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Escherichia coli and Metals status of Hand-dug Wells and a River in Oproama Community, Rivers State, Nigeria

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Abstract

Escherichia coli and metals status of hand-dug wells and a river in Oproama Community were investigated for both dry and wet seasons employing standard laboratory procedures. *Escherichia coli* recorded the highest values of 3.32x102 cfu/ml (log10 2.5211) and 3.40x102 cfu/ml (log10 2.5314) for wet and dry seasons respectively. Lead had highest values of 0.318 ppm and 0.27 ppm for wet and dry seasons respectively; copper had highest values of 0.03ppm and 0.019 ppm for wet and dry seasons respectively; zinc had highest values of 0.068 ppm and 0.03 ppm for wet and dry seasons respectively; cadmium had highest values of 0.030 ppm and 0.04 ppm for wet and dry season respectively; nickel had highest values of 0.165 ppm and 2.021 ppm for wet and dry season while mercury had highest value of <0.15 ppm for both wet and dry season. *Escherichia coli* counts which exceed the standard for both drinking and recreational waters pose a potential health hazard to the consumers although, the metal values were within acceptable limits, yet consumer education is highly recommended.

Keywords: *Escherichia coli*; Hand-dug well; Metals; River

1 Introduction

The need for potable water by humans is a key requirement, whether it is intended for drinking, recreational activities and other domestic purposes. It is an essential desire of life. This therefore makes it very necessary that sufficient amount of potable, clean and safe water be made available to other life forms such as flora and fauna [1]. Simpi *et al.* [2] observed that inadequate quantity of it results to mobility and fatality rate in rural settlements where chemicals contaminants and water-based infections are endemic and persistent as a result of poor groundwater and surface waters quality. Lack of safe drinking water and inadequate sanitation measures introduce diseases causing pathogens such as *Escherichia coli* into water, and these pathogens can cause water-borne diseases like diarrhoea in either human host [3]. Water-borne pathogens pose special risk for millions of lives especially infants, young children under the age of five and people with severe compromised immune system [4]. Every year millions of lives are claimed in developing countries and death of more than 2 million people per year worldwide is caused by diarrhoea, mostly among children under the age of five [4].

In the environment, heavy metals remain one of the major contaminant of water sources. Heavy metals are elements having some atomic weight between 63.54 and 200.59, and a specific gravity greater than 4 [5]. Heavy metals such as mercury, lead, arsenic and cadmium are harmful heavy metals [6] while cooper, and nickel which are not found abundantly in the earth's crust also tend to constitute health risks to consumers [7]. Their presence in water sources have been linked with toxicity in man and aquatic organisms, and become visible after bioaccumulation for a long period

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of time since heavy metals cannot be degraded [8]. According to Egbe and Ahunanya [9], heart, kidney and blood related diseases as well as lung and skin cancers have been associated with areas polluted with heavy metals. With the foregoing, there is the need to investigate the *Escherichia coli*, lead, copper, zinc, cadmium, nickel and mercury status of the hand-dug wells and the river water in Oproama Community, Rivers State, Nigeria.

2 Material and Methods

The study was carried out in Oproama Community, Asari-toru Local Government Area, Rivers State. The community lies on latitudes 4^o 47' and 4^o 56' North and longitudes 6^o 50' and 6^o 41' East.

For the purpose of the study, ten (10) sampling stations were selected. Seven (7) hand-dug wells which are being used extensively for drinking and other domestic purposes and three (3) source points along the Oproama River were sampled monthly for *Escherichia coli*, lead, copper, zinc, cadmium, nickel and mercury concentrations for twelve (12) months to cover both dry and wet seasons

Seven (7) clean plastic buckets were used to collect well water samples from each of the seven hand-dug wells in the community using '*okowa'* (stick with hook) and transferred immediately into already labelled 2-litre plastic containers. River water samples were collected by wading to slightly above knee depth and plunging the neck of the already labelled clean and sterile 2-litre plastic containers downward to about 30cm below the water surface and tilted slightly upward towards upstream to let it fill and a space of 1.5cm left in each plastic container to facilitate mixing before carefully replacing the cap under water. The samples were collected in triplicate for microbiological and metal analysis. All the samples were then taken to the laboratory in a cold box for analysis within 2 hours.

Membrane filtration techniques [10] was employed. The dilution used was 10^{-3} for *Escherichia coli* and 10ml was filtered. The membrane filter was then placed on Eosin Methylene Blue (EMB) Agar which was prepared according to manufacturer's instruction. All the plates in duplicates were incubated at 44^{o}C for 24 hours. Discrete colonies were picked and subcultured onto Nutrient Agar plates using streak plate method. Stock cultures were prepared on sterile Nutrient Agar in Bijou bottles, coded for ease of identification and stored in the refrigerator (4^{o}C) until needed for further tests. The isolates were identification on the basis of their cultural, morphological and physiological characteristics in accordance with schemes and methods described by Cheesbrough [11]. Microscopic examination of isolates was carried out using oil immersion objectives (x100). The following tests were carried out: Gram staining and Biochemical tests which were catalase, oxidase, coagulase, citrate utilisation, indole, methyl red, VogesProskauer, Hydrogen Sulphide, Urease, motility, salt tolerance and sugar fermentation test.

The water samples were analysed for the presence of lead, copper, zinc, cadmium, nickel and mercury concentrations using atomic absorption spectrophotometer (AAS) (HACH DR 2400).The method involves direct aspiration of the water sample into an air/acetylene or nitrous oxide/acetylene flame in the presence of energy at specific wavelength generated by hollow cathode lamp peculiar only to the metal under investigation. Prior to analysis, the AAS was calibrated with standards of known concentrations to obtain a calibration curve for the individual metal.

3 Results

There were seasonal changes in *Escherichia coli* of the different sampling stations (wells and rivers) in Oproama Community (Figure 1). Generally, apparent seasonality was shown especially in well water sources (stations 1-7). Station 5 (well) and station 10 (river) recorded the highest values of $2.62x10^2$cfu/ml (log_{10} 2.4183) and $3.32x10^2$cfu/ml (log_{10} 2.5211) for wet season amongst the well and rivers samples respectively, while dry season values show that station 1 (well) and station 10 (river) recorded the highest values of $5.6x10^1$cfu/ml (log_{10} 1.7481) and $3.40x10^2$cfu/ml (log_{10} 2.5314) for well and river samples, respectively. With the analysis of variance (ANOVA), it was observed that there was no significant difference in the counts obtained for the stations while there was significant difference in the months (wet and dry seasons) over the monitoring period at $p<0.05$.

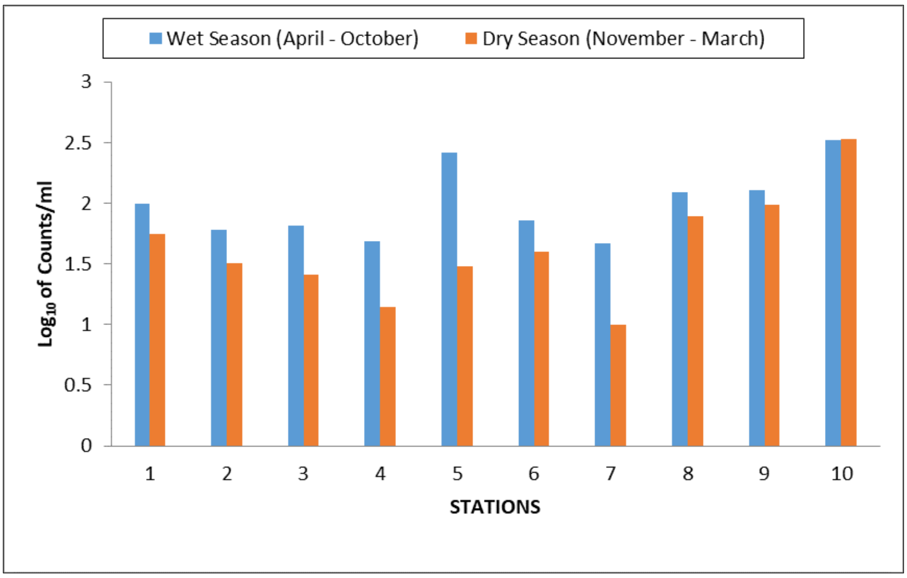

Figure 1 *Escherichia coli* Counts of Water Samples from Oproama Community covering the wet and dry seasons

The mean levels of heavy metals (lead, copper, zinc, cadmium, nickel and mercury) obtained from the various stations are recorded in Tables 1-6. The lead (Pb) level detected was very low among the various stations. Generally, among the stations, values ranged from ND-0.318 ppm and ND-0.27 ppm for wet and dry seasons respectively (Table 1). Table 2 reveals low levels of copper (Cu) recorded in all the stations. For the wet season, the highest value of 0.03ppm was recorded in station 8, while the lowest value of ND-<0.001 ppm was recorded in station 3. During the dry season, station 8 recorded the highest value of 0.019 ppm while the lowest value of ND-<0.001ppm was recorded in stations 2 and 3.

Table 1 Concentration (ppm) of Lead (Pb) in Water Samples from Oproama

Station	Wet Season (ppm)	Dry Season (ppm)
1	ND – 0.027	<0.001 – 0.003
2	ND – 0.047	<0.001 – 0.004
3	ND – 0.042	<0.001 – 0.046
4	ND - <0.001	<0.001
5	ND – 0.049	<0.001
6	ND – 0.070	<0.001
7	ND – 0.038	ND – 0.003
8	ND – 0.300	0.18
9	ND – 0.318	0.25
10	ND – 0.270	0.27
WHO (2004), NIS (2007) 0.01mg/l		

ND: Not Detected; WHO: World Health Organisation; NIS: Nigeria Industrial Standard

In Table 3, the zinc (Zn) level in station 7 has a range of <0.001-0.068 ppm which was the highest during the wet season while station 10 recorded the lowest value of 0.006 ppm. During the dry season, station 10 recorded the highest value of 0.03 ppm while the lowest value of ND-<0.003 ppm was recorded in station 3. The cadmium level recorded for the wet season is within the range of ND-0.030 ppm with the highest value of ND-0.030 ppm recorded in station 8 while stations 2, 4, 5, 6 and 7 recorded the lowest value of ND-<0.001 ppm. During the dry season, the highest value of 0.04 ppm was recorded for stations 9 and 10 while the lowest value of ND-<0.001 ppm was recorded for stations 4 and 6 (Table 4). The level of nickel (Ni) obtained from this study is shown in Table 5. The lowest value of <0.001-0.017 ppm was recorded in station 4 while the highest value of 0.165 ppm was recorded in station 10 for wet season. During the season, the lowest value of <0.001-0.005 ppm was recorded in station 5 while the highest value of 2.021 ppm was recorded in station 1. Table 6 reveals the mercury (Hg) level obtained from the various stations. During the wet season, the lowest value of ND-<0.01 ppm was recorded in stations 1, 2, 6, 7, 9 and 10 while the highest value of ND-<0.15 ppm was recorded in station 5. In the dry season, the range recorded for the stations is ND-<0.15 ppm.

Table 2 Concentration (ppm) of Copper (Cu) in Water Samples from Oproama

Station	Wet Season (ppm)	Dry Season (ppm)
1	<0.001 – 0.005	<0.001 – 0.001
2	<0.001 – 0.006	ND - <0.001
3	ND - <0.001	ND - <0.001
4	<0.001 – 0.008	<0.001 – 0.001
5	<0.001	<0.001
6	<0.001 – 0.002	<0.001
7	<0.001	<0.001
8	0.03	0.019
9	0.02	0.013
10	0.023	0.014
WHO (2004) 2 mg/l, NIS (2007)1 mg/l		

ND: Not Detected; WHO: World Health Organisation; NIS: Nigeria Industrial Standard

Table 3 Concentration (ppm) of Zinc (Zn) in Water Samples from Oproama

Station	Wet Season (ppm)	Dry Season (ppm)
1	0.006	0.017
2	ND – 0.019	0.005
3	<0.001 – 0.019	ND - <0.003
4	<0.044 – 0.025	<0.0004 – 0.006
5	<0.001 – 0.049	ND – 0.010
6	<0.015 – 0.027	<0.0001 – 0.21
7	<0.001 – 0.068	0.13
8	0.03	0.027
9	0.037	0.028
10	0.03	0.03
WHO (2004), NIS (2007) 3mg/l		

ND: Not Detected; WHO: World Health Organisation; NIS: Nigeria Industrial Standard

Table 4 Concentration (ppm) of Cadmium (Cd) in Water Samples from Oproama

Station	Wet Season (ppm)	Dry Season (ppm)
1	<0.001	<0.001
2	ND - <0.001	<0.001
3	<0.001- 0.001	ND – 0.0004
4	ND - <0.001	ND - <0.001
5	ND - <0.001	<0.0004 - <0.001
6	ND - <0.001	ND - <0.001
7	ND - <0.001	ND – 0.0001
8	ND – 0.030	0.03
9	ND – 0.023	0.04
10	ND – 0.021	0.04
WHO (2004), NIS (2007) 0.003 mg/l		

ND: Not Detected; WHO: World Health Organisation; NIS: Nigerian Industrial Standard

Table 5 Concentration (ppm) of Nickel (Ni) in Water Samples from Oproama

Station	Wet Season (ppm)	Dry Season (ppm)
1	0.008	2.021
2	0.010	<0.001- 0.03
3	<0.001 – 0.022	<0.001 – 0.012
4	<0.001 – 0.017	2.027
5	0.003	<0.001 – 0.005
6	<0.001 – 0.024	<0.001 – 0.006
7	<0.006 – 0.029	0.017
8	0.139	0.125
9	0.127	0.151
10	0.165	0.155
WHO (2004), NIS (2007) 0.02 mg/l		

ND: Not Detected; WHO: World Health Organisation; NIS: Nigeria Industrial Standard

Table 6 Concentration (ppm) of Mercury (Hg) in Water Samples from Oproama

Station	Wet Season (ppm)	Dry Season(ppm)
1	ND - <0.01	ND - <0.15
2	<0.01	<0.001 -<0.01
3	<0.01	ND - <0.15
4	ND - <0.01	ND - <0.15
5	ND - <0.15	<0.001 - <0.15
6	ND - <0.01	ND - <0.15
7	ND - <0.01	ND – <0.15
8	<0.01	<0.001 - <0.15
9	ND - <0.01	<0.001 - <0.15
10	ND - <0.01	<0.001 - <0.15
NIS (2007)	0.001mg/l	

ND: Not Detected; NIS: Nigeria Industrial Standard

4 Discussion

There were variations in *Escherichia coli* during the wet and dry seasons. Also, when the counts obtained are compared to the World Health Standard for safety and portability which is 0/100ml of water, it shows poor microbiological quality and indicated very high level of contamination. The presence of *Escherichia coli* in water supply indicates human faecal contamination. Medically, *Escherichia coli* have been reported to be the leading cause of diarrhoea diseases in addition to pathogens such as *Salmonella*, *Shigella*, *Yersinia*, *Vibrio*, *Campylobacter* species, *Entamoeba histolytica*, and *Giardia lamblia* in developing countries [12].

Generally minute quantities of heavy metals were detected in water sources and their concentrations were within the acceptable limits. Lead is the ubiquitous toxicant in the environment [13]. Therefore, body levels depend on environment exposure conditions. Lead monitoring is important because of its toxicity to human health. Lead poisoning is rare [14], but low levels of chronic exposure as observed in the study area can produce adverse health effects. The presence of lead in water beyond the permissible level could result in hypertension, interference with Vitamin D and calcium metabolism, brain development hindrance in foetus and young children, damage to tissues and organs in human and many more [15]. The possible source of lead in samples could be attributed to leaching of natural deposits of lead ores in the soil into the groundwater [16].

The WHO [17] recommended limit for copper (Cu) is 2 mg/l. For all the water samples, copper was detected in levels below the limit in both seasons. Though widely distributed and an essential element, acute toxicity of copper results to hypotension, coma and death. Copper poisoning also cause gastrointestinal disorder after a long period of exposure [15].

Zinc is a ubiquitous essential trace mineral. All the samples contained zinc in very minute quantities for both seasons which is below the 3 mg/l limit stipulated by WHO [17] and NIS [18] for drinking water. Happily, zinc does not accumulate with continued exposure; rather, body content is modulated by homeostatic mechanisms that act mainly on absorption and liver levels [19]. From the results, there is no life threat from zinc. However, zinc imparts an undesirable taste to drinking water [20]. Zinc toxicity results in vomiting and diarrhoea. Studies suggest that excessive amounts of free zinc ions can cause neuron death by interfering with the energy production process [21].

Cadmium exists as natural ores in rocks, soils and as zinc refining by-product [22]. Its presence in groundwater occurred via leaching when in contact with soil contaminated with discharges from mining, paints, electroplating, petrochemicals, plastics and fertilizer industries [23]. WHO [17] recommended 0.003 mg/l for cadmium in drinking-water. All the samples analysed showed absence to very low levels of cadmium. The well water samples had values below the recommended limit for both wet and dry seasons while slightly higher values were observed for the river water samples which can render it potentially toxic. Though cadmium concentrations were below the permissible value, according to [15], epidemiological studies have shown that long exposure to cadmium could lead to kidney damage, lung cancer, high blood pressure and bone defects (osteoporosis and osteomalacia).

The recommended level of nickel in water is 0.02 mg/l [17, 18]. The results showed that the well samples (1-7) recorded values below the recommended level for both seasons except for station 1 and 4 which recorded high values of 2.021 and 2.027 ppm, respectively for dry season. The nickel levels for stations 8, 9 and 10 (river samples) were all above the recommended level for both wet and dry seasons and this may be due to tidal actions. The health impact according to NIS [18] is possible carcinogenic. The recommended level of mercury in water is 0.001 mg/l [17, 18]. Mercury (Hg) has long been identified as an element that is injurious, even lethal to living organisms. Exposure to its inorganic form, mainly from elemental Hg (Hg(0)) vapour [24] can cause damage to respiratory, neural, and renal systems [25]. The possible sources of metal contaminants of the open wells are uncertain. It is likely due to natural processes and anthropogenic activities since there are no industrial activities, mining or petroleum drilling commonly observed in the study area.

5 Conclusion

The microbiological investigation reveals that *Escherichia coli* counts showed seasonal variation and the concentration level could be potential pathogens and harmful to human health. Generally, higher microbial flora occurred during the wet season than the dry season. Lead, copper, zinc, cadmium, nickel and mercury values of the water samples were minute and within the recommended range for drinking water for the parameters analysed during the study period and showed seasonal variation. Measures must be in place to ensure proper siting, use and maintenance of hand-dug wells; open defecation by humans (including use of jetty latrines) and animals, and dumping of waste close to these water-points should be discouraged as well as proper channeling of water away from the hand-dug wells.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest between the authors

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