HEAVY METALS AND BACTERIA CONTAMINATION IN DRINKING WATER: THE WASSA IDP CAMP CASE STUDY, ABUJA, FEDERAL CAPITAL TERITORY, NIGERIA

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Abstract: Heavy metal and microbial contamination are a common challenge affecting most water sources in many Nigerian communities. The present study is therefore aimed at investigating the heavy metal and microbial contamination of water consumed by the internally displaced persons (IDPs) in the Wassa camp of the Federal Capital Territory. Water was sampled from four water sources (Borehole, a dug-out pond and two stream points). Water samples were collected in triplicates and processed for heavy metal and microbial contamination according to standard methods. Data obtained was subjected to One Way Analysis of Variance in R statistical package. The result showed that the primary source of water (Borehole) at the camp had higher Lead (0.07 ± 0.0 mg/L), Cadmium (0.05 ± 0.0 mg/L) and Zinc (0.09 ± 0.0 mg/L) levels, which were above the recommended WHO limits. The observed variations in heavy metal concentrations across the water sources were significantly different ($p < 0.05$). The coliform bacteria identified include *Enterobacter* spp. (31.25%), *Escherichia coli* (25%), *Salmonella* spp. (18.75%), *Proteus mirabilis* (18.75%), and *Shigella* spp. (6.25%). The present study revealed that the Borehole water poses serious health threats of lead and cadmium toxicity. While the IDPs exposed to the two stream points are at risk of bacterial infection. Hence, there is a need for intervention from the government and concerned agencies in terms of providing quality water for the IDP camp.

Keywords: Bacteria contamination, heavy metals, internally displaced persons, water quality, Nigeria

Introduction

Accessible and portable drinking water is crucial to the sustenance of any community and for maintaining health and well-being (Gao *et al*., 2023; Ongeri, 2023). The need for portable and accessible drinking water is on the increase due to population explosion, shortage of government interventions coupled with, the contamination of our aquatic resources with contaminants such as personal care products, pesticides, herbicides, heavy metals and a myriad of biological contaminants (Whelan *et al*., 2022). Communities with abundant and safe water sources tend to have better public health outcomes and a higher quality of life, while populations without access to clean and safe water sources face serious health risks from several waterborne diseases such as cholera, dysentery, typhoid fever, hepatitis, giardiasis, cryptosporidiosis, *E. coli* infections caused by poor water quality (Fida *et al*., 2022; Izah *et al*., 2022; Gao *et al*., 2023). Typically, the pathogenic bacteria that cause these diseases pollute water, rendering it hazardous for use and consumption (Kumar *et al*., 2023). It is also worth noting that drinking water sources contaminated with non-biological materials like heavy metals can predispose the community to reproductive disorders, cancer and lead poisoning. Several studies have shown that drinking water sources can be a host to significant concentrations of heavy metals (Gadzama *et al*., 2014; Anyanwu and Nwachukwu, 2020; Egbueri and Unigwe, 2020; Ajiboye *et al*., 2022; Ogarekpe *et al*., 2023).

The growing number of internally displaced persons (IDP) and camps have been on the increase in recent years in Nigeria. The boomerang effect of ecological crises such as flood and security challenges ranging from Boko Haram, Banditry, and Farmer-Herdsmen clashes have resulted in the displacement of many communities. The report by the Nigeria Health Watch (2017) and a study by Sampson *et al.* (2023), showed that the Wassa IDP camp plays host to many displaced Nigerians experiencing various sorts of neglect such as toilets, and lack of potable water in the Federal Capital Territory (FCT). More so, the camp is the largest camp by population size in the Federal Capital Territory.

IDPs in several states around the nation frequently lament that the Federal and State administrators have abandoned them and in the Wassa IDP camp in the Federal Capital Territory (FCT), the scenario is the same. A community borehole had been sunk close to the IDP camp; however, according to campers, the borehole is not always accessible to most of them due to a water charge fee. More so, the consumption of drinking water varies from household to household within the camp and also the financial status of the campers is not the same, hence most have no other option than to source water from a nearby stream and dug-out ponds for drinking and other domestic activities. Therefore, periodic monitoring of water is crucial for the development of policies that will enhance the livelihood of any community. In addition, there is currently no study on the water quality of Wassa IDP Camp. Hence, we investigated the physicochemical parameters, heavy metal contamination as well as microbial load of the source of water for the IDPs in Wassa camp of the FCT, Abuja.

Materials and Methods

Description of the study area

The study area (Figure 1); Wassa IDP camp is situated about 5 km away from the city center behind Apo Village right after Waru and Kabusa. It consists of 7 communities, with a population of about 5121 IDPs (Sampson *et al*., 2023). The camp residents are IDP migrants majorly from Adamawa, Borno and Yobe States in North East of Nigeria. The Wassa IDP camp was purposively selected from the list of IDP camps in the FCT because of its population size, and due to the difficulty faced by the residents in accessing portable drinking water. Noticeable anthropogenic features around the stream banks are Agricultural activities, washing and swimming and open defecation.

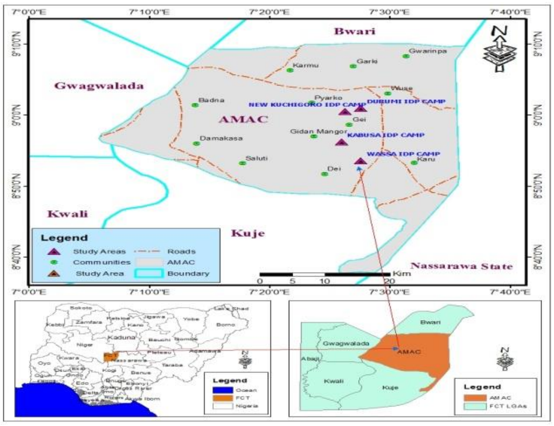

Figure 1. Map of AMAC Showing Study Area

Sampling stations
A total of four (4) sampling stations (Angwan Primary = Station 1, Farm Zinc = Station 2, Rafin Dutse = Station 3, and Bore Hole = Station 4) were purposively selected; based on available water sources and accessibility.

Collection and analyses of water samples
Water samples from each point or station were collected in transparent amber bottles and *in situ* measurements of physicochemical parameters such as pH, temperature, total dissolved solids and electrical conductivity were determined using portable handheld HANNA instrument model 98129. Water samples for other physicochemical and heavy metal analysis were ice-packed while water samples for bacteriological analysis were collected in 50 ml sterile sample bottles. The water samples were collected in triplicates at each sampling point and were collected between 7:00 am and 10:00 am.

Heavy metal analysis
The screening of water samples for potential heavy metal (Lead, Cadmium, Mercury, Copper, Chromium) contamination was aided by simple digestion followed by analysis with an Atomic Absorption Spectrophotometer (AAS) and was carried out in the laboratory of the Department of Biological Sciences, National Open University of Nigeria, Jabi, Abuja.

Bacteria analysis
Isolation, purification and macroscopic screening of bacteria was carried out using serial dilution method. Isolation, purification and macroscopic screening of colonies of well-differentiated bacteria were coded and subjected to successive replicates on nutrient agar and re-incubated at 37°C for 24 hours. Each series of replicates was preceded by macroscopic screening based on cultural characters (colony appearance; colour metabolite production etc.) to eliminate cases of redundant isolates. The selected pure isolates were kept on slant agar at 4°C for future analysis.

Analysis of samples by most probable number
Presumptive, confirmatory and completed tests for detection of the presence of coliforms were carried out according to the methods described by Chessbrough (2006).

Presumptive Test
The samples were analyzed for coliform bacteria using the five-tube lactose-fermentation technique. Clean inverted Durham tubes were inserted into five different tubes of lactose fermentation. Ten milliliters (10 ml) of already prepared lactose broth were added to the tubes containing inverted Durham tubes, which were then inoculated with 10 ml, 1 ml and 0.1 ml of the water sample separately. The five-tube lactose-fermentation bottles were incubated by placing them in an oven at 37 ^{0}C for 24 hours. The bottles were examined for the production of gas which indicates positive bottles.

Confirmatory Test
After the incubation of the cultures, two drops from each of the positive tubes from the presumptive test were transferred into separate tubes containing 10 ml of Brilliant Green Bile Broth with Durham tubes. The tubes were incubated at 37°C for 24h. The formation of gas in any of the inverted Durham tubes indicated a positive test. A count of several tubes showing positive results for the complete test was noted, this count gives the MPN ratio. The MPN ratio was checked against standardized MPN probability tables to obtain the Most Probable Number of coliforms for the sample.

Completion test
The completed test was carried out in order to confirm the presence of coliforms in the water samples. A loopful of samples from each positive Brilliant Green Bile Broth tube was streaked on MacConkey agar and Nutrient agar respectively and then incubated at 37°C for 24 hours and the number of colonies on nutrient agar was counted using a colony counter.
The number of colony-forming units was counted using a colony counter and the colonial density was calculated as the colony-forming unit (CFU) multiplied by the dilution factor. The mean total count obtained was recorded and expressed in colony-forming units per milliliter (Cfu/ml) of the sample.

Preparation of Pure Cultures of isolated bacteria
Representatives of each colony type (that is discrete colonies) on Mac Conkey Agar were aseptically transferred to freshly prepared sterile Mac Conkey Agar and Eosin Methylene Blue Agar respectively to obtain pure cultures. The pure cultures were maintained on nutrient agar slants and stored at 4 ^{o}C for biochemical tests (Cheesebrough, 2006). Purification was done by repeated sub-culturing. Isolated colonies were identified by Gram staining, and cultural and biochemical tests according to Bergey's manual. The biochemical characteristics used are; the indole test, citrate utilization test, catalase test, methyl red test, Voges proskauers test and oxidase test.

Determination of frequencies of occurrence
The sum of all the numbers of colony-forming unit per millilitre (Cfu/ml) of the organisms in each sample was calculated using the expression:

$$\frac{\text{Number of each isolate}}{\text{Total number of isolates}} \times 100$$

Data analysis
The data generated was subjected to a one-way analysis of variance to compare the mean differences in physioch emical parameters, heavy metals and bacteria across the s

ampling points. Where a significant difference (p < 0.05) exists, Tukey's post hoc test was employed to separate th e means. A cluster dendrogram was constructed to establi sh the similarity in investigated parameters viz a viz the s ampling points. A correlation plot was developed to deter mine the relationship between the investigated parameter s. All analyses were carried out with R statistical softwar e. R version 4.3.0 (2023-04-21 ucrt).

Results and Discussion

The results show that the physicochemical properties of t he water sources varied significantly ($p < 0.05$) Figure 2a and b. The highest temperature observed was 28.33±0.28 °C in the Borehole. There was no significant ($p > 0.05$) v ariation in the mean temperature values of water samples from Angwan primary and Rafin Dutse during the sampli ng period (Figure 2a). Water pH ranged from 7.06±0.1 – 5.56±0.05 (Figure 2b). The zinc concentration was in the order of Borehole > Angwan primary > Farm Zinc with t he highest zinc concentration of 0.092±0.00 mg/L observ ed in the water sample collected from the borehole, while Zn metal was not detected in the Rafin Dutse water samp les (Figure 3a). The mean copper concentration observed was in the order, Farm Zinc > Rafin Dutse > Angwan Pri mary > Borehole (Figure 3b). The highest lead concentra tion was observed from the Borehole water sample (0.07 0±0.00 mg/L) but was not detected in water samples obta ined from Rafin Dutse and Farm Zinc (Figure 3c). Cadmi um level was relatively high in all the water samples and was in the order Borehole > Angwan primary > Farm zin c > Rafin Dutse (Figure 3d). The results also showed that water samples from the Borehole had 0 MPN while Ang wan Primary, Farm Zinc and Rafin Dutse had 28, 31 and 22 MPN respectively (Table 1). The highest CFU/mL wa s recorded in water samples from Farm Zinc ($1.53 \times 10^2 \pm 0.12$ CFU/mL) while no coliform was recorded in the Bo rehole water sample (Table 2). The occurrence and distri bution of bacteria isolates are presented in Table 3. *Esche richia coli*, *Salmonella* spp. and *Proteus mirabilis* were t he only isolates found in water samples of Angwan Prim ary. Meanwhile, *Enterobacter* spp. and *Proteus mirabilis* were found in water samples from Farm Zinc. Rafin Duts e water samples had *Shigella* spp., *Enterobacter* spp. and *Proteus mirabilis* (Table 3). The percentage occurrence o f these bacteria isolates is *Enterobacter* spp. > *Escherichi a coli* > *Salmonella* spp. > *Proteus mirabilis* > *Shigella* s pp. As depicted (Table 4). The present research investiga tion showed a strong negative relationship between all th e heavy metals and the bacteria isolates. The heavy metal s all had a strong positive relationship with each other (Fi gure 4a). The water temperature had a negative associati on with the bacteria isolates. Also, a strong positive relati onship was observed between copper and two bacteria is olates from Farm Zinc water source (Figure 4b). *Escheri chia coli* and *Salmonella* spp. had a strong positive relati onship with water pH. Natural phenomena such as erosio n, sedimentation, and volcanic activity can alter the physi cochemical properties of water bodies over time (Shinoh ara *et al*., 2021). Open defecation, agricultural activities, washing and swimming are the anthropogenic features n oticeable around the camps by our visit. These observed human activities and possibly the natural processes may be responsible for the significant changes in the physicoc hemical properties of the water source at the studied loca tion. The high-temperature value of the borehole water o bserved in this study could be related to solar radiation as the black water storage tank used to store the borehole w ater receives more heat than the streams. This perhaps m ay be because the storage tank is situated at about 15 met ers feet above sea level. Also black being a good conduct or of heat energy, could also have contributed to the incr eased temperature differences between the water sources. pH is an important indicator of water quality (Banna *et al* ., 2014). Natural variations in pH can occur due to factor s such as geology, soil composition, and organic matter d ecomposition. However, human activities such as polluti on, agriculture, and mining can also significantly alter wa ter pH, leading to environmental degradation and ecosyst em disruption (Dewangan *et al*., 2023). In this study, wat er pH was almost neutral at the sampling points except at Farm Zinc. The water pH of Farm zinc was acidic which is attributable to the high agricultural practices in the are a. This is why the locals call the location *Farm Zinc*. The use of fertilizers, pesticides, and animal waste in agricult ure can contribute to nutrient runoff and soil erosion (Kh atri and Tyagi, 2015). As a consequence, water bodies su ch as the dug-out pond at Farm Zinc may have experienc ed elevated levels of nutrients and organic matter. It is im portant to emphasize that the decomposition of organic m atter can lead to the production of acids, which ultimately acidify the water (Akpan, 2004). In this study, the high le vel of lead and zinc as heavy metals in the borehole wate r sample compared to the other sources may be related to , the corrosion of lead and zinc-coated pipes and fittings used in the plumbing systems. This may have led to the r elease of lead and zinc into drinking water. Borehole wat er that travels through lead and zinc-coated pipes are cap able to pick up elevated levels of lead and zinc, especiall y if the water is acidic or soft (Gonzalez *et al*., 2013). Hi gh levels of Zn, Pb and Cd have also been reported in sa mples taken near Odo-Efon River in Ilorin, Kwara State which is in the same geographical region with Abuja (Ari se *et al*., 2015). Extended periods of exposure to elevate d zinc levels have been associated with a higher risk of a number of illnesses, such as immune system malfunction , cardiovascular disease, and several cancers (Chasapis *et al*., 2012; Chasapis *et al*., 2020). Lead is a neurotoxin tha t can accumulate in the body over time, particularly in bo nes and soft tissues and chronic exposure to lead, even at low levels, can lead to neurological damage, developmen tal delays, learning disabilities, decreased IQ, and behavi oral problems especially in children (Brown *et al*., 2024). In addition, lead can accumulate in the kidneys, impairin g their function over time thereby increasing the risk of k idney disease and failure (Marcello *et al*., 2024). The con centration of cadmium was above WHO safe limits for c admium metals in drinking water. The presence of worris ome concentrations of cadmium in the water samples whi ch was above permissible limits may be due to agricultur al practices in the study area. Cadmium is a toxic heavy metal that can pose harmful effects on human health whe n present in drinking water. Harmful effects of cadmium in drinking water include kidney damage, bone damage, cancer, cardiovascular and reproductive damage, as well as reproductive and gastrointestinal complications (Cirov ic and Satarug, 2024). Copper contamination in streams c an result from a combination of natural geological proces ses and human activities. For instance, through runoff an d leaching, the use of fertilizers, fungicides, and pesticide s containing copper in agriculture can lead to copper poll ution in streams. During irrigation or rainfall, copper co mpounds sprayed on crops may wash off and enter neigh boring water bodies, thereby increasing the amount of co pper in streams (Kumari *et al*., 2024). Prolonged exposur e to elevated copper concentrations in drinking water can cause malfunction and damage to the liver. Over time, copper builds up in the liver, making it more difficult for the liver to digest toxins and carry out vital processes like detoxification and protein synthesis (Johnsen and Aaneby, 2024; Kumari *et al*., 2024). From our investigation, the borehole water was free of bacterial contamination, while other water sources had various microbial contamination. This is related to exposure of those sources to open defecation from human and animal. Significant public health concerns are raised when *E. Coli* is found in drinking water, and this can damage public trust in the security and caliber of the water supply. The danger of serious health consequences from *E. coli* contamination in drinking water is higher for specific populations. These comprise young children, pregnant women, the elderly, those with weakened immune systems, and anyone with underlying medical disorders. Exposure to water contaminated with *E. coli* can exacerbate sickness and increase vulnerability to complications in these susceptible individuals (Cabrera-Sosa and Ochoa, 2020). A form of gastroenteritis known as salmonellosis, which is marked by symptoms including fever, vomiting, cramping in the abdomen, diarrhoea, and nausea, can be contracted by drinking water infected with Salmonella (Foster *et al*., 2021). Severe cases can result in dehydration, electrolyte imbalances, and potentially fatal consequences like septicemia (bloodstream infection) and reactive arthritis, especially in susceptible groups like small children, the elderly, and people with compromised immune systems (Foster *et al*., 2021). The IDPs are at risk of shigellosis and complications from proteus-related infections since the natural water sources were found to be contaminated with these microbes. Heavy metals can exert toxic effects on bacteria by interfering with enzyme function, inducing oxidative stress, causing DNA damage, disrupting membrane function, competing with essential metal ions, and overwhelming detoxification mechanisms (Jalilvand *et al*., 2020; Imron *et al*., 2021). This may account for the negative relationship observed between heavy metals and the bacteria isolates in this study.

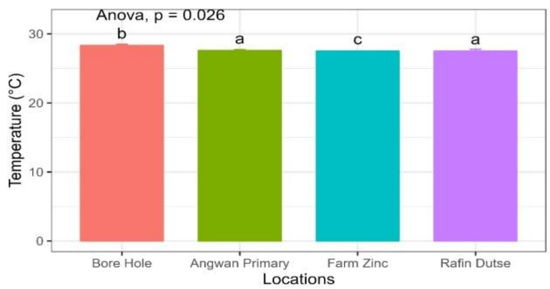

Figure 2a: Temperature of water sources from Wassa IDP camp. Values are mean ± standard error of three replicate values

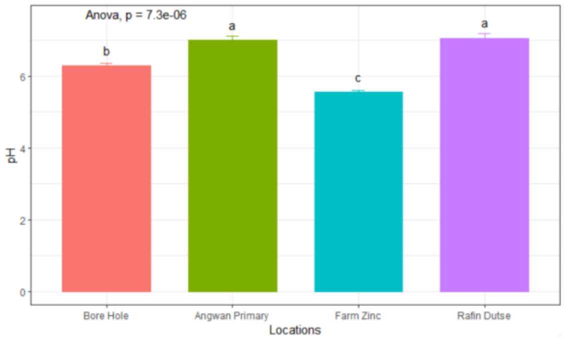

Figure 2b: pH of water sources from Wassa IDP camp. Values are mean ± standard error of three replicate values

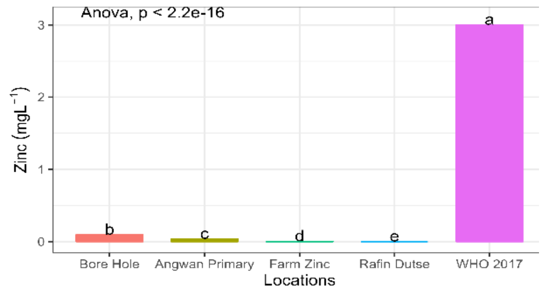

Figure 3a: Concentration of Zinc in water sources from Wassa IDP camp. Values are mean ± standard error of three replicate values

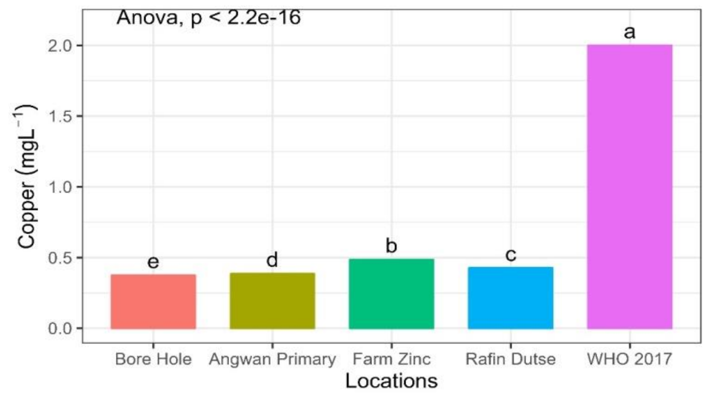

Figure 3b: Concentration of copper in water sources from Wassa IDP camp. Values are mean ± standard error of three replicate values

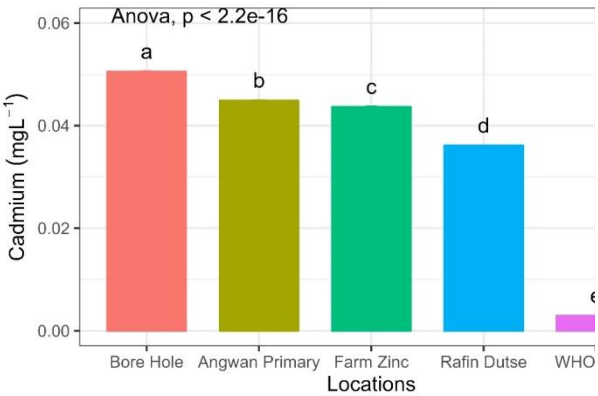

Figure 3c: Concentration of Cadmium in water sourc es from Wassa IDP camp. Values are mean ± standar d error of three replicate values

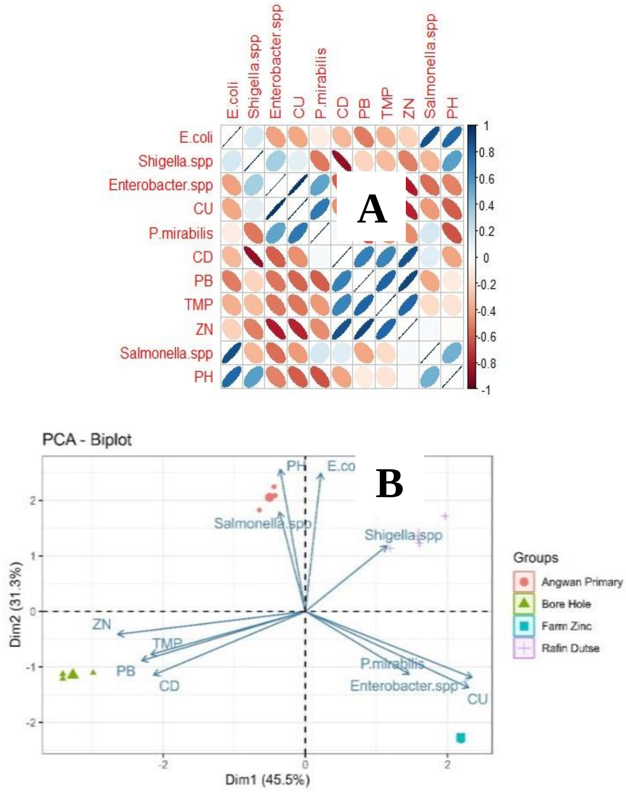

Figure 4 a & b: Relationship between heavy meta ls and bacteria isolates

Table 1: Most probable number of Bacteria isolates from the water sources

Samples	Incubation period	10 ml sample	1 ml sample	0.1 ml sample	MPN Ind ex
Borehole	24	0	0	0	0
Borehole	24	0	0	0	0
Borehole	24	0	0	0	0
Angwan Pri mary	24	4	2	1	26
Angwan Pri mary	24	4	3	1	33
Angwan Pri mary	24	4	2	1	26
Farm Zinc	24	4	3	1	33
Farm Zinc	24	4	3	1	33
Farm Zinc	24	4	2	1	26
Rafin Dutse	24	4	3	1	33
Rafin Dutse	24	4	2	1	26
Rafin Dutse	24	2	1	1	9.2

Table 2: Total aerobic bacterial load from the water sources

Sample Locations	Total bacterial load (CFU/ml)
Borehole	ND
Angwan primary	$1.42 \times 10^2 \pm 0.12$
Farm Zinc	$1.53 \times 10^2 \pm 0.12$
Rafin Dutse	$1.14 \times 10^2 \pm 0.35$

ND = Not Determined, CFU/ml = colony forming units per milliliter.
Values are mean ± standard error of three replicate

Table 3: Occurrence and distribution of bacteria isolates from the water sources

Sample sites	Sample Size	Bacteria Isolates	Occurrences
Borehole	3	No coliforms	0
Angwan Primary	3	*Escherichia coli*	2
		Salmonella spp	3
		Proteus mirabilis	1
Farm Zinc	3	*Proteus mirabili*	2
		Enterobacter spp.	3
Rafin Dutse	3	*Shigella* spp.	1
		Enterobacter spp.	2
		Escherichia coli	2

Table 4: Percentage occurrence of Bacteria isolates

Isolates	Frequency of occurrence	Percentage (%)
Enterobacter spp.	5	31.25
Escherichia coli	4	25.00
Salmonella spp.	3	18.75
Proteus mirabilis	3	18.75
Shigella spp.	1	6.25
Total	16	

Conclusion

The present study revealed that the water sources pose serious health threats of lead and cadmium toxicity as well as high risk of microbial infection on internally displaced persons. Hence, there is a need for intervention from the government and concerned agencies in terms of providing quality water for IDP camps.

Conflict of Interest

The authors declared there are no conflicts of interest

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