Physicochemical Evaluation of the Effects of Total Suspended Solids, Total Dissolved Solids and Total Hardness Concentrations on the Water Samples in Nsukka Town, Enugu State of Nigeria.

NDEFO, Chinedum Joseph; ALUMANAH, Eddy O., JOSHUA, Parker Elijah and ONWURAH, Ikechukwu, N. E.

Department of Biochemistry, University of Nigeria, Nsukka, Nigeria
Author's Correspondence: josephchinedum@yahoo.co; parkeselisco@yahoo.co.uk
+2348039211604; +2348037804687 and +2348039569800

ABSTRACT: The problem of environmental pollution due to toxic metals has begun to cause concern now in most major metropolitan cities. Nsukka environs have been plagued with perennial problem of water supplies round the year and a better understanding of its water physicochemically status will help to address this daunting problem and issues of human health. The analysis carried out was on the utility water supplies in Nsukka area. Thirteen sampling areas consisting of four boreholes, six dugwells and three springs were chosen for this research work. A total of 26 water samples were taken from the sampling areas during the dry season and another 26 samples during the wet season. Water samples were collected from these sampling areas and refrigerated at 4^0C for processing. Harch Model C50 digital multirange meter was used to measure total dissolved solid. Complexiometric titration was employed in the determination of total hardness of water samples. Bacteriological analysis of the water samples were carried out to ascertain whether there was faecal contamination by the use of multiple tube/most probable number techniques. It was observed that total suspended solid concentration of water samples from dugwell sources was found to have significant increase ($p<0.05$) when compared with the water samples from the samples obtained from borehole and spring sources during both dry and rainy seasons. Total dissolved solid concentration was found to be significantly higher ($p<0.05$) in the water sample from dugwell sources when compared with the total dissolved solid concentration in the water samples from both borehole and spring sources during both dry and rainy seasons. Water sample from dugwell sources had showed significant increase ($p<0.05$) in the level of total hardness as compared with water samples from borehole and spring sources during dry and rainy seasons. Also, there was significant increase ($p<0.05$) in the level of total hardness of water sample from borehole sources when compared with the spring sources during dry and rainy seasons. Therefore, from the foregoing, it could be concluded that these boreholes, springs and dugwells water tested in Nsukka town are physicochemically good for human consumption as all the physicochemical parameters tested conformed to WHO, SON and NAFDAC water quality standards except Iyi-adoro spring water which might not be very good for consumption during rainy season because of possible bacteria contamination.

[NDEFO, Chinedum Joseph; ALUMANAH, Eddy O., JOSHUA, Parker Elijah and ONWURAH, Ikechukwu, N. E. **Physicochemical Evaluation of the Effects of Total Suspended Solids, Total Dissolved Solids and Total Hardness Concentrations on the Water Samples in Nsukka Town, Enugu State of Nigeria.** Journal of American Science 2011;7(5):827-836]. (ISSN: 1545-1003). http://www.americanscience.org.

Keywords: Physicochemical; Total Dissolved Solids; Total Suspended Solids, Total Hardness.

INTRODUCTION

Most of our water resources are gradually becoming polluted due to the addition of foreign materials from the surroundings. These include organic matter of plant and animal origin, land surface washing, and industrial and sewage effluents (Karnataka State Pollution Control Board, 2002)[1]. Rapid urbanization and industrialization with improper environmental planning often lead to discharge of industrial and sewage effluents into lakes. The lakes have a complex and fragile ecosystem, as they do not have self-cleaning ability and therefore readily accumulate pollutants. Bellandur Lake, the largest one in Bangalore urban area, recently attracted a lot of public attention because of the formation of froth during rainy season due to chemicals (soaps, detergents, etc.) and biosurfactants. For the last few decades, the treated, partially treated and untreated wastewater has been discharged to this lake and the lake water is being used for farming purposes (Pruss *et al*., 2002)[2].

Individual rural homeowners are often responsible for providing and protecting their own water supplies. Where safety of these sources is concerned, no "short-cuts" can be taken. Protecting the quality of individual water supplies is a combination of controlling land use around the supplies and using proper water treatment techniques where necessary. Rural homeowners must assume responsibility for protecting their families from contaminated drinking water. Assistance in this regard can be obtained from a number of agencies (Ward, 1995)[3]. Local health authorities can answer questions relating to applicable local regulations; health hazards posed by contaminated water, and suggested procedures for sampling and analyzing drinking water for contaminants. In some cases, local health officials will analyze individuals' water samples for common pollutants at no cost or for a nominal charge. Complete well water analysis is the homeowner's responsibility and is not free. State regulatory agencies charged with water resource management can answer questions regarding water use. They usually also have information regarding the availability and suitability of water sources in the State. Such agencies usually administer safety regulations for dams as well (Ward, 1995)[3].

Although hardness may have significant aesthetic effects, a maximum acceptable level has not been established because public acceptance of hardness may vary considerably according to the local conditions. Water supplies with a hardness greater than 200 mg/L are considered poor, but have been tolerated by consumers; those in excess of 500 mg/L are unacceptable for most domestic purposes. Higher levels are generally associated with groundwater sources. Water hardness is a traditional measure of the capacity of water to react with soap. Hard water requires a considerable amount of soap to produce lather, and it also leads to scaling of hot water pipes, boilers and other household appliances. Water hardness is caused by dissolved polyvalent metallic ions. In fresh waters, the principal hardness-causing ions are calcium and magnesium; strontium, iron, barium and manganese ions also contribute (Rajesh ***et al***., 2004)[4].

Faecal coliforms, otherwise known as thermotolerant coliforms, are a type of coliform bacteria generally found in the intestines of healthy humans and animals. Coliform bacteria can be found everywhere in the environment, and most coliforms, including most faecal coliforms are relatively harmless, naturally occurring organisms. Faecal coliforms, which include *E. coli* and a few other species, are an indicator of faecal contamination. Faecal coliform testing has been replaced by *E. coli* testing in most jurisdictions as more specific tests for *E. coli* have become routinely available. The maximum acceptable concentration (MAC) of faecal coliforms in drinking water is zero. If fecal coliforms are found in treated drinking water, a boil water advisory is generally issued right away (Rajesh ***et al***., 2004)[4].

Research Objective

This study is aimed at evaluating the effects of total suspended solids (TSS), total dissolved solids (TDS) and total hardness concentrations on the water samples in Nsukka Town, Enugu State of Nigeria with a view of creating the consciousness of the inhabitants of such location on the state of domestic drinking water as it affects human health.

Table 1: Physicochemical Combined Standards of WHO, SON and NAFDAC (IPAN, 2005)[5]

S/No.	Parameter	NAFDAC MAXIMUM ALLOWED LIMITS	SON STANDARD	Highest Desirable WHO STANDARDS	
1.	Color	3.0TCU	3.0 TCU	3.0TCU	15.0TCU
2.	Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
3.	Taste	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
4.	pH at 20^{0}C	6.50-8.5	6.50-8.5	7.0-8.9	6.50-9.50
5.	Turbidity	5.0 NTU	5.0 NTU	5.0 NTU	5.0 NTU
6.	Conductivity	1000 (us/cm^{-1})	1000 (us/cm^{-1})	900 (us/cm^{-1})	1200 (us/c^{-1})
7.	Total solids	500 mg/L	500 mg/L	500 mg/L	1500 mg/L
8.	Total Alkalinity	100mg/L	100 mg/L	100 mg/L	100 mg/L
9.	Phenolphthalein Alkalinity	100mg/L	100 mg/L	100 mg/L	100 mg/L
10.	Chloride	100mg/L	100 mg/L	200 mg/L	250 mg/L
11.	Fluoride	1.0mg/L	1.0 mg/L	1.0 mg/L	1.5 mg/L
12.	Copper	1.0mg/L	1.0 mg/L	0.5 mg/L	2.0 mg/L
13.	Iron	0.3 mg/L	0.3 mg/L	1 mg/L	3 mg/L
14.	Nitrate	10 mg/L	100 mg/L	10 mg/L	50 mg/L
15.	Nitrite	0.02 mg/L	0.02 mg/L	0.2 mg/L	3 mg/L
16.	Manganese	2.0 mg/L	0.05 mg/L	0.1 mg/L	0.4 mg/L
17.	Magnesium	20 mg/L	20 mg/L	20 mg/L	20 mg/L
18.	Zinc	5.0 mg/L	5.0 mg/L	0.01 mg/L	3.0 mg/L
19.	Selenium	0.01 mg/L	NS	0.01 mg/L	0.01 mg/L
20.	Silver	-	-	NS	NS
21.	Cyanide	0.01 mg/L	0.01 mg/L	0.01 mg/L	0.07 mg/L
22.	Sulphate	100 mg/L	100 mg/L	250 mg/L	500 mg/L
23.	Calcium	75 mg/L	75 mg/L	NS	NS

24.	Aluminum	0.5 mg/L	NS	0.2 mg/L	0.2 mg/L
25.	Potassium	10.0 mg/L	10.0 mg/L	NS	NS
26.	Lead	0.01 mg/L	0.01 mg/L	0.01 mg/L	0.01 mg/L
27.	Chromium	0.05 mg/L	0.05 mg/L	0.05 mg/L	0.05 mg/L
28.	Cadmium	0.003 mg/L	0.003 mg/L	0.003 mg/L	0.003 mg/L
29.	Arsenic	0.01 mg/L	0.01 mg/L	0.01 mg/L	0.01 mg/L
30.	Barium	0.05 mg/L	0.05 mg/L	0.05 mg/L	0.07 mg/L
31.	Mercury	0.001 mg/L	0.001 mg/L	0.001 mg/L	0.001 mg/L
32.	Antimony	NS	NS	-	0.02 mg/L
33.	Tin	-	-	-	1.2 μg/L
34.	Nickel	-	-	-	0.02 mg/L
35.	Total Hardness ($CaCO_3$)	100 mg/L	100 mg/L	100 mg/L	500 mg/L
36.	Vinyl chloride	0 mg/L	0 mg/L	0 mg/L	0003 mg/L

NAFDAC - National Agency for Food and Drug Administration and Control.
SON - Standards Organization of Nigeria
WHO – World Health Organization
IPAN – Institute of Public Analysts of Nigeria.

MATERIALS AND METHODS

Water Sampling Sources

Thirteen sampling areas consisting of four boreholes, six dug wells and three springs were chosen for this research work. A total of 26 samples were taken during the dry season and another 26 during the wet season. The sampling was carried in Nsukka (Fig. 1) and were sampled seasonally as follows: dry season (January, 2004); and rainy season proper (August, 2004). All were equipped with headwall and cover, and some had a cemented surrounding. The analyses carried out were on the utility water supplies in Nsukka area. Water samples were collected from these sampling areas and refrigerated at $4^{O}C$ for processing.

Chemicals/Reagents/Samples

All chemicals used in this study were of analytical grade and products of May and Baker, England; BDH, England and Merck, Darmstadt, Germany.

Experimental Design

The analyses carried out were on the utility water supplies in Nsukka area. Five sampling stations consisting of four bore holes, six dug wells and three springs were chosen for this research work. A total of 26 samples were taken during the dry season and another 26 during the wet season. Water samples were collected from these sampling stations and refrigerated at $4^{O}C$ for processing. Concentrations of zinc and sulphate were determined by spectrophotometric method while Harch Model C50 digital multirange meter was used to measure pH value. Bacteriological analysis of the water samples were carried out to ascertain whether there was faecal contamination by the use of multiple tube/most probable number techniques.

Sampling Areas

The analyses carried out were on the utility water supplies in the University Campus of Nsukka town. The Sampling areas are shown on the sampling map. The sampling areas consists four boreholes, two of which are located in University of Nigeria, Nsukka Campus, they are Franco Hostel borehole and the UNN water works borehole. The other two boreholes are found in Nsukka town, they include Work and Pay borehole near Peace Mass Transit Motor Park, and the Nsukka water scheme borehole. Sampling areas also include six dug wells and three springs. The dug wells are found, one at No 4 Saint Theresa Road one at No 95 New Anglican Road, one at Amaozala village, three at Eburu Mmili village after Saint Cyprian's college.

The three springs are Asho spring off Ugwuawarawa/Onuiyi Road. Ajie spring behind El-rina Hotels Limited, and Iyi- Adoro at Alo-uno village. These are utility water supplies in Nsukka town and environs. Contamination of these water sources will result in epidemic outbreak or health problems in the Nsukka populace.

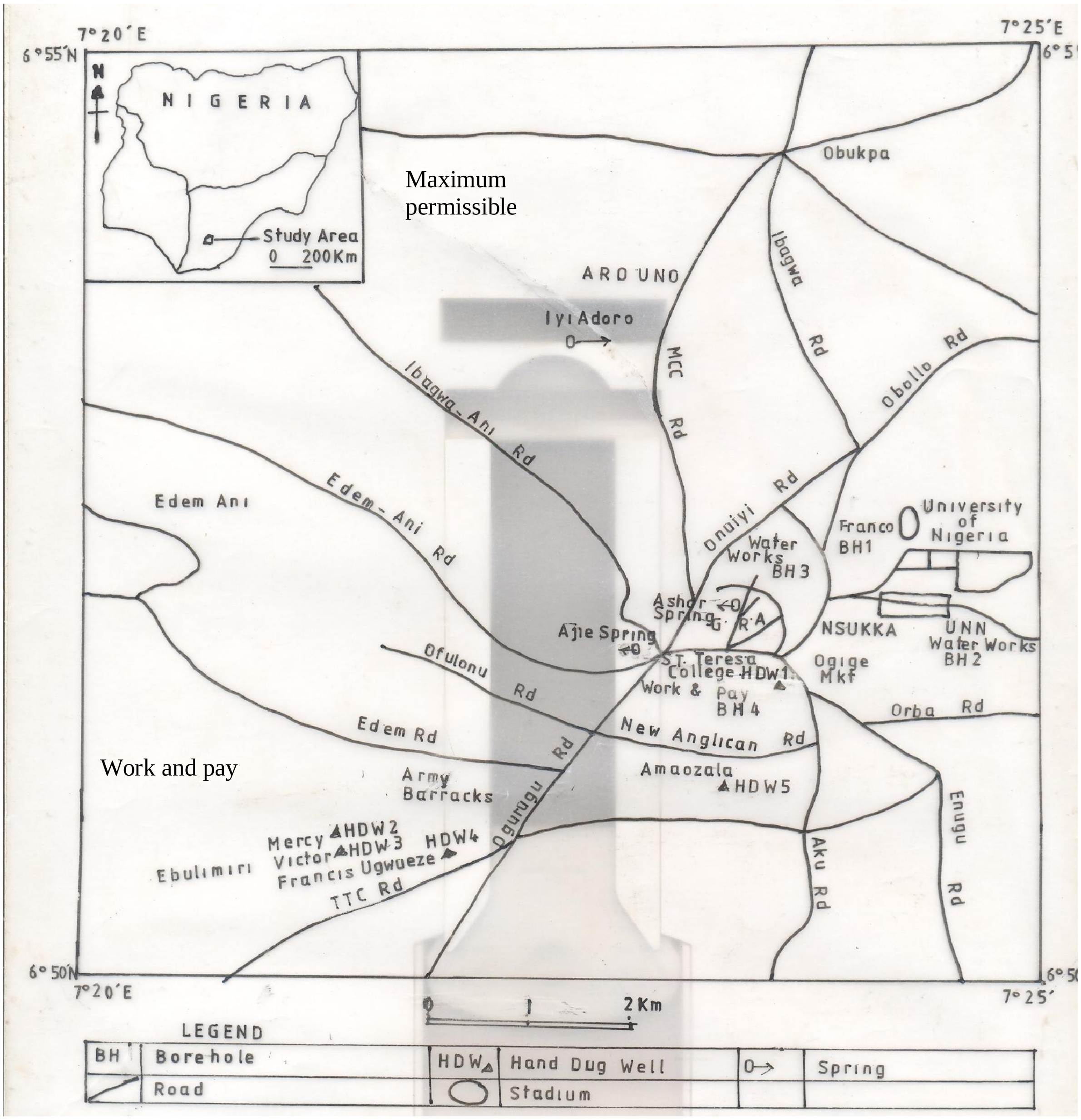


Fig. 1: Map of Nsukka showing the location of sampled areas

Table 2: Sampling points description

Sampling points	Description and location
UNN water works borehole	The UNN water scheme borehole is located near the gate leading to Owerre-Eze-Orba village. The University of Nigeria, Nsukka Campus receives greater supply of water from this borehole. Occasionally water is pumped to the surface and aerated before storage. Currently there is a major work going on around the place to upgrade it.
Franco borehole	This is the second borehole from which the University Community receives her supply of water. It is about 700ft deep and it is surrounded by small farm land. The inhoff sewage treatment plant is about 350-450 meters away.
Nsukka water scheme borehole	Sample of water was collected from the overhead pipe feeding the water-tankers that collect water for sale and distribution to Nsukka inhabitants. It has a dept of 725ft, and is located behind peace mass transit. It belongs to Mr. Augustine Madueke of No 23c Amaeze Lane Nsukka.
Saint Theresa's Road Dug well (Mr. Vincent Ezeh)	This is located at No 47 Saint Theresa's road, behind Bishop Shanahan Hospitals, Nsukka. It has a dept of about 30ft.
New Anglican Road (Mr. N.E. Ogboso) Dug well	This is situated at No 95 New Anglican Road, Nsukka. It is about 60ft. They use water pumping machine to pump out water hygienically

Amaozala village. Dug well	The well is about 28ft deep with clean surroundings. It is cited along the road off New Anglican Road to Aku.
Mr. Francis Ukwueze of Eburu	Mr. Francis Ukwueze's dugwell in Eburu Minili village is about 32ft deep. The surrounded well is by
Mrs. Mercy Onah of Eburu-Minili village.dug well	Mrs. Mercy's dugwell in Eburu-Minili village is about 40ft deep. It is surrounded by farm lands.
Mr. Victor Ugwuanyi's dug well	Mr. Victor Ugwuanyi dugwell located in front of his house is about 38ft deep. The surroundings is relatively clean.
Asho spring water	This is off Ugwuawarawa /Onuiyi Road just after Tochukwu motor depot as one goes to Odenigbo roundabout. The water is channeled through a pipe as it descends the forested steep hill of the area
Ajie spring water	This is located right behind Elrina Hotels limited. The water is also channeled through a pipe.
Iyi-adoro spring water	This is located at Alo-Uno village. It is on a think forested hill just as one passes the Adoro shrine. The water perculates from the rocks and it is exposed to dust and fallen leaves as it collects in a trough of the rocks.

Determination of Total Hardness of Water Samples

Principle:

Complexiometric titration was employed in the determination of total hardness of water samples. Originally water hardness was understood to be a measure of the capacity of water to precipitate soap, but in conformity with current practice, total hardness is defined as the sun of the calcium and magnesium concentrations, both expressed as calcium carbonate in milligrams per litre (mg /l). The significance of this analysis is to check if the water is hard, so as to know the kind of treatment the water will be subjected to.

Total Dissolved Solids (TDSs) and Total Suspended Solids (TSSs)

Principle:

Harch Model C50 digital multirange meter was used to measure total dissolved solids (TDSs) and total suspended solids (TSSs). Total dissolved solids is the expression used to describe the total amount of minerals dissolved in a water sample. TDS is commonly expressed in ppm (part per million or mg/l). Water with high dissolved solid greater than 500ppm often have a laxative effect upon people whose bodies are not adjusted to them.

Bacteriological Examination

The bacteriological analysis of water can confirm whether a water supply has been faecally contaminated. The *E. coli* count is the most useful test for detecting faecal contamination of water supplies in water quantity analysis. Two principal techniques are available for counting faecal coliforms.

(a) Membrane filtration

In this technique, a 100ml water sample or a diluted sample is filtered through a membrane filter. The membrane with the coliform organisms on it is then cultured on a pad of sterile selective broth containing lactose and an indicator. After incubation, the number of coliform colonies can be counted. This gives the presumptive number of *E. coli* in the 100ml water sample.

(b) Multiple tube/Most Probable Number (MPU)

In this technique, a 100ml water sample is distributed (five 10ml amounts and one 50ml amount) in bottles of sterile selective culture broth containing lactose and an indicator. After incubation, lactose fermentation with acid and gas production has occurred are counted. The lactose is fermented by the coliform in the water. By reference to probability tables, the most probable number of coliforms in the 100 water sample can be estimated.

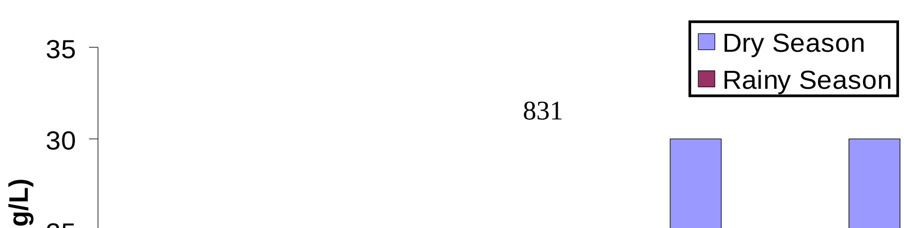
Statistical Analysis

The results were expressed as mean ± SD and tests of statistical significance were carried out using student t-test and both one-way and two-way analysis of variance (ANOVA). The means were separated using Duncan Multiple Test. The statistical package used was Statistical Package for Social Sciences (SPSS); version 18.

RESULTS

Effect of Total Suspended Solid on Different Water Sources Compared to WHO And NAFDAC

Total suspended solid concentration of water samples from dugwell sources was found to have significant increase ($p<0.05$) when compared with the water samples from the other test water samples from borehole and spring sources during both dry and rainy seasons (as shown in Fig. 2). There was no significant ($p>0.05$) difference in the total suspended solid level between the dry season and rainy season of all test samples when considering different seasons. Likewise, the water samples from borehole and spring sources showed no significant difference ($p>0.05$) in the level of total suspended solid as shown in Fig. 2. The levels of total suspended solid in the two standards (WHO and NAFDAC) are found to be relatively higher than the three test samples (borehole, dugwell and spring).



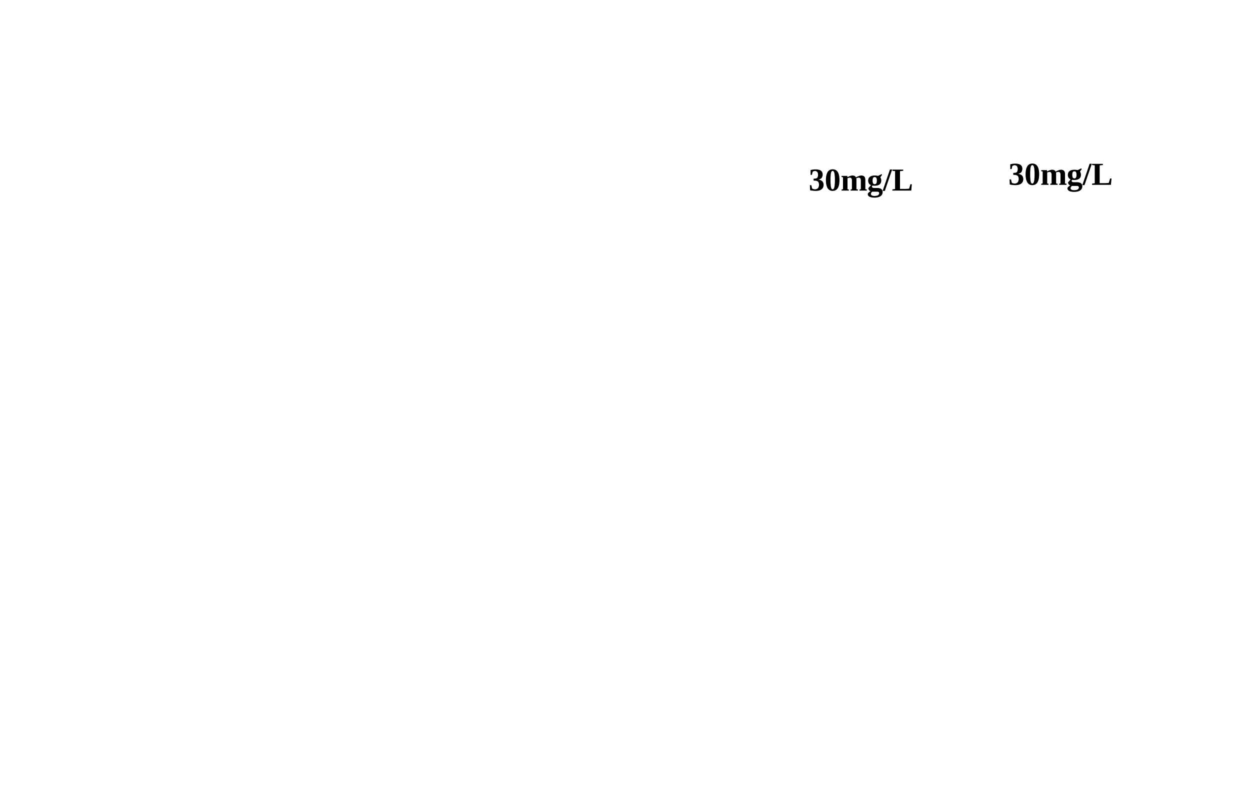


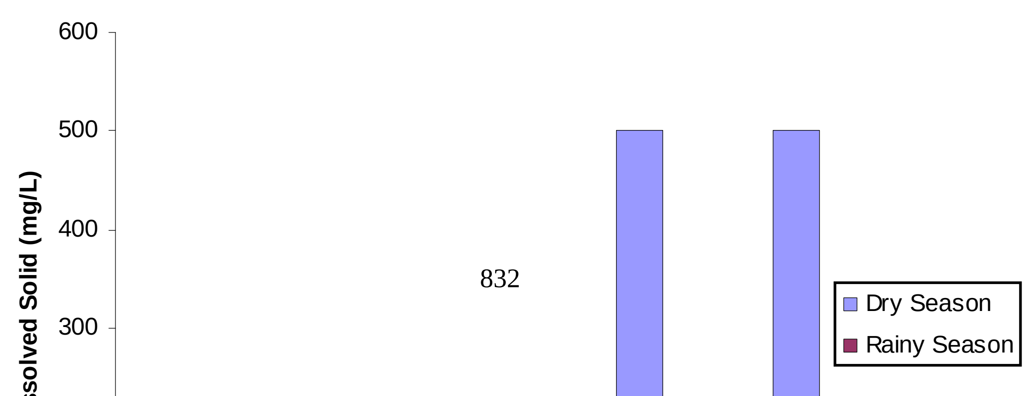
Fig. 2: Total suspended solid (mg/L) concentration of different water sources in Nsukka compared with WHO and NAFDAC standards

Effect of Total Dissolved Solid Concentration on Different Water Sources Compared to WHO and NAFDAC

Total dissolved solid concentration, as shown in Fig. 3, was found to be significantly higher ($p<0.05$) in the water sample from dugwell sources when compared with the total dissolved solid concentration in the water samples from both borehole and spring sources during both dry and rainy seasons. In terms of seasonal comparison, the total dissolved solid concentration of water sample from spring source during rainy season was observed to be relative higher than that observed during the dry season. However, significant difference ($p<0.05$) was also observed between the two standards and the test water samples from the three sources (borehole, dugwell and spring) during both dry and seasons. Comparatively, Fig. 3 shows that the two reference standards (WHO and NAFDAC) have the same value (500mg/L) of total dissolved solid.

Effect of Total Hardness Concentration on Different Water Sources Compared to WHO and NAFDAC

Fig. 4 shows significant increase ($p<0.05$) in the level of total hardness in the water sample obtained from dugwell sources as compared with water samples from borehole and spring sources during dry and rainy seasons. Also, there was significant increase ($p<0.05$) in the level of total hardness of water sample from borehole sources when compared with the spring sources during dry and rainy seasons. There was no significant difference ($p>0.05$) in the level of total hardness when comparing between the dry and rainy seasons across the test water samples from the three test sources (borehole, dugwell and spring). The standards (WHO and NAFDAC) had relatively higher values (100mg/L each) of total hardness compared to the test samples. But the two reference standards (WHO and NAFCON) have the same level of total hardness as shown in Fig. 4 below.



500mg/L 500mg/L

Fig. 3: Total dissolved solid (mg/L) concentration of different water sources in Nsukka compared with WHO and NAFDAC standards

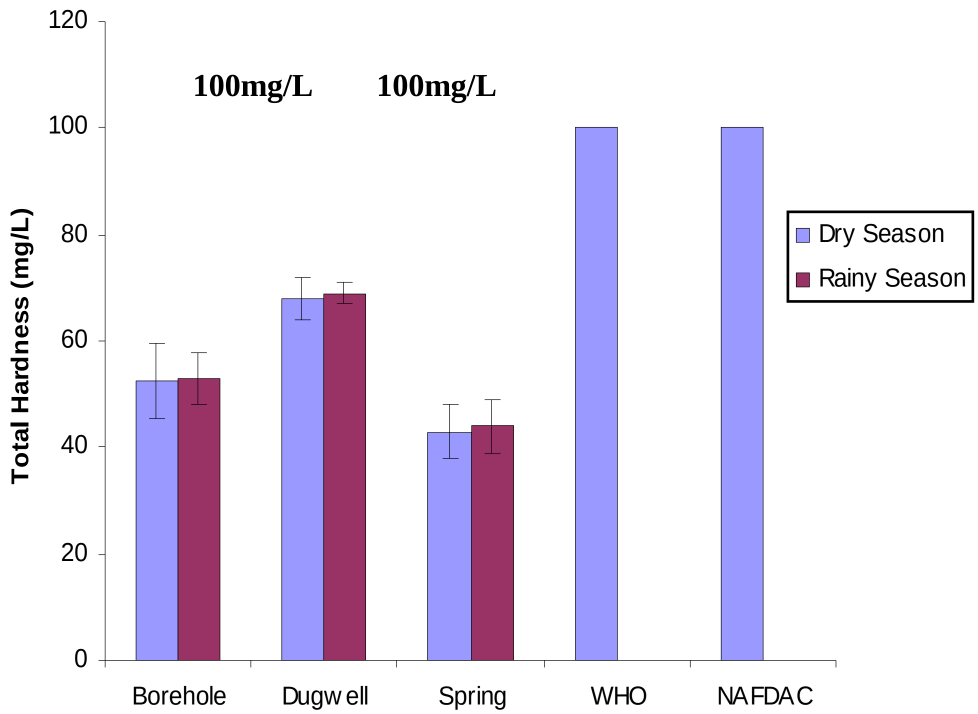


Fig. 4: Total hardness (mg/L) concentration of different water sources in Nsukka compared with WHO and NAFDAC standards

Effect of most Probable Number of Coliform on Different Water Sources Compared to WHO and NAFDAC

As shown in Fig. 5 below, most probable number of coliform was found to be significantly higher ($p<0.05$) in the three test water samples (borehole, dugwell and spring) during the rainy seasons as compared with the dry season. The most probable number of coliform in the water sample of spring sources during rainy season showed significant increase ($p<0.05$) as compared with the two reference standards (WHO and NAFDAC). Both WHO and NAFDAC had relatively the same range of most probable number of coliform range of values (1 – 10 npm). The standards (WHO and NAFDAC) had most probable number of coliform count to be significantly higher ($p<0.05$)

than that of the water samples from the test sources with the exception of most probable number of coliform count obtained in water samples from spring sources during rainy season.

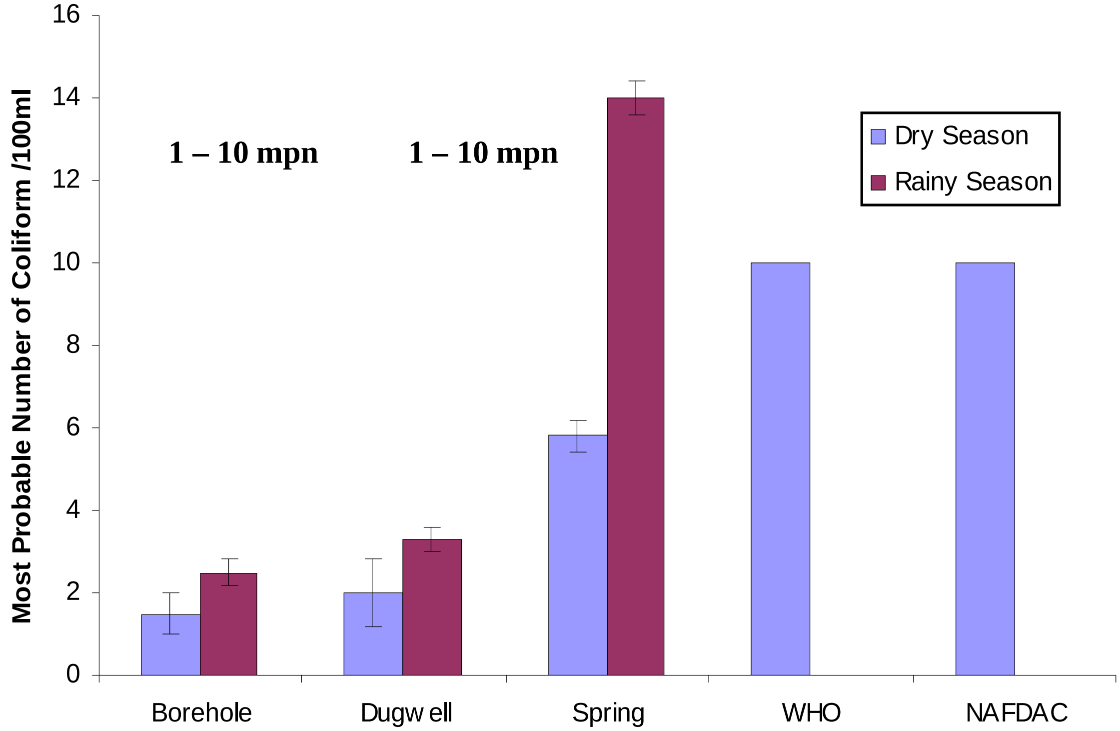


Fig. 5: Most probable number of coliform of different water sources in Nsukka compared with WHO and NAFDAC Standards

DISCUSSION

Virtually all metals can produce toxicity when ingested in sufficient quantities, but there are several which are especially important because either they are so pervasive, or produce toxicity at such low concentrations. In general heavy metals produce their toxicity by forming complexes or "ligands" with organic compounds. These modified biological molecules lose their ability to function properly, and result in malfunction or death of the affected cells. The most common groups involved in ligand formation are oxygen, sulfur, and nitrogen. When metals bind to these groups they make inactive important enzyme systems, or affect protein structure.

Different physical parameters studied are total suspended solids and total dissolved solids. The chemical parameter studied was total hardness with extension to the number of coliforms. The values were compared with the WHO and NAFDAC standard values which are given in the same figures (Figures 2 to 5). The results indicate that the quality of water considerably varies from location to location.

Water quality in Nsukka area of Enugu State of Nigeria is spatially variable and has been impacted by some contaminants which are mostly organic. The replacement of forestland with impervious surfaces during urbanization can have significant effects on watershed hydrology and the quality of storm water runoff. One component of water quality, total suspended solids (TSS), is both a significant part of physical and aesthetic degradation and a good indicator of other pollutants, particularly nutrients and metals that are carried on the surfaces of sediment in suspension. A TSS turbidity relationship can be affected by water colour from dissolved organic compounds which can absorb more light than inorganics (Packman *et al.*, 1999)[6]. In Fig. 2, it was observed that total suspended solid concentration of water samples from dugwell sources was found to have significant increase ($p<0.05$) when compared with the water samples from the other test water samples obtained from borehole and spring sources during both dry and rainy seasons. Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life. This could also be attributed to the fact that dugwells are at higher risk of contamination than drilled wells because they obtain water from shallow groundwater aquifers, and contaminants are more likely to be found closer to the surface. There was no significant ($p>0.05$) difference in the total suspended solid level between the dry season and rainy season of all test samples when considering different seasons.

Total dissolved solids (TDS) is the term used to describe the inorganic salts and small amounts of organic matter present in solution in water (WHO, 1996)[7]. Water with extremely low concentrations of TDS may also be unacceptable because of its flat, insipid taste (WHO, 1996)[7]. Total dissolved solid concentration was found to be significantly higher ($p<0.05$) in the water sample from dugwell sources when compared with the total dissolved solid concentration in the water samples from both borehole and spring sources during both dry and rainy seasons. This may be attributed to the principal constituents which are usually calcium, magnesium, sodium, and potassium cations and carbonate, hydrogencarbonate, chloride, sulfate, and nitrate anions, as outlined by WHO (1996)[7], found in the surrounding environmental sources where the dugwells are located. The result as shown in Fig. 3 showed that concentration threshold of total dissolved solids (TDS) fell below 300 mg/litre. This is consistent with the findings of WHO (1996)[7] which stated that the palatability of drinking water has been rated by panels of tasters in relation to its TDS level as follows: excellent, less than 300 mg/litre; good, between 300 and 600 mg/litre; fair, between 600 and 900 mg/litre; poor, between 900 and 1200 mg/litre; and unacceptable, greater than 1200 mg/litre.

Stone and Droppo (1994)[8] suggest suspended solids probably act as the primary transport mechanism for pollutants and nutrients in streams through flocculation, adsorption and colloidal action.

Water sample from dugwell sources had showed significant increase ($p<0.05$) in the level of total hardness as compared with water samples from borehole and spring sources during dry and rainy seasons. Also, there was significant increase ($p<0.05$) in the level of total hardness of water sample from borehole sources when compared with the spring sources during dry and rainy seasons. Geetha *et al.* (2008)[9] attributed total hardness contamination on the probable effluent effect, though it affects the ground water, and it has no adverse effect on human health. In most of the samples, total hardness value exceeds the tolerance limit; this may be due to industrial discharge of the effluents on to the land.

In terms of seasonal variation, the result x-rayed the fact that most probable number of coliform was found to be significantly higher ($p<0.05$) in all the three test water samples (borehole, dugwell and spring) during the rainy seasons as compared with the dry season. The most probable number of coliform in the water sample of spring sources was found to have the highest significant increase ($p<0.05$) during the rainy season. This may be as a result of possible contamination of spring water sources with sewage from immediate surroundings of Nsukka environ. The coliform group is an indicator bacteria to evaluate the quality of drinking water and any presence of coliforms indicates the contact of water with sewage or inadequate treatment/post treatment contamination. In unpiped water supplies, sometimes up to 10 coliforms/100 ml are as allowed per WHO standards for tropical countries but this should not occur repeatedly; if occurrence is frequent and sanitary conditions cannot be improved, an alternative source must be found if possible (Geetha *et al*., 2008)[9].

Therefore, from the foregoing, it could be concluded that these boreholes, springs and drugwells water samples tested in Nsukka town are physicochemically good for human consumption as all the physicochemical parameters tested conformed to WHO, SON, and NAFDAC water quality standards, although Iyi-adoro spring water might not be very good for consumption during the rainy season because of possible bacteria contamination.

REFERENCES

37. Geetha, A., Palanisamy, P. N., P. Sivakumar, P., Ganesh Kumar, P. and Sujatha, M. (2008). Assessment of underground water contamination and effect of textile effluents on Noyyal River Basin in and around Tiruppur Town, *Tamilnadu. E-Journal of Chemistry*, **5**(4): 696 – 705.
38. IPAN (2005) Pre-Admission Training Workshop on Food, Drugs, Cosmetics, Medical Devices, Water, Environment and Petroleum, Appendix II. March, 2005.
39. Karnataka State Pollution Control Board. (2002). Water quality monitoring of lakes in and around Bangalore city, Bangalore, Vol. 2, pp. 1–8.
40. Packman, J. J., Comings K. J. and Booth, D. B. (1999). Using turbidity to determine total suspended solids in urbanizing streams in the Puget Lowlands: in Confronting Uncertainty: Managing Change in Water Resources and the Environment, Canadian Water Resources Association annual meeting, Vancouver, BC, 27–29 October 1999, p. 158–165.
41. Pruss, A. Kay, D. Fewtrell, L. and Bartram, J. (2002). 'Estimating the burden of disease from water, sanitation and hygiene at a global level'. *Environ. Heal. Perspectives*, **110** (5): 537-542.
42. Rajesh, K. S., Madhoolika, A. and Marshall, F. M. (2004). Effects of waste water irrigation on

heavy metal accumulation in soil and plants. Paper presented at a National Seminar, Bangalore University, Bangalore, Abst. no. 7, p. 8.

43. Stone, M. and Droppo, I. G. (1994). In-Channel Surficial Fine-Grained Sediment Laminae (Part II): Chemical Characteristics and Implications for Contaminant Transport by Fluvial Sediments. *Hydrological Processes*, **8**(2): 113-124.
44. Ward, N. I., (1995). Environmental analytical chemistry. In *Trace Elements* (eds Fifield, F. W. and Haines, P. J.), Blackie Academic and Professional, UK, pp. 320–328.
45. WHO (1996). Total dissolved solids in Drinking-water. Background document for development of WHO *Guidelines for Drinking-water Quality*. Originally published in Guidelines for drinking-water quality, 2nd ed. Vol. 2. *Health criteria and other supporting information.* World Health Organization, Geneva.

12/19/2011