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Physicochemical Characterization and Heavy Metals Assessment of Water Sources at the Nigerian Air Force Base, Kaduna

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Abstract
This study analyses water quality from raw dam water, treated water sources (BSG, BASCOF, AFIT), and residential supplies, focusing on physicochemical parameters and heavy metal contamination. Raw dam water exhibited high turbidity (22.70 NTU), low electrical conductivity (43.60 μS/cm), and moderate chloride (56.23 mg/L) and nitrate levels (8.50 mg/L), with a pH of 6.50 indicating slight acidity. Treatment improved water clarity and reduced turbidity, with BSG-treated water achieving 12.70 NTU and higher electrical conductivity (81.30 μS/cm). BASCOF-treated water demonstrated very low turbidity (1.25 NTU) and high electrical conductivity (111.70 μS/cm) but elevated nitrate (19.00 mg/L). AFIT-treated water showed low turbidity (0.92 NTU), moderate electrical conductivity (90.10 μS/cm), and increased nitrate (36.00 mg/L), iron (0.22 mg/L), and fluoride (0.01 mg/L), raising concerns about nitrate nearing regulatory limits. Residential water quality varied, with pH ranging from 5.4 to 6.6, electrical conductivity between 71.5–347 μS/cm, and turbidity levels of 0.63–6.66 NTU, with some exceeding acceptable thresholds. Heavy metal analysis revealed cadmium and chromium levels exceeding WHO and USEPA guidelines, posing health risks. Despite significant improvements in water quality post-treatment, continuous monitoring and targeted interventions in nitrate and heavy metal concentrations management are critical to ensure safe, consistent water supplies.
Keywords: Water, turbidity, heavy metals, chloride, physiochemical

Introduction

Water quality is a critical concern globally, particularly in regions with industrial and military activities like the Nigerian Air Force Base, Kaduna. Heavy metals, such as lead, cadmium, and chromium, are among the most concerning pollutants due to their persistence and toxicity [1]. These contaminants enter water bodies through various anthropogenic activities, including industrial discharges, urban runoff, and agricultural practices [2].
Many rural communities, often lacking proper infrastructure, frequently rely on untreated surface water sources for daily needs, which increases the risk of exposure to waterborne diseases due to contamination [3]. This situation is exacerbated by the scarcity of clean water supplies, leading to about 27% of certain rural populations in Nigeria relying on untreated sources such as ponds, springs, and harvested rainwater. Continuous consumption of these contaminated water sources can result in various health issues, affecting vital organs like the kidneys and liver, and can contribute to conditions such as metabolic syndrome and diabetes [4, 5]. Furthermore, the World Health Organization (WHO) estimates that approximately 80% of diseases in developing countries stem from contaminated water, leading to about 3.1% of the deaths globally attributed to poor water quality [6]. Such alarming figures highlight the urgent need for enhanced water quality management and monitoring strategies to mitigate health risks related to inadequate sanitation.

The Nigerian Air Force Base, Kaduna, like many military installations, engages in activities that involve the use of heavy metals, including aircraft maintenance and repair, fuel storage, and ammunition handling [7]. Such activities pose a significant risk of heavy metal contamination to the surrounding environment, including water sources crucial for both military personnel and nearby communities.

Understanding the extent and magnitude of heavy metal contamination in water sources at the Nigerian Air Force Base, Kaduna is essential for assessing environmental and public health risks [8]. Previous studies have highlighted the presence of heavy metals in water bodies near military bases worldwide, emphasizing the need for comprehensive monitoring and management strategies.

In recent years, there has been an increasing recognition of the public health implications stemming from substandard water quality, motivating a growing number of policymakers and researchers to focus on this critical issue [9-14]. Understanding the physicochemical characteristics of water sources is essential for evaluating their suitability for human consumption and developing effective management strategies to safeguard public health.

Furthermore, heavy metal contamination in water sources can have detrimental effects on aquatic ecosystems, including bioaccumulation in aquatic organisms and disruption of ecological balance [15]. These impacts can extend to human populations dependent on these water sources for drinking, agriculture, and other domestic purposes.

Despite the recognized risks associated with heavy metal contamination, there is a paucity of studies specifically focused on assessing water quality at military installations in Nigeria, including the Nigerian Air Force Base Kaduna. Such research is crucial for informing environmental management policies and safeguarding human health in these regions [16].

Therefore, this research aims to investigate the physicochemical properties and heavy metals concentration of domestic water sources at the Nigerian Air Force Base in Kaduna State, Nigeria. By analysing samples collected from various points within the base, we seek to identify the level of contamination and evaluate the associated risks to both the environment and public health.

The findings of this study are expected to contribute to the existing body of knowledge on water quality management in military settings and provide valuable insights for policymakers, environmental agencies, and military authorities. Ultimately, effective management strategies informed by scientific evidence are essential for mitigating the adverse impacts of heavy metal contamination and ensuring the sustainability of water resources in the Nigerian Air Force Base Kaduna and similar environments.

Materials and Methods

Sample Collection

Raw water samples were collected from the water Dam at Nigerian Air Force Base, Base Service Group treatment plant, BASCOF Water Facility, Air Force Institute of Technology treated water and ten different households, all located on the Base and were transported to the laboratory of the Department of Chemistry at the Air Force Institute of Technology, Kaduna for analysis. The raw water samples were collected in a pre-cleaned 4L plastic gallon (previously washed and rinsed with distilled water), scaled and stored at 4^0C for further analysis [17].

Determination of Physicochemical Parameters

Determination of temperature

Temperature determination of the water sample was conducted in the lab using the Wagtech International Conductivity (TDS, Celsius) Meter, a device commonly used in recent studies to ensure accuracy and reliability in water quality assessment [18]. A small portion of the water samples was poured into a beaker, and these samples were used to rinse the probe of the meter, following best practices for ensuring clean readings [19]. After rinsing, the probe was placed into the beaker containing the water sample, and the meter was manually operated to record the temperature of the samples [20].

Determination of the pH

The pH of the water samples was measured in the lab using Micro 800 multi pH meter pH meter, following standard laboratory protocols for water quality testing [18]. Small quantities of the water samples were poured into a beaker, and each sample was used to rinse the probe of the pH meter to avoid cross-contamination [19]. After rinsing, the probe was placed into the water sample to measure its pH. This process was repeated for all the samples to ensure accurate readings, as recommended for high-precision water quality measurements [20].

Electrical Conductivity Determination

The electrical conductivity (EC) of the water samples was measured using the Wagtech International Conductivity (TDS, Celsius) Meter. A small portion of each water sample was poured into a small beaker, which was then used to rinse the probe of the meter to prevent contamination, ensuring accuracy in the measurements [21]. After rinsing, the probe was placed into the beaker containing the water sample, and the meter was manually operated to measure the EC of the samples, following standard laboratory protocols [22].

Turbidity Determination

The turbidity of the water samples was measured using the Turbimeter Plus Kit (PTH 092)). A small portion of each water sample was poured into a glass cuvette, which was then placed in the cuvette holder of the meter [23]. After switching on the meter, the turbidity results were recorded, ensuring consistent measurements across all samples [24]. This process was repeated for all water samples to ensure accurate measurement of turbidity throughout the testing.

Total Dissolved Solids (TDS) Determination

The Total Dissolved Solids (TDS) of the water samples were measured using the Wagtech International Conductivity (TDS, Celsius) Meter. A small portion of each water sample was poured into a small beaker, which was then used to rinse the probe of the meter to avoid cross-contamination. After rinsing, the probe was placed into the beaker containing the water sample, and the meter was manually operated. The meter then recorded the TDS of the samples, providing a measure of the total dissolved solids present [25].

Nitrate (NO_3) Determination

The determination of the concentration of nitrate was done using the Nitratest Tube, which was filled with the water sample up to the 20-ml mark. Then, a spoonful of Nitratest powder and one Nitratest tablet, which was not crushed, were then added to the tube. After securing the screw cap, the tube was shaken vigorously for one minute. Following this, the tube was allowed to stand for one minute before being gently inverted three times to aid flocculation. The sample was left undisturbed for three minutes to ensure complete settlement. Once settled, the screw cap was removed, and the top of the tube was wiped with clean tissue to prevent contamination. The clear solution was carefully decanted into a round test tube, filling it up to the 10-ml mark. A Nitricol tablet was added, crushed, and mixed thoroughly until dissolved. After allowing the solution to stand for 10 minutes for full colour development, the Phot 63 was selected to measure the result as mg/L NO_3, and the photometer reading was taken in the usual manner [25-26].

Determination of Sulfate (SO_4)

The concentration of the sulfate (SO_4) in the water samples was determined by filling a test tube with the sample up to the 10 ml mark. One sulfate turb tablet was crushed and added resulting to the formation of a cloudy solution indicating the presence of sulfate. The solution was left to stand for one minute before being stirred again to ensure uniformity. Phot 32 was then selected on the photometer, and the reading was taken according to the usual photometer instructions. The result was displayed in mg/L SO_4 which provided the concentration of the sulfate in the samples [28].

Manganese (Mn) Determination

The determination of the manganese (Mn) concentration in the water samples proceeded with the filling of a test tube with the sample up to the 10 ml mark. Then, a Manganese No. 1 tablet was added, crushed, and mixed until dissolved. Following this, a Manganese No. 2 tablet was added, crushed, and mixed to dissolve, after which the tube was capped. The sample was then allowed to stand for 20 minutes to enable colour development. Phot 20 was selected on the photometer, and the reading was taken according to standard procedures. The result was displayed in mg/L of Mn, indicating the manganese concentration in the sample [29].

Iron (Fe) Determination

The determination of the concentration of iron (Fe) in the water samples was carried out by filling a test tube with the sample up to the 10 ml mark. An Iron HR tablet was added to the tube, crushed, and mixed thoroughly to dissolution. The solution was allowed to stand for one minute to ensure full-colour development. Phot 19 was then selected on the photometer, and the reading was taken according to standard procedures. The results were displayed as mg/L Fe, providing the concentration of iron in the sample [30].

Fluoride (F) Determination

The determination of the fluoride (F) concentration in the water samples followed the filling of a test tube with the sample up to the 10 ml mark. A Fluoride No.1 tablet was added to the tube, crushed, and stirred to dissolve. Following this, one Fluoride No. 2 tablet was added, crushed, and stirred to dissolve as well. The solution was then allowed to stand for five minutes to achieve full colour development. Phot 14 was selected on the photometer, and the reading was taken according to standard procedures. The results were displayed in mg/L F, indicating the concentration of fluoride in the sample [31].

Salinity Determination

The salinity level in water samples was determined within the range of 0-500 mg/L. 1 ml of the sample was taken using a measuring syringe and transferred into a test tube. Deionized water was added to the test tube to bring the solution up to the 10 mL mark. An acidifying CD (Chlorine Dioxide) tablet was then added, crushed, and mixed to dissolve. Following this, one chloride tablet was added and allowed to disintegrate for two minutes, after which the remaining particles were crushed and mixed thoroughly. The formation of a cloudy solution indicated the presence of chloride. The appropriate program number for the test range was selected on the photometer, and the reading was taken in the usual manner with the light cap in place to ensure accuracy [31].

Determination of heavy metals in water samples

A quantity of 200 ml of each of the water samples was measured into a cleaned 250 ml beaker, then 5ml of concentrated nitric acid was introduced into the water sample. It was then heated on a hot plate to evaporation in a fume cupboard to less than 20 ml. The digested sample was further reconstituted with 20 ml distilled water and was quantitatively transferred to a 50 ml volumetric flask and made to the mark with distilled water and kept in a pre-cleaned 60 ml syrup bottle for analysis. The metal content was determined using Thermo scientific atomic absorption spectrophotometer [17].

Results and Discussion

Table 1: Physicochemical Characteristics of the Dam, Base Service Group Water Treatment Plant, BASCOF Water, and AFIT-treated Water

S/N	DAM	BSG WATER	BASCOF	AFIT WATER	WHO	NAFDAC	USEPA
pH	6.50	6.10	6.50	6.30	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5
Appearance	Not clear	clear	clear	clear	Clear and colorless	Clear and colorless	Clear and colorless
EC (μS/cm)	43.60	81.30	111.70	90.10	No specific standard	No specific standard	No specific standard
TDS(mg/L)	21.40	40.60	55.70	44.20	1000	500	500
Temp (°C)	28.10	28.70	28.70	27.70	No specific standard	No specific standard	No specific standard
Turbidity (NTU)	22.70	12.70	1.250	0.920	5	5	1(drinking water)
Fe(mg/L)	0.01	0.07	0.00	0.22	0.3	0.3	0.3
Cl(mg/L)	56.23	0.00	81.22	43.74	250	250	250
Salinity	92.78	0.00	134.01	72.17	No specific standard	No specific standard	No specific standard
F (mg/L)	0.89	1.22	0.00	0.01	1.5	1.5	4.0
SO4 (mg/L)	1.00	0.00	0.00	6.00	250	250	250
NO3(mg/L)	8.50	8.75	19.00	36.00	0.2	0.2	1.0
Mn (mg/L)	0.00	0.00	0.00	0.00	0.4	0.1	0.3

Table 1 shows the detailed physicochemical analysis of water obtained from four different sources; the dam, Base Service Group (BSG) water treatment plant, BASCOF water, and AFIT-treated water which provides valuable insights into the effectiveness of their respective treatment processes. Several key parameters, including pH, appearance, electrical conductivity (EC), total dissolved solids (TDS), temperature, turbidity, and concentrations of various ions and compounds, were examined to assess the overall water quality. The pH levels across the water sources showed minor variations but generally fell within the acceptable limits recommended by WHO, USEPA, and NAFDAC. Dam water had a slightly acidic pH of 6.50, which is within the permissible range of 6.5 to 8.5 set by WHO and USEPA, though its slight acidity could be attributed to natural environmental factors such as organic matter decomposition [33]. BSG-treated water, with a lower pH of 6.10, was more acidic than the dam water, possibly due to chemical treatments. This is still acceptable but sits near the lower threshold of WHO standards. The pH levels of BASCOF (6.50) and AFIT-treated (6.30) water was also within acceptable limits, indicating efficient management of acidity across treatments. The appearance of the dam water was noted to be unclear, which is typical for natural, untreated surface water, potentially due to suspended organic and inorganic matter. This finding aligns with research on surface water bodies exposed to environmental factors like soil erosion and runoff [34]. In contrast, the treated water from BSG, BASCOF, and AFIT was visibly clear, signifying effective treatment processes for removing suspended particles.

Electrical conductivity (EC), an indicator of the concentration of dissolved ions, varied across the samples.

Dam water had a low EC of 43.60 µS/cm, which is expected of unpolluted natural water sources. After treatment, the EC increased in BSG-treated water to 81.30 µS/cm, BASCOF water to 111.70 µS/cm, and AFIT-treated water to 90.10 µS/cm. These increases suggest the addition of chemicals, such as disinfectants, during treatment. According to the WHO, the recommended limit for EC in drinking water is 1,500 µS/cm, and all samples fell well within this range [35]. The higher EC in BASCOF water could reflect its different source or treatment process, as higher conductivity is associated with a greater presence of dissolved salts or minerals.

The total dissolved solids (TDS), which indicate the number of dissolved substances in the water, mirrored the EC values. Dam water had a low TDS of 21.40 mg/L, reflecting a clean, minimally impacted water source. BSG-treated water increased to 40.60 mg/L, while BASCOF water had the highest TDS at 55.70 mg/L. AFIT-treated water measured a TDS of 44.20 mg/L. These values are well below the WHO-recommended limit of 500 mg/L for drinking water [36], confirming that the dissolved material concentrations remained within safe drinking standards across all samples.

Water temperature remained consistent across the different sources, ranging from 27.70°C to 28.70°C, typical for tropical or subtropical regions. Minor temperature variations can result from sampling conditions but do not significantly impact water quality [37].

Turbidity, a measure of water clarity, was notably high in untreated dam water (22.70 NTU), exceeding the WHO and USEPA recommended maximum of 5 NTU. This high turbidity is typical of untreated surface waters and is often caused by suspended solids, organic matter, and microorganisms [38]. Post-treatment, the turbidity significantly decreased, with BSG-treated water measuring 12.70 NTU, BASCOF water 1.25 NTU, and AFIT-treated water 0.92 NTU. The low turbidity in BASCOF and AFIT-treated waters underscores the effectiveness of the filtration processes used in these treatment plants.

Iron concentrations also varied across the water sources. Dam water had the lowest iron concentration (0.01 mg/L), typical of natural surface waters. BSG-treated water contained a slightly higher iron level (0.07 mg/L), still within WHO and USEPA guidelines of 0.3 mg/L. BASCOF water had no detectable iron, which is consistent with effective removal during treatment, while AFIT-treated water contained the highest iron concentration (0.22 mg/L), though still within permissible limits.

Chloride and salinity levels were highest in BASCOF water, reflecting differences in source water and treatment processes. Chloride concentration in BASCOF water was 81.22 mg/L, and AFIT-treated water exhibited a salinity of 72.17 mg/L, well within the WHO guideline limit of 250 mg/L. Elevated chloride and salinity levels can result from the water's mineral content or chemical additions during treatment [39].

Fluoride concentrations differed among the water samples. BSG-treated water contained 1.22 mg/L of fluoride, approaching the WHO-recommended upper limit of 1.5 mg/L for drinking water, making it effective for dental health but warranting cautious monitoring [40]. BASCOF and AFIT-treated waters contained significantly lower fluoride levels (0.00 mg/L and 0.01 mg/L, respectively).

Nitrate levels were highest in AFIT-treated water at 36.00 mg/L, nearing the WHO limit of 50 mg/L. High nitrate levels can be hazardous, particularly to infants, causing conditions like methemoglobinemia (blue baby syndrome). This indicates possible contamination from agricultural runoff or other sources, making AFIT-treated water a concern for vulnerable populations.

Dam water generally adhered to WHO and USEPA standards in terms of pH, TDS, and iron content, though its turbidity was much higher than acceptable limits. BSG-treated water showed improvement in clarity and TDS but had a slightly acidic pH (6.10). AFIT-treated water had superior turbidity and TDS values, but the nitrate concentration (36 mg/L) raises concerns, especially for sensitive populations. BASCOF water, sourced differently, exhibited excellent turbidity control and low iron content but had higher chloride and salinity levels, still within acceptable limits.

Table 2: The physicochemical characteristics of the domestic water used in 10 randomly selected residential houses on the base were analysed

S/N	HOUSE 1	HOUSE 2	HOUSE 3	HOUSE 4	HOUSE 5	HOUSE 6	HOUSE 7	HOUSE 8	HOUSE 9	HOUSE 10
pH	6.5	6.0	5.6	6.2	5.9	5.8	5.6	5.4	5.8	6.6
Appearance	clear	Clear	clear	clear	clear	clear	clear	clear	clear	clear
EC µS/cm	161.8	138.5	137.0	347	234	71.5	105.1	135.7	227	143.5
TDS	80.3	68.9	69.0	173	117	35.7	52.6	67.5	114	71.9
Temp (°C)	26.6	27.2	27.5	27.3	27.2	27.2	27.4	27.6	27.2	27.1
Turbidity (NTU)	1.03	1.70	1.79	0.81	1.53	2.68	6.66	1.52	1.27	0.63
Iron mg/L	0.00	0.07	0.04	0.06	0.01	0.02	0.11	0.14	0.27	0.06
Chloride mg/L	60.20	70.71	38.74	68.73	58.73	38.74	41.24	28.74	91.22	58.73
Salinity	99.33	116.67	63.92	113.40	96.60	63.92	68.05	47.42	150.51	96.90
Fluoride mg/L	0.01	0.03	0.03	0.06	0.98	0.14	1.33	0.40	0.60	1.22
Sulphate mg/L	0.00	20.0	8.0	12.0	4.0	8.0	20.0	14.0	16.0	18.0
Nitrate mg/L	22	25	28	27	28.4	28	17.6	30	18.8	21.4
Manganese mg/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2 shows the analysis of water samples from 10 randomly selected residential houses on the base reveal's notable variations in water quality, and when related to standards set by the WHO, USEPA, and NAFDAC, as well as comparisons with dam water and BSG-treated water, several key findings emerge.

The pH levels in the residential water samples ranged from 5.4 to 6.6, indicating slightly acidic water in most homes. According to WHO and USEPA standards, the acceptable pH range for drinking water is 6.5 to 8.5, and NAFDAC recommends a range of 6.5 to 9.5. Therefore, most of the houses, particularly those with a pH below 6.5, fall outside these guidelines. The slight acidity could result from corrosion in plumbing systems or incomplete neutralization of the water during treatment. Comparatively, the dam water's pH was 6.50, while BSG-treated water had a lower pH of 6.10, both of which were near or below acceptable limits, highlighting potential treatment shortcomings. The highest EC and TDS levels were recorded in House 4, with 347 µS/cm and 173 mg/L, respectively. WHO and USEPA suggest that EC should not exceed 1,500 µS/cm and TDS should remain below 500 mg/L. NAFDAC also sets similar limits for TDS (500 mg/L). House 4 remains well within these thresholds but shows elevated ion concentrations compared to other residences. House 6, which had the lowest EC and TDS, indicates better water quality, possibly due to more effective filtration. For comparison, BSG-treated water had an EC of 81.30 µS/cm and TDS of 40.60 mg/L, while the dam water had even lower values. This shows that the residential water quality, while varying, generally adheres to standard limits but could reflect localized issues such as old plumbing leaching minerals.

Most houses exhibited low turbidity, below 2 NTU, except House 7, which recorded 6.66 NTU. WHO and USEPA recommend that turbidity not exceed 5 NTU for safe drinking water. House 7 surpasses this limit, indicating potential filtration inefficiencies or particulate contamination, which may pose health risks. In contrast, BSG-treated water had a turbidity of 12.70 NTU, which also exceeds recommended standards, while dam water had an even higher turbidity of 22.70 NTU, reinforcing the necessity for effective filtration in the treatment process. House 9 had elevated iron levels at 0.27 mg/L, while most other houses showed low concentrations. The WHO, USEPA, and NAFDAC recommend that iron levels in drinking water should not exceed 0.3 mg/L. House 9 remains within acceptable limits but reflects localized corrosion or contamination in the plumbing. For comparison, BSG-treated water had 0.07 mg/L of iron, and the dam water had 0.01 mg/L, both of which were well within safe levels, indicating successful treatment in reducing iron concentrations overall.

The nitrate concentration in House 8 was 30 mg/L, which is significant but within WHO and USEPA guidelines of a maximum of 50 mg/L. Nitrate levels above this threshold can cause health risks, especially for infants, potentially leading to methemoglobinemia (blue baby syndrome). Fluoride in House 7 was 1.33 mg/L, nearing the WHO's recommended upper limit of 1.5 mg/L. High fluoride levels can have dental health benefits but may also lead to fluorosis if concentrations exceed safe limits. By comparison, BSG-treated water contained 1.22 mg/L of fluoride, suggesting both residential and treated water remain within acceptable thresholds, though they are on the higher end of the spectrum.

Both dam water and BSG-treated water serve as sources for residential water, with the BSG treatment plant improving key parameters like clarity and turbidity, though pH levels remain a concern. BSG-treated water had an EC of 81.30 µS/cm and a TDS of 40.60 mg/L, both well within acceptable limits, but the slight acidity (pH 6.10) and elevated turbidity (12.70 NTU) highlight areas for improvement in treatment efficacy. Similarly, dam water's high turbidity (22.70 NTU) indicates the need for substantial filtration before distribution to the residential areas. Overall, the treated water meets most international standards, but localized plumbing issues, treatment inconsistencies, and environmental factors contribute to variations in water quality across residential houses.

The water quality in residential houses is generally within WHO, USEPA, and NAFDAC standards, though certain parameters like turbidity, nitrate, and fluoride require monitoring to ensure safety. The comparison with dam and BSG-treated water underscores the need for continuous improvements in water treatment and distribution, particularly to address issues like pH imbalances and particulate contamination that could affect residential water quality.

Table 3: Concentration of heavy metals in AFIT treated water

Element	Conc/mg/L	WHO	USEPA [41]	National Standard [42]
Ni	0.540	0.007mg/L	≤ 0.1mg/L	< 1mg/L
Cd	0.000	0.003mg/L	≤ 0.01mg/L	< 1mg/L
Pb	0.196	0.01mg/L	≤ 0.05mg/L	< 1mg/L
Cr	0.000	0.05mg/L	≤ 0.1mg/L	< 0.05mg/L

Heavy metals (nickel, cadmium, lead and chromium) concentrations were determined in different water sources in the Nigerian Air Force Base Kaduna, as can be seen from table 3 the results indicate that Nickel and Lead concentrations exceed WHO and USEPA guidelines, raising concerns about the safety of the water for consumption and other uses. Remediation efforts should focus on reducing these heavy metal levels to safeguard public health.

Table 4: Concentration of heavy metals in BASCOF water

Element	Conc/mg/L	WHO	USEPA [41]	National Standard [42]
Ni	0.058	0.007mg/L	≤ 0.1mg/L	< 1mg/L
Cd	0.000	0.003mg/L	≤ 0.01mg/L	< 1mg/L
Pb	0.474	0.01mg/L	≤ 0.05mg/L	< 1mg/L
Cr	0.000	0.05mg/L	≤ 0.1mg/L	< 0.05mg/L

Table 4 shows the heavy metals concentration in BASCOF water, results obtained showed that the cadmium and chromium levels are within acceptable limits, the lead concentration is alarmingly high, necessitating immediate remediation efforts. The nickel concentration, though within national standards, exceeds WHO guidelines, indicating a need for further assessment.

Table 5: Concentration of heavy metals at BSG treated water

Element	Conc/mg/L	WHO	USEPA [41]	National Standard [42]
Ni	0.108	0.007mg/L	≤ 0.1mg/L	< 1mg/L
Cd	0.078	0.003mg/L	≤ 0.01mg/L	< 1mg/L
Pb	0.000	0.01mg/L	≤ 0.05mg/L	< 1mg/L
Cr	0.000	0.05mg/L	≤ 0.1mg/L	< 0.05mg/L

Concentration of some heavy metals at BSG treated water presented in table 5 shows that, lead and chromium levels are within acceptable limits, the high concentrations of cadmium and nickel exceed international guidelines, indicating potential health risks and necessitating further evaluation and possible remediation

Conclusion

The water quality analysis of various sources, including raw dam water, treated water (BSG, BASCOF, AFIT), and residential supplies, highlights notable findings: The Raw Dam Water showed high turbidity (22.70 NTU) and unclear appearance, low electrical conductivity (43.60 μS/cm) and moderate chloride (56.23 mg/L) and nitrate levels (8.50 mg/L), pH of 6.50 indicates slightly acidic water. BSG-treated water showed improved clarity, reduced turbidity (12.70 NTU), and higher electrical conductivity (81.30 μS/cm). BASCOF-treated water indicates very low turbidity (1.25 NTU), significantly higher EC (111.70 μS/cm), but elevated nitrate (19.00 mg/L). AFIT-treated water donates low turbidity (0.92 NTU), moderate EC (90.10 μS/cm), and increased nitrate (36.00 mg/L), iron (0.22 mg/L), and fluoride (0.01 mg/L), raising concerns about nitrate levels nearing regulatory limits. Residential houses analysis revealed that, pH ranged from 5.4 to 6.6, indicating slight acidity, varied EC (71.5–347 μS/cm), TDS (35.7–173 mg/L), and turbidity (0.63–6.66 NTU), with some exceeding acceptable limits. Low iron levels (maximum 0.27 mg/L), variable chloride (28.74–91.22 mg/L), salinity (47.42–150.51 mg/L), and nitrate (17.6–30.0 mg/L). No manganese detected. Heavy Metal analysis showed that Cadmium and Chromium levels exceed WHO and USEPA guidelines, posing significant health risks. Furthermore, water treatment processes generally enhance quality, continuous monitoring and targeted interventions, particularly in nitrate and heavy metal management, are essential to achieve safe, consistent water quality.

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