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An Assessment of the Quality of Some Portable Water Obtained within Enugu Metropolis

I.I. Ujah ✉
Department of Applied Biochemistry, Faculty of Applied Natural Sciences, Enugu State University of Science & Technology, Enugu State, Nigeria
C.E. Achikanu
Department of Applied Biochemistry, Faculty of Applied Natural Sciences, Enugu State University of Science & Technology, Enugu State, Nigeria
O.N. Ani
Department of Applied Biochemistry, Faculty of Applied Natural Sciences, Enugu State University of Science & Technology, Enugu State, Nigeria
C.A. Nsude
Department of Applied Biochemistry, Faculty of Applied Natural Sciences, Enugu State University of Science & Technology, Enugu State, Nigeria
D.O. Okeke
Department of Biochemistry, Faculty of Biological Sciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria
C.K. Onyishi
Department of Pharmacognosy, Enugu State University of Science and Technology, Nigeria
I.O. Okpako
Department of Molecular Biology and Biotechnology, Pan African University Institute for Basic Sciences, Technology and Innovation, Nairobi, Kenya
J.C. Ude
Department of Applied Biochemistry, Faculty of Applied Natural Sciences, Enugu State University of Science & Technology, Enugu State, Nigeria
C.O. Okechukwu
Department of Food and Nutrition, Enugu State University of Science & Technology, Enugu State, Nigeria
E.O. Nneji
Department of Applied Biochemistry, Faculty of Applied Natural Sciences, Enugu State University of Science & Technology, Enugu State, Nigeria
K.C. Ogbu
Department of Applied Biochemistry, Faculty of Applied Natural Sciences, Enugu State University of Science & Technology, Enugu State, Nigeria
G.U. Nwankwo
Department of Applied Biochemistry, Faculty of Applied Natural Sciences, Enugu State University of Science & Technology, Enugu State, Nigeria
O.J. Uzowuru
Department of Applied Biochemistry, Faculty of Biological Sciences, ENugu State University of Science & Technology, Enugu State, Nigeria

Abstract

Provision of clean water is one of the United Nations Sustainable Development Goals. Water quality assessment as an ongoing exercise, in view of the threat of contamination from natural sources and human activities, plays a pivotal role in the sustainable management of water resources. Potable water samples were collected from Enugu Metropolis for water quality assessment. The physicochemical parameters were determined using APHA (1995 - 1998) protocols, and the presence of 7 heavy

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WHO limit.

metals (Chromium, Zinc, Manganese, Silver, Cadmium, Iron and Lead) in the waters were determined using Atomic Absorption Spectrophotometer (AAS). The results of the physicochemical analysis of the four samples show a pH range of 8.60 - 8.95mg/l; this result showed that pH of the water samples were slightly alkaline and above the WHO stipulated range of 6.50 - 8.50. Acidity ranged from 5.00 - 6.88mg/l, while alkalinity values were between 7.52 - 13.00mg/l. The total dissolved solid (TDS) and total solids (TS) was present in very minute quantities and below their permissible limit of 0.45mg/l; while total suspended solid (TSS) was not present at all. The heavy metal analysis showed that all but 2 heavy metals (Cadmium and Lead) were below thepermissible standard set by the WHO in all four samples. Cadmium was present in samples Aand C with values 0.021mg/l and 0.006mg/l respectively, which is above its WHO limit of 0.005mg/l; while Lead was present in samples A, B and C with values of 0.021mg/l, 0.011mg/l and 0.015 mg/l respectively, which were above the WHO limit of 0.010mg/l. Given the well-documented toxicity of certain metals, there is a need for safety checks to be carried out in potable water companies to address the source of this contamination and ensureproduction of safer drinking water.

Introduction

Water is a vital substance on Earth, serving as both a prime natural resource and a fundamental human necessity [1,2]. To be considered safe or potable, water must meet specific quality standards, making it suitable for human consumption, whether for drinking or cooking purposes [3]. To ensure water quality, it must adhere to chemical, biological, and physical standards at the point of supply to users [4]. The World Health Organization's (WHO) Guidelines for Drinking-water Quality provide a framework for evaluating water quality, outlining characteristic parameters and guideline values [5]."

The World Health Organization [6] categorizes water quality assessment into four primary aspects: microbial, chemical, radiological, and acceptability. Microbial aspects involve detecting waterborne pathogens and indicator microorganisms, such as Helicobacter pylori, Legionella spp., and Escherichia coli [7], which indicate contamination. Chemical aspects, on the other hand, focus on identifying chemical contaminants like heavy metals, including bromide, chlorine, and aluminum [8], which have been linked to various adverse health effects. These health effects include cancer, cardiovascular disease, neurological disease, and miscarriage [9]. Additionally, radiological aspects involve detecting radionuclides in drinking water. Acceptability aspects evaluate the water's appearance, taste, and odor, which can be affected by chemical contaminants, such as high iron concentrations, causing a reddish appearance [10]Ultimately, the presence of these contaminants poses significant health risks, making water hazardous to consume [11].

Drinking water research has primarily focused on microbial contamination due to its significant disease burden, as waterborne diseases like diarrhoea remain a leading cause of mortality globally, particularly among children [12,13]. However, chemical pollution of drinking water has emerged as a growing global concern, albeit with limited attention. This oversight is likely because the communities most affected by chemical contaminants in drinking water are often socioeconomically disadvantaged and marginalized, primarily in low- and middle-income countries [12].

This study undertakes a comprehensive assessment of potable water quality in Enugu Metropolis, Enugu State, Nigeria. Located in Southeast Nigeria, Enugu State is notable for its coal mining industry and historical significance. However, the state's underground water resources are often insufficient, leading to reliance on potentially contaminated water sources [14]. This research evaluates the physicochemical characteristics of potable water samples, including pH, acidity, alkalinity, TDS, TSS, TS, and heavy metal concentrations.

Materials and Methods

Collection of Sample

A total of four (4) cans of potable water were obtained from various locations within Enugu Metropolis.

Determination of Total Dissolved Solid

The total dissolved solids are determined according to APHA (1995) method. After filtration for total suspended solids analysis, the filtrate was heated in an oven at above 100°C until all the water was completely evaporated. The remaining mass of the residue represents the amount of total dissolved solids in a sample and evaluated using

Calculation:

$$\text{Total dissolved solids} = \frac{(w_2 - w_1)\cdot 1000}{\text{Sample volume}} \qquad (1)$$

W_1 =weight of total solids
+dishW_2 = weight of dish [mg]

Determination of Total Suspended Solid (TSS)

Total suspended solid was determined according to APHA (1995) method. A fixed volume ofwater sample was poured on a pre-weighed glass, fiber filter of a specified pore size before
starting the vacuum filtration process. The filter was removed after the completion of the filtration process and placed in an aluminium dish in an oven at 100°C for 2-3 hours to completely dry off the remaining water.

The filter was then weighed and the gain in filter weight represented the total suspended solid contents, expressed in mass per volume of sample filtered (mg/L)

$$TSS(mg/L) = \frac{(A-B)}{1,000,000} \cdot V \quad (2)$$

Where:

A -Mass of filter + Dried residue [mg]

B -Mass of filter [mg]

V -Volume of sample filtered

Determination of Alkalinity

Alkalinity was determined according to the WHO (1997) protocol. A volume, 100 cm^3 of water was measured into a beaker while 2-3 drops of phenolphthalein indicator was added. Colour change was observed following the titration with 0.1N HCl until the colour changed from pink to colourless. Alkalinity is evaluated using the formula

$$Alkalinity = \frac{Total\ volume \cdot normality \cdot 50000}{Volume\ of\ sample} \quad (3)$$

Determination of Acidity

Acidity of the sample is determined by titration with sodium hydroxide to a phenolphthaleinindicator end point

$$Acidity\ (Meq/g) = \frac{ml\ 0.1N \cdot NaOH}{10g \cdot 10} \quad (4)$$

Determination of pH

The pH was determined following APHA (1998) procedure. The pH meter was calibrated,with three standard solutions (pH 4.0, 7.0 and 10.0), before taking the measurements. The value of each sample was taken after submerging the pH probe in the water sample and holding it for a couple of minutes to minutes to achieve a stabilised reading. After the measurements of each sample, the probe was rinsed with deionised water to avoid cross contamination among different samples.

Determination of Heavy Metals

A volume, 5 ml of HCl, was mixed with 100 ml of water and heated for 15 minutes in anoven at 100^oC. The filtered solution was allowed to cool and the heavy metals content was determined using Atomic Absorbance Spectrophotometer.

Results and Discussion

Table 1: Water Quality Parameter of the Potable Water Samples from Enugu Metropolis

PARAMETERS	A	B	C	D	WHO STD
pH	8.95 ± 0.47	8.65 ± 0.47	8.60 ± 0.47	8.75 ± 0.47	7.50
Acidity (mg/l)	5.00 ± 1.24	6.25 ± 1.24	6.88 ± 1.24	5.00 ± 1.24	6.5
Alkalinity (mg/l)	13.00 ± 1.85	10.00 ± 1.85	10.25 ± 1.85	7.50 ± 1.85	8.50
TDS (mg/l)	0.01 ± 0.17	0.00 ± 0.17	0.00 ± 0.17	0.00 ± 0.17	0.45
TSS (mg/l)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00
TS (mg/l)	0.01 ± 0.17	0.00 ± 0.17	0.00 ± 0.17	0.00 ± 0.17	0.45

Table 2: Heavy Metal Concentration in Potable Water Samples from Enugu Metropolis

Heavy Metal	Sample A	Sample B	Sample C	Sample D	WHOSTD
Cr (mg/l)	0.007 ± 0.02	0.003 ± 0.02	0.004 ± 0.02	0.05 ± 0.02	0.05
Zn (mg/l)	0.00 ± 1.20	0.00 ± 1.20	0.00 ± 1.20	0.00 ± 1.20	3
Mn(mg/l)	0.00 ± 0.20	0.00 ± 0.20	0.00 ± 0.20	0.00 ± 0.20	0.5
Ag (mg/l)	0.005 ± 0.04	0.005 ± 0.04	0.002± 0.04	0.002 ± 0.04	0.1
Cd (mg/l)	0.021 ± 0.01	0.002 ± 0.01	0.006 ± 0.01	0.003 ± 0.01	0.003
Fe (mg/l)	0.008 ± 0.56	0.002 ± 0.56	0.000 ± 0.56	0.008 ± 0.56	1.500
Pb (mg/l)	0.021 ± 0.01	0.011 ± 0.01	0.015 ± 0.01	0.006 ± 0.01	0.010

Discussion

pH is a crucial parameter for evaluating water quality, despite having no direct impact on consumers. The physicochemical analysis of water samples revealed pH values ranging from 8.60-8.95, which exceeds the World Health Organization's [15] recommended limit of 6.5-8.5, indicating that all samples are slightly alkaline. Notably, water with a pH below 8 is preferable for effective disinfection with chlorine, but lower pH levels can be corrosive [16]. Conversely, pH levels above 8.5 can cause undesirable effects, including a slippery texture, soda-like taste, and deposits [43]. Furthermore, research on alkaline water's benefits and risks has yielded conflicting results [17], with potential harmful effects including neutralization of stomach acid, increasing the risk of pathogenic bacterial infections, and decreased nutrient absorption. Overall, the pH levels of the water samples suggest potential concerns regarding their quality and safety.

Total Dissolved Solids (TDS) measures the amount of particulate solids dissolved in water, including minerals, salts, metals, cations, and anions [18]. TDS values for all samples were well below the Nigerian Industrial Standard (NIS) limit of 500mg/l and World Health Organization (WHO) acceptable limit of <600mg/l [19]. Interestingly, the WHO recommends that water with a TDS level of less than 300mg/l is considered excellent. However, water with very low TDS levels can taste flat, which may not be desirable for many people (SDWF, 2024). TSS stands for total suspended solids, and refers to waterborne particles that exceed 2microns in size. Any particle that is smaller than 2 microns, on the other hand, is considered atotal dissolved solid [20]. In all 4 samples, there was no presence of total suspended solids. Total solids (TS) is the sum of both the total suspended solids (TSS) and total dissolved solids (TDS) in of water: TSS values up to 50 ppm is accepted in drinking water and the recommended level for total solids is 1000ppm [21]. The analysis showed absence of total suspended solids in all four samples, and presence of total solids in minute amounts in sample A only.

Heavy metals are metallic elements or compounds characterized by high density and toxicity, even at low concentrations [22]. These harmful substances primarily enter the human body through contaminated drinking water, although smaller amounts can also be absorbed through food and air [22]. As a result, prolonged exposure to heavy metals can lead to severe health issues, including renal injuries, cardiovascular disorders, neuronal damage, cancer risk, and diabetes risk [44]. Notably, analysis of the water samples revealed the presence of several heavy metals, specifically Chromium, Zinc, Manganese, Silver, Cadmium, Iron, and Lead.

Chromium (Cr) occurs naturally in three stable forms: metallic chromium (Cr), trivalent chromium (Cr(III)), and hexavalent chromium (Cr(VI)) [23]. While Cr(III) is naturally present in the environment and essential for human nutrition, Cr(VI) is primarily generated through industrial processes, according to the Agency for Toxic Substances and Disease Registry (ATSDR). Cr(III) plays a crucial role in glucose, protein, and fat metabolism by enhancing insulin activity. In contrast, Cr(VI) is toxic, classified as a known human carcinogen, and can severely impair various bodily systems, including digestive, gastrointestinal, urinary, reproductive, respiratory, and immune functions [24]. Our analysis revealed chromium levels ranging from 0.003 mg/l to 0.05 mg/l, well within the World Health Organization's (WHO) acceptable limit of 0.05 mg/l. These findings indicate that the chromium concentrations in our samples pose no significant health risks.

Zinc (Zn) is an essential mineral crucial for human health and growth, required in small amounts. Naturally, groundwater typically contains zinc levels below 0.05mg/l, and the World Health Organization (WHO) has set a limit of 3mg/l for zinc in drinking water [15]. Analysis of our four samples revealed nondetectable zinc levels, well within the acceptable limits of both the WHO (3mg/l) and the United States Environmental Protection Agency (USEPA) (5mg/l) [25]. This is fortunate, as zinc deficiency can cause adverse effects, including impaired cognition [26]. Conversely, excessive zinc intake is linked to various toxic effects, such as gastrointestinal diseases, cardiovascular issues, carcinogenic effects, and potentially fatal outcomes at high levels [27]. Furthermore, elevated zinc levels can also impart an undesirable flavor to water.

Manganese (Mn) is a naturally occurring substance found in rocks and soils [29]. As an essential trace element, manganese is readily absorbed by humans and plays a crucial role in various enzymatic processes, including activating kinases [15]. However, high levels of manganese in water supplies (exceeding 0.1mg/l) can impart an undesirable taste, affecting water acceptability. Notably, the health-based value of manganese is 4.0 mg/l, but consumer complaints may arise at lower concentrations [28]. Fortunately, our analysis revealed manganese levels of 0.00 mg/l across all four samples, indicating no detectable presence. While manganese deficiency is rare due to its abundance in food [15], adverse health effects can still occur from excessive intake. Specifically, excessive manganese exposure has been linked to negative neurodevelopmental outcomes in children [30].

Silver (Ag), a transitional precious metal, is classified among the most toxic heavy metals, belonging to the highest toxicity class of contaminants [31]. Its toxicity affects soil microorganisms and avian and mammalian species. Silver has been detected in groundwater, surface water, and drinking water at concentrations above 0.005 mg/l [6]. To ensure safety, the World Health Organization (WHO), US Environmental Protection Agency (EPA), and Australian EPA have established a drinking water standard of 0.1 mg/l [32]. Our analysis revealed trace amounts of silver in all four samples, ranging from 0.002 mg/l to 0.005 mg/l, well below the established limits. However, ingesting or absorbing silver into the human body can lead to accumulation in tissues, primarily targeting mucous membranes and eyes (Water Research Center). Prolonged exposure causes argyria or argyrosis, characterized by skin discoloration, turning skin purple-grey.

Cadmium (Cd) is a naturally occurring metal typically found in the environment combined with elements like chlorine, sulfur, and oxygen [33] Cadmium levels in drinking water are usually below 0.001mg/l, with a guideline value of 0.003mg/l established by the World Health Organization [6]. However, our analysis revealed varying cadmium levels: samples B and D fell within the acceptable limit, while samples A (0.021mg/l) and C (0.006mg/l) exceeded the WHO limit (0.003mg/l) and the United States Environmental Protection Agency

(USEPA) limit (0.005mg/l) [6] Ingesting cadmium through drinking water poses serious health risks, including acute gastroenteritis and renal cancer, leading to its classification as a human carcinogen (Group 2A) by the International Agency for Research on Cancer and European Commission [34]. Cadmium primarily targets the kidneys and bones, causing damage to the nephron's proximal tubule, reduced bone mineral density, osteoporosis, and fractures [35]. Moreover, childhood exposure to cadmium may increase the risk of developing various diseases later in life.

Iron (Fe) is an abundant metal and essential component of all living organisms [36]. Interestingly, groundwater with high iron content may offer protection against anemia in vulnerable rural children and contribute to elevated serum ferritin levels [37]. However, excessive iron exposure increases the risk of developing various diseases, including Parkinson's, Huntington's, cardiovascular disease, hyperkeratosis, diabetes mellitus, Alzheimer's, and renal, liver, respiratory, and neurological issues [38]. Moreover, unwanted iron consumption is linked to weariness, weight loss, joint pain, cognitive difficulties, reproductive issues, liver and heart damage, pancreatic damage, and diabetes [38]. Despite potential health risks, iron concentrations below 0.3mg/l can cause water discoloration without affecting taste, and 2mg/l is considered safe for drinking water [39]. Our analysis revealed iron concentrations well within safe limits: iron was undetectable in sample C, present in sample B at 0.002mg/l, and in samples A and D at 0.008mg/l. These values are significantly below the acceptability limit and health-based value, indicating the water's iron concentration poses no health hazards.

Lead (Pb), a naturally occurring toxic metal in the earth's crust, poses significant health risks, particularly to infants and children's developing brains. Exposure can result in reduced IQ, attention span, impaired learning ability, and increased risk of behavioral problems. To mitigate these risks, the US Environmental Protection Agency (EPA) set an action level of 0.015 mg/l for lead in public water supplies under the Lead and Copper Rule (LCR) [40] The World Health Organization (WHO) established a guideline value of 0.010 mg/l, noting typical lead occurrence in drinking water is below 0.005 mg/l [39]. Our analysis revealed mixed results: sample D had a safe lead level of 0.006 mg/l, below both WHO and EPA limits. However, samples A (0.021 mg/l), B (0.011 mg/l), and C (0.015 mg/l) exceeded the WHO limit, raising health concerns. Excessive lead intake has been linked to various cancers, including stomach, intestine, ovary, kidney, lung, myeloma, lymphoma, and leukemia [41]. Lead exposure can also cause diverse health problems, such as renal, cardiovascular, hematological, immunological, and reproductive effects [35] Notably, a previous study in Enugu, Southeast Nigeria, found widespread lead contamination in well water [42].

Conclusion

Physicochemical analysis of potable water samples from Enugu Metropolis revealed significant variations in drinking water quality. Among the samples, only Sample D met acceptable heavy metal levels, deeming it relatively safe for consumption. In contrast, Sample B was deemed not fairly safe due to elevated lead levels. Samples A and C raised health concerns with excessive cadmium (Cd) and lead (Pb) levels, necessitating further safety assessments and treatment to ensure safer drinking water. Crucially, raising awareness about the role of heavy metals in various diseases is essential. Healthcare settings in Nigeria often overlook heavy metal assays as a diagnostic tool. Encouraging its use can facilitate early detection and prevention of heavy metal-related health issues.

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