FUDMA Journal of Sciences (FJS)
ISSN Online: 2616-1370
ISSN Print: 2645-2944
Vol. 2 No.3, September, 2018, pp. 146 - 153

SPATIAL ANALYSIS OF SULPHATE AND PHOSPHATE LEVELS OF MAJOR DOMESTIC WATER INTAKE SOURCES IN DUTSIN-MA TOWN, KATSINA STATE, NIGERIA

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ABSTRACT

This study aims at determining phosphates and sulphates levels of major domestic water intake sources in Dutsin-Ma town in order to observe some spatial patterns. The field and sampling design gave a target of thirty four (34) samples from open surface, shallow wells, boreholes, and pipe borne evenly distributed among the spatial local administrative units of the town. Gravimetric method was applied in the analysis of Total Dissolved Solids (TDS), while the spectrophotometric method was used analysis of both sulphate and Phosphate. Results of analysis showed that TDS and phosphate have very high levels, while sulphate is lower in most of the domestic water intake sources. The levels of TDS, sulphate and phophate were scaled into a 4-class suitability quality for domestic uses. Based on this classification about 72.00, 72.41 and 6.90% of intake sources fall into the 'More Unsuitable' limits for domestic uses for TDS, phoslphate and sulphate respectively. The treated water from Water Board at source shows all these parameters to be at 'More Suitable" levels for domestic uses. However, result identified possible contamination along distribution pipes as levels at terminal intake points of these pipe showed higher values of these parameters investigated. It is recommended therefore, that the results of the study should be used to develop a framework for domestic water quality surveillance and intervention infrastructure. Pipe borne water supply system should have a routine maintenance. All other sources of domestic water with unsuitable levels of these contaminants should be tagged with precaution notices and the community advice on selective domestic uses which do not have major adverse effects.

Keywords: boreholes, open surface, pipe borne, shallow wells, spatial, and surveillance

INTRODUCTION

There is an increasing concern and commitment of researchers to understanding the biological and environmental effects of high levels of anionic surfactants or pollutants especially in water sources (Castellato and Negrisolo, 1989; Tibor et al., 2002). One of the primary goals of World Health Organisation (WHO) and its member states is that "all people, whatever their stage of development and their social and economic conditions, have the right to have access to an adequate supply of safe drinking water" (WHO, 2003)

Phosphates and sulphates exist in different inorganic forms in both soil and water. The source of phosphates can be either natural or anthropogenic depending on the activities occurring in the area under study (American Public Health Association, 1999).

In most developing countries, discharges from point sources have increased significantly as a result of industrialization and high living standards. Additionally, excessive nutrient loads to rivers in these countries have been accompanied by untreated wastewater discharges (Smith et al., 1999). The activities of farming inputs such as sulphate and phosphate based fertilizers have accentuated the increasing levels of dissolved solids or salts especially sulphate and phosphate in most reservoirs that are used for public water supply.

It is a fact that fresh water sources are generally scarce; the situation is further worse in semi-arid and arid zones. The increasing use of fertilizers in most watershed due to agricultural activities, domestic and industrial wastes increase the vulnerability of these meager fresh resources in most parts of developing countries as the strive to attain economic growth (Swamy et al., 2013)

The presence of phosphates in water is permissible to some extent; however the increased infiltration into water bodies is of international concern due to its effects on water quality (Razman et al, 1999). Sulphates is widely distributed in nature and may be present in natural water in substantial concentration. Sulphates occur naturally in numerous minerals, including barite, epsomite and gypsum (APHA, 2003).

Smith et al (1999) have provided details of eutrophication effects of high levels of phosphates on aquatic systems. When the concentration of phosphates rises above 100 mg/L the coagulation processes in domestic drinking water treatment plants may be adversely affected (John, 1993)..

Sulfates are discharged into water from mines and smelters and from kraft pulp and paper mills, textile mills and tanneries. Sodium, potassium and magnesium sulfates are all highly soluble in water, whereas calcium and barium sulfates and many heavy metal sulfates are less soluble. Atmospheric sulfur dioxide, formed by the combustion of fossil fuels and in metallurgical roasting processes, may contribute to the sulfate content of surface waters. (Delisle and Schmidt, 1977).

Most studies on phosphates have been focused on its levels in natural surface sources such as rivers, lakes and underground sources (Fadiran et al., 2007), waste water (Greenberg et al., 1992) and industrial effluents , very few on drinking water (Digesti and Weeth, 1976; Barker, 2000; Gomez et al., 1995; Heizer, 1997)

Many researchers have studied the effects of high sulphate levels on domestic animals. For instance, Digesti and Weeth, (1976) reported the effects of high concentrations of sulphate on livestocks, Paterson et al. (1979) studied on the effects sulphate on swine reproduction and young pigs performance.

The main objective of this study is to investigate the spatial patterns of levels of these parameters (TDS, sulphate and phosphate). This approach is believed will provide better understanding of the environmental sources of contamination, vulnerability based on intake sources with high levels of these salts. In the overall, the outcome can provide a basis for developing a spatial framework for surveillance activities aimed at provision of standard water quality to houserhold consumers.

MATERIALS AND METHODS

Sampling Techniques

The most important task of water quality analysis is sampling (Abdur, 2013). A systematic approach was used to achieve a spatial sampling of domestic water intake sources.

The two political wards that divide the town into north and south were as follows:

A = northern ward
B = southern ward
Ward A was further divided into four spatial traditional units referred to as ‘’Unguwa’’
A1 = Unguwar Doroyi/Abuja road
A2 = Unguwar Yan daka
A3 = Unguwar Lowcost/ Banza-Wakaji
A4 = Hayin Gada
Similarly, Ward B was further divided into four (4) spatial traditional units as follows;
B1 = Unguwar Kadangaru
B2 = Unguwar DanRimi/ Tsamiya
B3 = Unguwar Dogon Karfe/Doctor Campus
B4 = Unguwar Dangaje/ShemaQuaters/sokoto Rima Qtrs
Stratified sampling was to sample different domestic water intake sources from the 8 Unguwas follows:
PP = Pipe Borne
BH = Bore Hole
WL = Shallow Well
Hence, coded as follows to make 21 samples;

A1PP	A1BH	A1WL
A2PP	A2BH	A2WL
A3PP	A3BH	A3WL
A4PP	A4BH	A4Wl
B1PP	B1BH	B1WL
B2PP	B2BH	B2WL
B3PP	B3BH	B3WL
B4PP	B4BH	B4WL

Another set of stratified sampling included open surface sources as follows:
Dam (DM) and Stream (SR). They were coded as follows:
SDMN = Surface Dam to the north
SDMS = Surface Dam to the south
SDME = Surface Dam to the east and
SDMW = Surface Dam to the west
SRUC = Stream Upper Course of the town
SRMC = Stream Middle Course of the town
SRLC = Stream Lower Course of the town
Two samples were collected from Water Board
WBRW = Water Board Raw Water
WBTW = Water Board Treated Water at source
By this sampling a total of thirty three (33) samples were targeted for collection.

Sample Collection, Handling and Storage

Water samples were obtained from field using 150 ml plastic containers which had been thoroughly washed and rinsed with distilled water. A total of 33 samples using systematic and stratified random sampling were collected for analysis, one each from surface, pipe borne, boreholes and shallow wells making four (4) from each spatial local administrative unit called ‘Unguwa’. The samples were tightly caped and placed in a cooler boxes containing ice-chips immediately. Samples were preserved by adding 2 mL of concentrated HNO_3/L of sample with subsequent refrigeration at 4^{o}C after transportation to the laboratory. Analyses were carried out within 48 hours after sampling (Stewart, 1989; Chapman, 1992; ASTM, 1993).

Analysis of Total Dissolved Salts (TDS)

Considering the fact that both sulphate and phosphates are soluble anions among others, it was pertinent for TDS to be determined as an indicator parameter for the sulphate and phosphates under investigation.

The TDS of the water samples were determined by the gravimetric method. The measurements of TDS in the water samples were carried out according to the standard methods of APHA by the filtration process. This is because the accuracy and precision of this methods is well approved and cited in the scientific literature. A fixed volume of water sample (100ml) was poured on a pre-weighed glass fiber filter of a specified pore size and filtered. The filtrate was heated in oven at above 100°C over night until all the water was completely evaporated. The remaining mass of the residue represents the amount of TDS in a sample.

Calculations for Total Dissolved Solids (TDS)

TDS = (A-B) x 1000/C

Where;

A = Weight of dried sample + Stable Weight (mg)

B = Weight of Stable Weight (mg)

C = Volume of sample (ml)

Analysis of Total Sulphate and Phosphate

Both sulphate and phosphate were analysed using the spectrophotometric method. The APHA (1999) standard method for examination of water was used for the preparation of Blank, standard sulphate and phosphate solutions and Samples for Analysis
The standard sulphate solution was prepared by weighing exactly 1.479 g of analytical grade anhydrous sodium sulphate and dissolved in distilled water and made to a volume of 1000 ml in a standard volumetric flask using distilled water. This solution is equivalent to 1000 ppm sulphate (1ml=1.0 mg SO42-). 10 ml of Standard Sulphate solution was measured to the first flask, 20 ml to the second, 30 ml to the third, 40 ml to the fourth, and 50 ml to the fifth. To the sixth flask was added distilled water alone and labeled as blank. The samples were prepared by pipetting 10 ml of each sample into a 25 ml standard volumetric flask. 5 ml of the conditioning reagent was added independently to each sample and the standards after every 3 minutes.
The analysis was done at a wavelength of 420 nm using Spectrophotometer.
The 1000 ppm of standard phosphate solution was prepared by weighing exactly 1.4329 g of analytical grade potassium dihydrogen orthophosphate and diluting to 1000 ml in a standard volumetric flask using distilled water**.** 0.1 ml, 0.2 ml, 0.3 ml, 0.4 ml, 0.5 ml and 0.6 ml of the standard phosphate solutions were accurately pipetted into a 100 ml volumetric flask using 1ml pipette equivalent to 1-6 ppm. The analysis was done at a wavelength of 420 nm using Spectrophotometer.

NB: The analysis of phosphates is all the samples requires good digestion which converts phosphorus to orthophosphate in the process. Therefore, ascorbic acid digestion method was employed in the phosphate analysis. The sulphates spectrophotometric analysis is based on the formation of colloids by sulphates and Barium chloride.

The recorded values were further converted to total sulphate and phosphate as follows;

Total sulphate (mg/l) = spectrometer value for sample x 1000/ sample volume (ml)
Total Phosphate (mg/l) = spectrometer value for sample x 1000/ sample volume (ml)

Suitability Ranking of TDS, Sulphate and Phosphate Levels for Domestic Water Uses

WHO/USEPA Maximum Contaminant Level (MCL)/Secondary Maximum Contaminant Level (SMCL) standards are used for ranking or classification. Ranking of Suitability of water quality of these domestic water intake sources base on outcome of the investigations was carefully structured considering that even high levels of these dissolved anions under study are not rated as very harmful compared to cations and especially the trace cations. Therefore their suitability or unsuitability is more subjective and relative. A 4-class scheme was adopted as follows: More Suitable, Less Suitable, Less Unsuitable and More Unsuitable.

More Suitable: Acceptable standard even for drinking purpose and thus for all other domestic uses
Less Suitable: Less acceptable standard for drinking purpose but acceptable for most other domestic use
Less Unsuitable: Not safe for drinking purpose and less acceptable even for most other domestic uses
More Unsuitable: Harmful for drinking purpose and not acceptable for most other domestic uses

RESULTS AND DISCUSSION

The results generally revealed that most of domestic intake water sources have high levels of dissolved salts with phosphates being most widely spread and sulphate least as presented in the tables below.

Table 1: Levels and Suitability of Total Dissolved Salts (TDS) of Major Domestic Water Intake Sources in Dutsin-ma

Sample intake source	**TDS (mg/l)**	**More Suitable (less than 500 mg/l)**	**Less Suitable (501 – 1000 mg/l)**	**Less Unsuitable (1001 – 1500 mg/l)**	**More Unsuitable (Over 1500 mg/l)**
A1PP	2000				✓
A1BH	5000				✓
A1WL	3000				✓
A2PP	0000	✓			
A2BH	3000				✓
A2WL	5000				✓
A3PP	-	-	-	-	-
A3BH	1000		✓		
A3WL	2000				✓
A4PP	1000		✓		
A4BH	7000				✓
A4WL	3000				✓
B1PP	-	-	-	-	-
B1BH	5000				✓
B1WL	6000				✓
B2PP	3000				✓
B2BH	1000		✓		
B2WL	1000		✓		
B3PP	-	-	-	-	-
B3BH	2000				✓
B3WL	3000				✓
B4PP	-	-	-	-	-
B4BH	2000				✓
B4WL	2000				✓
SDMN	4000				✓
SDMS	4000				✓
SDME	1000		✓		
SDMW	5000				✓
SRUC	1000		✓		
SRMC	3000				✓
SRLC	2000				✓
WBRW	4000				✓
WBTR	1000		✓		
Total No of Samples	**29**	**1**	**7**	**0**	**21**
Total % of Samples	**100**	**3.45**	**24.14**	**0**	**72.41**

As shown in Table 1 about 72.41% of domestic water intake sources TDS levels are generally higher with considered to be unsuitable quality for domestic uses compared to the WHO maximum contaminant level of 500 mg/l. Only about 27.59% are considered suitable. Higher levels of TDS observed in both underground and open surface sources indicate possible sources of dissolved salts are from both bedrock (underground) and surface due to human activities as generally posited in many literatures.

Table 2: Levels and Suitability of Total Sulphate of Major Domestic Water Intake Sources in Dutsin-ma

Sample intake source	Available sulphur (mg/l)	Total sulphate (mg/l)	More Suitable (0 – 250 mg/l)	Less Suitable (251 – 500 mg/l)	Less Unsuitable for level (501 – 1000) mg/l	More Unsuitable (1001 – Above mg/l)
A1PP	0.004	10.03	✓			
A1BH	0.013	32.61	✓			
A1WL	0.003	7.53	✓			
A2PP	0.005	12.54	✓			
A2BH	0.001	2.51	✓			
A2WL	0.008	20.07	✓			
A3PP	-	-	-			
A3BH	0.004	10.03	✓			
A3WL	0.004	10.03	✓			
A4PP	0.020	50.17	✓			
A4BH	0.981	2460.64				✓
A4WL	0.006	15.05	✓			
B1PP	-	-	-			
B1BH	0.002	5.02	✓			
B1WL	0.015	37.63	✓			
B2PP	0.005	12.54	✓			
B2BH	0.009	22.58	✓			
B2WL	0.713	1788.42				✓
B3PP	-	-	-			
B3BH	0.004	10.03	✓			
B3WL	0.401	1005.83				✓
B4PP	-	-	-			
B4BH	0.010	25.08	✓			
B4WL	0.092	230.76	✓			
SDMN	0.047	117.89	✓			
SDMS	0.091	228.26	✓			
SDME	0.043	142.97	✓			
SDMW	0.136	381.26		✓		
SRUC	0.011	32.61	✓			
SRMC	0.002	7.53	✓			
SRLC	0.012	30.10	✓			
WBRW	0.075	218.22	✓			
WBTR	0.016	45.15	✓			
Total No of Samples	**29**	**29**	**26**	**1**	**-**	**2**
Total % of samples	**100**	**100**	**89.66**	**3.45**	**-**	**6.90**

In Table 2, more domestic water sources indicated lower levels compared to the 250 mg/l limits by WHO and USEPA. Only about 6.90% of the sources are considered to be unsuitable, while 93.11% are suitable. The sampled borehole at Unguwar Hayin gada (A4BH) and the shallow well at Unguwar Danrimi /Tsamiya (B2WL) indicated very extreme high concentrations of sulphate of 2460.64 and 1788.42 mg/l respectively.

Even though there is no health-based guideline proposed for sulphate, intake of high sulphate levels has gastrointestinal effects. This would pose health effects such as osteoporosis and kidney damage. It is recommended that health authorities be notified of sources of drinking water that contain sulfate concentrations in excess of 500 mg/L. The presence of sulphate in drinking-water may also cause noticeable taste and may contribute to the corrosion of distribution systems (WHO, 2008) .Sulphate may also contribute to corrosion of pipelines in the public distribution system (Mariraj et al., 2013). When the concentration of phosphates rises above 100 mg/L the coagulation processes in drinking water treatment plants may be adversely affected

Table 3: Levels and Suitability of Total Phosphate of Major Domestic Water Intake Sources in Dutsin_ma

Sample intake source	Available phosphorus (mg/l)	Total phosphate Level in mg/l	More Suitable (less than - 5 mg/l)	Less Suitable (6 – 10 mg/l)	Less Unsuitable (11 – 20 mg/l)	More Unsuitable (21 – Above mg/l)
A1PP	11.35	35				✓
A1BH	30.55	94				✓
A1WL	38.40	118				✓
A2PP	15.71	48				✓
A2BH	12.22	38				✓
A2WL	0.00	00	✓			
A3PP	-	-	-	-	-	-
A3BH	15.72	48				✓
A3WL	13.09	40				✓
A4PP	38.40	118				✓
A4BH	9.60	29				✓
A4WL	0.00	00	✓			✓
B1PP	-	-	-	-	-	-
B1BH	31.42	96				✓
B1WL	16.58	51				✓
B2PP	9.60	29				✓
B2BH	16.58	50				✓
B2WL	0.00	00	✓			✓
B3PP	-	-	-	-	-	-
B3BH	0.00	00	✓			✓
B3WL	0.00	00	✓			✓
B4PP	-	-	-	-	-	-
B4BH	2.62	8				✓
B4WL	12.22	38				✓
SDMN	0.00	00	✓			✓
SDMS	12.22	38				✓
SDME	16.58	51				✓
SDMW	13.96	43				✓
SRUC	0.00	00	✓			✓
SRMC	13.09	40				✓
SRLC	17.46	54				✓
WBRW	6.11	19				✓
WBTR	0.00	00	✓			
Total No of samples	**29**	**29**	**8**	**0**	**0**	**21**
Total % of Samples	**100**	**100**	**27.59**	**0**	**0**	**72.41**

Furthermore, as shown in Table 3 phosphate levels showed that 72.41 of domestic water intake sources have levels of phosphate that are unsuitable for domestic uses and 27.59 as suitable. It is fascinating to observe that most of the shallow wells recorded no traces of phosphate, while boreholes and surface sources showed relatively higher levels. This indicates that phosphate contamination is traceable to deep underground aquifers and open surface sources. The sulphate and phosphate content in water is important in determining the suitability of water for public and industrial use.

The results of this study are similar to those obtained by Swammy et al., (2013) in Kaptildil, Kenya a semi-arid town where 92% of the sampled water had phosphate level beyond the WHO recommended maximum of 5 mg/L. Although, in their study the concentration of phosphates was attributed to the farming activities being undertaken where there is heavy use of phosphate fertilizers and laundry activities being performed by residents of Baraton Centre next to this water source using phosphate containing detergents. But in this study phosphates levels were largely adduced to lithological or bedrock.

The results of treated water at the Water Board source which was 0.00 mg/l total sulphate level, was compared to those of terminal pipe borne intake sources such as A1PP, A2PP, A4PP and B2PP.it was observed that sulphate levels were recorded as 10.02, 12.54, 50.17 and 12.54 mg/l respectively. This indicates possible contamination along the distribution pipe system. Similarly, the sulphates levels at most boreholes are comparatively lower than shallow wells. Sulphates levels at all the dam intake points and raw water tank of the Water Board were also observed to be comparatively higher than those of streams. This may be attributed to accumulation effect at the dam. All these observations clearly depict that sulphate sources are more traceable surface activities than associated to bedrock.

CONCLUSION AND RECOMMENDATIONS

One of the major findings of this study is that most domestic water sources in Dutsinma indicated unsuitable levels of TDS and phosphate while for sulphate only a few indicated unsuitable levels. Most of the intake sources with high phosphate levels were traceable to underground water sources (ie Borehole and wells) which to depicts lithological factor as major cause. A further comparative analysis of deep boreholes and shallow wells showed that boreholes indicated higher levels than wells to buttress the role of bedrock or underground acquifer. It was observed that possible contamination resulting in changes in changes in TDS, sulphate and phosphate levels from suitable to unsuitable limits at terminal intake sources of tap water. This may be due to leakages, breakages in distribution pipes conveying water

The existing pipe borne water distribution system showed possible sources of contamination which may be due to damages to pipes. Therefore there is the need for a maintenance project to update this pipeline system. For residents of the town that rely on either shallow wells or boreholes with higher contaminant levels which makes them unsuitable for domestic uses should be educated and encourage to adopt domestic methods of water treatment that can reduce these levels to safety limits. Human activities that seem to be the most possible sources of contaminations of both surface and underground sources should be targeted to minimize pollution and guide surveillance activities.

Therefore Sustainable farming methods should be encouraged to avoid influx of nutrients into the water bodies and impact on the quality of domestic water systems. More research work need to be undertaken during different seasons of the year to ascertain the two inorganic ions in water bodies and the variations in the concentrations during different times of the year.

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