ABSTRACT

Most of our water resources are gradually becoming polluted due to the addition of foreign materials from the surroundings. These include organic of plant and animal origin, land surface washing, and industrial and sewage effluents. 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 dug wells 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°C for processing. Concentration of zinc was determined in each sample by
spectrophotometric method. Harch Model C50 digital multi-range meter was used to measure the 
pH. Chemical parameter such as sulphate was also determined by spectrophotometric method. 
Bacteriological analysis of the water samples was carried out to ascertain whether there was faecal 
contamination by the use of multiple tube/most probable number techniques. Sulphate concentration 
of water sample from spring sources increased significantly (p<0.05) during dry season when 
compared with that of wet season. No significant difference (p>0.05) exists in the concentration of 
zinc compared to all other test samples.

Keywords: Physicochemical; pH; sulphate; zinc and water sample.

1. INTRODUCTION

The problem of environmental pollution due to toxic metals has begun to cause concern now in 
most major metropolitan cities. The toxic heavy metals entering the ecosystem may lead to 
geoaccumulation, bioaccumulation and biomagnification. Heavy metals like Fe, Cu, Zn, 
Ni and other trace elements are important for proper functioning of biological systems and their 
deficiency or excess could lead to a number of disorders [1].

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 [2]. 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 [3]. 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 [4].

An acceptable range for drinking water pH is from 6.5 to 8.5. Water with a pH below 6.5 is 
considered acidic and may cause corrosion. Water with a pH above 8.5 is considered basic, 
and may result in incrustation and scaling problems. As pH increases, there is a 
progressive decrease in the efficiency of the chlorine disinfection process [5].

2. MATERIALS AND METHODS

2.1 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°C for processing.

2.2 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°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.

2.3 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 Amazala 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
2.4 Determination of pH Value

Principle:

The pH of an aqueous solution is defined by the expression.

\[ pH = -\log_{10} [H^+] \]  

(1)

Where \([H^+]\) is the mole concentration of hydrogen ion in the solution. The pH of water is one of the most important water quality parameters it is a measure of acidity or alkalinity of water. An optimal pH range is necessary to ensure clarification, disinfection and minimize corrosion of pipes. The pH of most natural water falls within the range of 4 to 9. The pH values outside the limit can result in the contamination of the water and adverse effect on the taste, odour and appearance [6].

2.5 Determination of Sulphate Concentration

The determination of sulphate concentration was carried out using the method of Atomic Absorption Spectrometry (AAS). This technique depends on the absorption of characteristic electromagnetic radiation by vapourized metal atoms in a flame. The extent of absorption of the radiation is proportional to the concentration of the metal atom in solution. The use of organic solvents in the presence of reducing flame such as oxyhydrogen or nitrous oxide acetylene flame enables the determination of refractory metal oxides.

2.6 Determination of Zinc Concentration

The concentration of zinc (Zn) was determined by the method described by Baldwin et al. [7].

Procedure:

Colorimetric standards were prepared serially from 2.5 mg – 50 μg in Erlenmeyer flasks, each 10 ml volume. To each flask 0.5 g sodium ascorbate was added, followed by 1 ml KCN solution in sequence, 5 ml buffer solution and 3 ml zincon solution. The flask was thoroughly mixed after each addition. Chloral hydrate (3 ml) was added and time noted. The absornance at 620nm exactly 5 min after adding the chloral hydrate solution was carried out.

Calculation:

\[ Zn (Mg/l) = \frac{\mu g \ Zn}{ml \ Sample} \]  

(2)

2.7 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.

2.7.1 Membrane filtration

In this technique, a 100 ml 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 100 ml water sample.

2.7.2 Multiple tube/Most Probable Number (MPU)

In this technique, a 100 ml water sample is distributed (five 10 ml 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.

2.8 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 20.
3. RESULTS

3.1 Effect of pH on Different Water Sources Compared to WHO and NAFDAC

![Bar graph showing pH levels of different water samples in various sampling areas in Nsukka compared with WHO and NAFDAC Standards.]

Fig. 2. pH levels of different water samples in various sampling areas in Nsukka compared with WHO and NAFDAC Standards.

3.2 Effect of Sulphate Concentration on Different Water Sources Compared to WHO and NAFDAC

![Bar graph showing sulphate concentration of different water sources in Nsukka compared with WHO and NAFDAC Standards.]

Fig. 3. Sulphate concentration of different water sources in Nsukka compared with WHO and NAFDAC Standards.
3.3 Effect of Zinc on Different Water Sources Compared to WHO And NAFDAC

![Zinc concentration graph](image)

Fig. 4. Zinc (mg/L) concentration of different water sources in Nsukka compared with WHO and NAFDAC Standards

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

![Coliform count graph](image)

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

4. DISCUSSION

The heightened concern for reduction of environmental pollution (especially water) that has been occurring over the past 20–25 years has stimulated active continuing research and literature on the toxicology of heavy metals. While the toxic effect of these substances is a
widespread concern in the modern industrial context, man has succeeded in poisoning himself with them repeatedly throughout recorded history. 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.

Various physico-chemical parameters were studied and are given in the different figures in Chapter three. Different chemical parameters studied are pH, zinc and sulphate 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 (Figs. 2 to 4). 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 result as shown in Fig. 2 shows that all the water samples from all samples/sources/locations were found to fall below 7.0. The most acidic among the water sources was found to be water samples from borehole sources (pH of 5.0) during dry season. Interestingly, the result as shown in Fig. 2 also indicated relative low pH values of water samples from all water sources during dry season. Water samples from dugwell sources had (pH of 5.8) during rainy season. This was closely followed by water sample from spring sources (pH of 5.7) during rainy season. However, there was no significant difference (p>0.05) in pH values across borehole, dugwell and spring. In comparing the pH value of WHO (7.0–8.9) with that of NAFDAC standard (6.5–8.5), it was discovered that all water samples from all sources had closer values to NAFDAC. It could be deduced that since the pH values in the result indicated pH values below 7, the water could be corrosive to plumbing, resulting in lead leaching into tap water.

Sulphate concentration of water sample from spring sources increased significantly (p<0.05) during dry season when compared with that of rainy season. This may be attributed some sulphur-containing contaminants in the environment during dry season. Also, the concentration of sulphur increased (though not significant) during dry season in dugwell when compared with the sulphur concentration during rainy season. Generally, 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, especially during dry season. However, in comparison with WHO and NAFDAC standards, it was observed that there was significant difference (p<0.05) in the sulphate concentration between WHO standard (250mg/L) and water samples from the three test samples (borehole, dugwell and spring sources) during both dry and rainy seasons. Levels of sulfate in rainwater and surface water correlate with emissions of sulfur dioxide from anthropogenic sources [8,9]. WHO [10] in its documentary titled ‘Background document for preparation of WHO Guidelines for drinking-water quality’ stated that sulphates occur naturally in numerous minerals and are used commercially, principally in the chemical industry. They are discharged into water in industrial wastes and through atmospheric deposition; however, the highest levels usually occur in groundwater and are from natural sources. In general, the average daily intake of sulphate from drinking-water, air and food is approximately 500mg, food being the major source. However, in areas with drinking-water supplies containing high levels of sulfate, drinking-water may constitute the principal source of intake [11].

Zinc concentration was found to be in trace amount (almost absent) which indicates relatively low concentration of zinc metal in all the test water samples from all the water sources (borehole, dugwell and spring). This indicates that non-significant difference (p>0.05) exists in the concentration of zinc when carrying out comparison in all the test samples. In natural surface waters, the concentration of zinc is usually below 10 μg/litre, and in groundwater, 10–40 μg/litre [12,13]. In tap water, the zinc concentration can be much higher as a result of the leaching of zinc from piping and fittings [14]. The most corrosive waters are those of low pH, high carbon dioxide content, and low mineral salts content. In a Finnish survey of 67% of public water supplies, the median zinc content in water samples taken upstream and downstream of the waterworks was below 20 μg/litre; much higher concentrations were found in tapwater, the highest being 1.1 mg/litre [15]. Even higher
zinc concentrations (up to 24 mg/litre) were reported in a Finnish survey of water from almost 6000 wells [15].

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 [16]. 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 unipiped 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 [17].

5. CONCLUSION

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 lyladoro spring water might not be very good for consumption during the rainy season because of possible bacteria contamination.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Wards R. Tap water blues: Herbicides in drinking water, environmental working group. 1994:12.
2. Adekunle IM, Adetunji MT, Gbadebo AM, Banjoko OB. Assessment of groundwater quality in a typical rural settlement in Southwest Nigeria. Int. J. Environ. Public Health. 2007;4:307-318.
3. Adelana SMA, Bale RB, Wu M. Quality assessment and pollution vulnerability of groundwater in Lagos metropolis, SW Nigeria. Proceedings of the 1st International Workshop on Aquifer Vulnerability and Risk, May 28-30, 2003, Salamena Mexico. 2003:1-17.
4. Ward NI. Environmental analytical chemistry. In Trace Elements (eds Fifield, F. W. and Haines, P. J.), Blackie Academic and Professional, UK. 1995;320–328.
5. Rajesh KS, Madhoolika A, Marshall FM. Effects of waste water irrigation on heavy metal accumulation in soil and plants. Paper presented at a National Seminar, Bangalore University, Bangalore, Abst. no. 2004;7:8.
6. Cech TV. Principles of water resources history, development, management and policy. 2nd Edn., John Wiley and Sons, New York, ISBN: 9780471658108. 2005; 468.
7. Baldwin DR, Marshall WJ. Heavy metal poisoning and its laboratory investigation (review article). Annals of Chemical Biochemistry. 1991;36:267-300.
8. Keller W, Pitblade JR. Water quality changes in Sudbury area lakes: A comparison of synoptic surveys in 1974–1976 and in 1981–1983. Water, Air and Soil Pollution. 1986;29:285.
9. WHO. Sulfate in drinking water: Background document for development of WHO guidelines for drinking-water quality. Published on behalf of the World Health Organization and the United Nations Environment Programme. Oxford, Alden Press; 2004.
10. WHO. Styrene in drinking-water. Background document for preparation of WHO Guidelines for drinking-water quality. Geneva, World Health Organization (WHO/SDE/WSH/03.04/27).
11. Wangboje OM, Ekundayo OT. Assessment of heavy metals in surface water of the Ikpoba reservoir, Benin City, Nigeria. Nigerian Journal of Technology. 2013; 32(1):61-66.
12. Elinder C. G. Zinc. In: Friberg L, Nordberg GF, Vouk VB. eds. Handbook on the toxicology of metals, 2nd ed. Amsterdam, Elsevier Science Publishers. 1988;664-679.
13. Sim SF, Ling TY, Nyanti L, Gerunsin N, Wong YE, Kho LP. Assessment of heavy metals in water, sediment, and fishes of a large tropical hydroelectric dam in
Sarawak, Malaysia. Journal of Chemistry. 2016; Article ID 8923183:10.

14. Nriagu JO. Zinc in the environment. Part I, Ecological cycling. New York, NY, John Wiley; 1980.

15. WHO. Zinc in drinking water. Background document for development of WHO guidelines for drinking-water quality. Originally published in Guidelines for drinking-water quality, 2nd ed. Health criteria and other supporting information. World Health Organization, Geneva. 1986;2.

16. Geetha A, Palanisamy PN, Sivakumar P, Ganesh Kumar P, Sujatha M. Assessment of underground water contamination and effect of textile effluents on Noyyal River Basin in and around Tiruppur Town, Tamilnadu. E-Journal of Chemistry. 2008; 5(4):696–705.

17. Awoyemi OM, Achudume AC, Okoya AA. The physicochemical quality of groundwater in relation to surface water pollution in Majidun area of Ikorodu, Lagos State, Nigeria. Am. J. Water Resour. 2014;2:126-133.