach upset, affect the kidneys making them work harder to filter and can also affect the heart. Of all the hand dug well sampled in Mando area of Kaduna state, the calcium concentration falls within the permissible limits as given by WHO which is 75ppm. The highest range of calcium obtained as



sampled was 22.995ppm as shown in Table 2 which is acceptable.

Concentration of calcium and magnesium together determines the hardness of water. Drinking water containing high concentration can cause laxative effects. Drinking of water containing moderate amount of magnesium may help protect against gastric, colon and rectal cancer. The permissible limit for magnesium is 30ppm. Locations analysed indicates the magnesium concentration falls within the permissible limit. It is observed that the

combination of the concentration of calcium and magnesium concentration from Table 2 proves that sample (fifteen) 15 has the highest concentration of magnesium amongst the total of 16 samples.

Potassium is one of the most important minerals in the body. It helps regulate fluid balance, muscle contractions and nerve signals. A high potassium diet may help reduce blood pressure and water retention protecting against stroke and prevent kidney stones.

Table 3: Statistical Analysis of the parameters

PARAMETERS	pH	Ec	TDS (ppm)	Turbidity (ntu)	Nitrate (mg/l)	Total alkalinity (mg/l)	Total hardness (mg/l)	Fe (mg/l)	Na (mg/l)	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Cl (mg/l)	Sulphate (mg/l)
MEAN	6.612	301.8	151.0	5.04	176.4	25.38	44.94	0.01063	14.331	5.63	2.975	9.184	51.11	2.438
S.D	0.655	198.5	98.6	5.01	199.3	16.80	30.80	0.01569	3.299	6.03	1.976	3.716	29.49	1.999
VARIANCE	0.429	39419.9	9719.6	25.05	39738.0	282.25	948.60	0.00025	10.881	36.36	3.903	13.808	869.50	3.946
MIN	5.500	90.7	45.8	0.50	6.0	8.00	1.00	0.00	6.501	0.44	0.010	2.952	15.70	0.00
MAX	7.800	754.0	374.0	18.20	780.0	80.00	130.00	0.04	18.091	23.00	6.507	17.059	139.70	7.00
MODE	6.70	0	121	2.70	0	151.19	29	0	0	0	0	0	43.24	0.13
SKEWNESS	0.16	1.22	1.20	1.62	2.08	2.50	1.43	1.30	-1.15	2.02	0.04	-0.11	1.85	0.56
KURTOSIS	-0.21	0.65	0.62	2.32	5.03	7.71	2.91	0.16	0.75	4.47	-1.10	0.67	4.87	0.25
MEDIAN	6.600	234.5	121.0	4.10	122.0	20.50	35.00	0.00	15.284	4.11	2.937	9.478	45.49	2.50
NSD WQ	6.5 – 8.5	1,000	500	5	50	-	150	0.3	200	75	30	12	200	100
WHO	6.5 – 8.5	1,000	500	5	50	500	500	0.3	200	75	30	12	200	100

Table 3 shows descriptive statistical analysis of the assessed parameters. Most (10 out of 14) of the parameters have skewness and kurtosis outside the range of normality and therefore the distribution is not normal. Magnesium, potassium and sulphate are the only parameters that are not highly skewed. While majority of the parameters are right skewed, sodium is the only parameter that has a left skewed distribution. 50% of the parameters were outside the range of normality based on kurtosis

values less than -1 and greater than +1. While turbidity, total hardness, magnesium were not normally distributed, nitrate (5.03), total alkalinity (7.71), chloride (4.87) and calcium (4.47) with kurtosis values greater than three (3) have highly leptokurtik distributions. The skewness and kurtosis values that are not normally distributed indicate that these parameters have high probability of having very high or low concentrations in the area of study in the future.

Table 4: Analysis of Variance of Physiochemical and Microbiological Analysis to Lateral Distance

S/N	PARAMETER	F VALUE	P VALUE	F VALUE (Critical)	STAT. SIGNIFICANCE
1	pH	164.181	312E-13		SS
2	Electrical conductivity	35.478	206E-06	4.196	SS
3	Total dissolved solids	35.529	203E-06	4.196	SS
4	Turbidity	4.308	0.047	4.196	SS
5	Nitrate	12.505	0.007435	4.196	SS
6	Total Alkalinity	28.1498	1.2E06	4.196	SS
7	Total Hardness	29.633	8.26E-06	4.196	SS
8	Iron	89.004	3.43E-10	4.196	SS
9	Microbiology (Ecoli)	4.14	0.0514	4.196	NS



The one-way analysis of variance (ANOVA) for physiochemical and microbiological analysis to lateral distance (see Table 4.6) shows that the effect of lateral distance to pH, electrical conductivity, total dissolved solids, turbidity, nitrates, total alkalinity, total hardness, and iron were statistically significant with $FCAL > FCRIT = 4.196$. For the E coli, the F calculated is less than the F critical which makes it not statistically significant at $FCAL = 4.14 < FCRIT = 4.196$.

One way analysis of variance was used because only one factor was compared with all the parameters which was the lateral distance from the well water sources to the septic tanks. The parameters that had values close to the F Critical were turbidity and nitrate. PH in turn had the largest of F Calculated which proves that pH can no way have an effect on groundwater.

CONCLUSION

The effect of sanitary sewage on hand dug wells was evaluated in Mando, Kaduna in relation to lateral distance. 87.5% of the sampled households hand dug well water sources contains potential faecal pathogenic organisms values above the 0cfu/100ML. Given the situations in the sampled households, acquaintance to microbiological contamination is cited as a major water quality problem in the focused households hand dug well water sources. The project findings signified that nitrate and *Escherichia coli* are major water quality problems associated with the sampled households hand dug well water sources.

Cations and Anions analyzed have values that are within the permissible range for WHO and NSDWQ and are therefore acceptable for all sampled households.

Statistical analysis indicates a strong relationship between the water quality parameters evaluated to the lateral distance of ground water source.

RECOMMENDATIONS

Taking all the project findings into consideration, the following recommendations are made with a view to enhance service provision and ensure safe water supply for the protection of consumers' health from the households hand dug well water sources:

1. Sources containing microbiological contamination should be remediated

appropriately using boiling or ultra violet (UV) radiation prior to domestic usage, especially drinking.

2. The recommended distance of 35m from groundwater sources to septic tanks/ sewage should be encouraged and strictly adhered too. This is to avoid microbiological contamination by E. coli.
3. Constant water quality evaluation should be encouraged by households and residents.

REFERENCE

- Akporido C. E. (2000). "A study of the Characteristics of Surface and Underground Water in Sapele and Ogharefe Oil Producing Areas of Delta State", *The Nigeria Journal. Science Environ.*, 5(7) :65 – 75
- Adewumi A. S, Ogbiye, E. O. Longe, and Omole D. O. (2011) "Effect of industrial effluents on water quality of River Atuwara in Ota, Nigeria," in Adeyemo, R, Urban Agriculture, Cities and Climate Change, CuvallierVerlag, Gottingen, Germany, ISBN: 978-386955-813-4:272-280,2011
- Corcoran E. C, Nelleman E. Baker, R. Bos, D. Osborn, H. (2010). *Sick water? The central role of wastewater management in sustainable development. A rapid response assessment.* Arendal, Norway: UNEP/GRID-Arendal. ISBN 978-82-7701-075-5. 12-18.
- GPA (2001). National Report for the Intergovernmental Review of the GPA 2001. Kenya. 18 September 2001
- Krantz D, Kifferstein B (2005). "Water Pollution and Society", *Environmental Law Practices.* 4(1): 1 – 12.
- Lalitha. S. (2003) "Impact of sewage disposal on water near Chinthamani, Tiruchirapalli" *Indian Journal of Environmental Protection.*
- Mc Quillan D, (2004): Ground Water Quality Impacts From Site Septic Systems Proceedings, National Onsite Wastewater Recycling Association 13 Annual Conference NM November 7 10, Page 1-13
- Omole D. O. (2013) "Sustainable Groundwater Exploitation in Nigeria," *Journal of Water Resources and Ocean Science, vol. 2(2),* pp. 9-14, 2013.
- WHO. (1985). *Guidelines for Drinking Water Quality. Drinking Water Quality Control in small community.* Publishers and distribution, Shahdara, Delhi India.