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Analysis of Selected Heavy Metals and Physicochemical Properties of Irrigation Water and Soil from Warwade Dam, Dutse LGA, Jigawa State

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ABSTRACT

This research examines the physicochemical characteristics and concentrations of selected heavy metals in irrigation water and soil from Warwade Dam, Dutse LGA, Jigawa State. The World Health Organization (WHO) guidelines are used in this research to compare the results obtained to assess if the water is suitable for agricultural use, given the significance of water quality for soils, crops, and the environment. According to the analysis, all the farms had mildly acidic pH values, with Farm A having the least acidic readings. While manganese (Mn) was noticeably high in Farm B, elevated amounts of lead (Pb) was identified in Farms A and C, surpassing the WHO allowable limits. The suggested threshold for cobalt (Co) concentration was not exceeded. The variations in temperature, turbidity, and total dissolved solids (TDS) among the samples indicate the impact of both man-made activities and natural processes. High concentrations of Pb and Mn can be harmful to health, which emphasizes the need for routine testing and efficient water treatment techniques to protect the environment and the general public's health. These results of this study highlight how urgently pollution control measures must be put in place to save the environment and maintain the region's agricultural output.

Keywords: Heavy metals, Health, Irrigation, Physicochemical, Soil, Water

INTRODUCTION

Soil and water resources are essential for delivering ecosystem services. They provide valuable products and possess qualities that benefit nearly all life forms, making them a crucial part of our natural heritage. Water quality is vital for human health as well as the quantity and quality of grain harvests since it influences soils, crops, and the environment (Ho and Hui, 2001). The quality of surface and groundwater is influenced by both human activity and natural factors, either separately or in combination. The weathering of bedrock minerals, atmospheric processes involving evapotranspiration, wind-driven deposition of dust and salts, natural leaching of organic matter and nutrients from the soil, hydrological factors causing runoff, and biological processes in aquatic environments that can change the physical and chemical composition of the water would be the only factors determining water quality in the absence of human impacts. (Khatri and Tyagi, 2015). Because of this, water in the natural world may contain both dissolved and undissolved particulate matter. Salts and minerals that have dissolved give water its flavor and are essential for many bodily metabolic processes. Additionally, they are necessary for the development of plants and other water-dependent living things (Srinkanth *et al.,* 1993). Human health risks from contaminated water sources can arise from the use of contaminated surface water for recreational activities (such as swimming), ingestion of toxins by aquatic species, or possible exposure to infections or toxic chemicals through plant irrigation (Schwarzenbach *et al.*, 2010). Industrial and economic growth, along with the production and increased consumption of various compounds and chemicals, have led to the creation of unwanted pollutants. Many of these pollutants pose significant risks and problems for both the environment and human health.

Heavy metals are elements with a specific density greater than 5 g/cm³. They are defined as metals that are at least five times denser than water. These metals can be categorized into essential metals (such as Mo, Mn, Cu, Ni, Fe, and Zn) and non-essential metals (such as Cd, Ni, As, Hg, and Pb) (Santamaria, 2008). Essential metals like copper, which are necessary for the synthesis of hemoglobin and the digestion of carbohydrates, support the human body's metabolism; nevertheless, an excess of these metals can lead to cellular damage. (Vasudevaraju *et al.,* 2008). Heavy metals are hazardous, non-biodegradable, and persist in the environment for extended periods. They have harmful effects on plants, humans, and animals, making them significant pollutants. In the ecosystem, heavy metals create a contamination cycle involving industry, the atmosphere, soil, water, food, and humans (Holmes, *et al.*, 2008). Joseph and co-workers highlighted (Table 1) the adverse effects of some common heavy metals on human health, their common source, and permissible limits based on WHO 2008 and USEPA 2019 (Joseph *et al.*, 2019). Because heavy metals do not biodegrade, they build up in the bodies of both humans and animals when they eat or drink tainted food or water. Most of the metals that are absorbed by the colon are soluble in water and are subsequently transported to many organs via the circulatory system. But even at low concentrations, heavy metals have an impact on numerous cells, including endothelial and epithelial, in the respiratory system. (EPA, 1996). Heavy metal pollutants inhibit plant growth. When metals are present in high concentrations in the soil, they negatively impact seed germination, plant development, productivity, and the plant's physiological, biochemical, and genetic aspects. The level of toxicity in plants depends on soil composition, pH, and the specific characteristics of the plant (Guidotti *et al.*, 2008).

In the Nigerian State of Jigawa, the Warwade Dam is situated close to Dutse. The dam, which has a total storage capacity of 300 million cubic meters, is 1.4 kilometers long, and 7 meters deep. The dam was founded by late Audu Bako, the military's sole administrator of the former Kano State in May 1977. The dam provides water for livestock, recreation, irrigation, aquaculture (fish production), and better fishing in the surrounding area, among other domestic uses. Throughout history, dams have been heavily polluted due to their easy access to waste disposal and often insufficient regulatory oversight. The Industrial Revolution significantly diminished the ability of these water sources to process and neutralize waste effectively (Mahvi *et al.*, 2005). Water quality is assessed through the periodic analysis of samples collected by monitoring stations. These monitoring results are crucial for identifying spatial and temporal trends in both surface water and groundwater. This project aims to determine the levels of lead, cadmium, zinc, manganese, nickel, zinc, and chromium in three farm irrigation water samples taken from the dam in Warwade, Dutse L.G.A., Jigawa state. Along with pH, turbidity, electrical conductivity, hardness, alkalinity, total suspended solids, total dissolved solids, and total solids, of the water samples. To ascertain whether the water is suitable for agricultural use, the outcomes will be compared to the World Health Organization's (WHO, 2008) permitted irrigation requirements.

Table 1: some heavy metals, their common source, health effects and recommended limit (WHO (2008) and USEPA (2019)

Common heavy metals	symbol	Sources	Effects on human health	WHO (2008) permissible limits (mgL^{-1})	USEPA permissible limits (mgL^{-1})
Arsenic	As	Naturally occurring minerals/ores Electronics products	Skin damage Blood circulatory system	0.010	0.010
Cadmium	Cd	Naturally occurring minerals/ores Chemical industries	Carcinogenic Kidney damage	0.003	0.005
Chromium	Cr	Naturally occurring minerals/ores Steel manufacturing Pharmaceuticals	Allergic dermatitis, Diarrhea, nausea and vomiting	0.05	0.1
Copper	Cu	Naturally occurring minerals/ores Household plumbing systems	Gastrointestinal issues Liver and kidney damage	2.0	1.3
Lead	Pb	Lead-based products Household plumbing system	Kidney damage Affects neural development	0.0	0.00
Mercury	Hg	Nervous system Kidney damage	Fossil fuel combustion Electronic Industries	0.006	0.002

MATERIAL AND METHODS

Reagents used

Concentrated nitric acid (HNO_3), concentrated hydrochloric acid (HCI), standard ethylenediaminetetraacetic acid (EDTA) solution (0.01), eriochrome black T indicator, ammonium buffer solution, hydrogen peroxide (H_2O_2), deionized water.

Sampling Technique

Water sampling

Irrigation water samples (500 cm^3) were collected from different areas with distinct intervals. The samples were placed in clean, labeled polyethylene bottles and securely sealed. The pH, and temperature of the water were measured at the sampling site. To prevent contamination, all the soil samples were stored in polyethylene bags and taken to the laboratory for further analysis (Sanae *et al.,* 2024).

Soil sampling

Around 300g of soil samples were taken from three separate farms in Warwade town, Jigawa state's Dutse local government. Up to a depth of 10 cm, samples were obtained at intervals of 5 cm from different depths. The gathered samples were put into plastic bags that were labeled and firmly tied. The soil samples were spread out and allowed to air dry for three days in the laboratory. The dirt was crushed and sieved through a 0–5 cm mesh sieve after drying(McLaughlin *et al.,* 2000)

Physicochemical Analyses

Determination of Temperature, pH and Conductivity

Using a basic pocket thermometer, the temperature of the water samples was recorded on the spot at the moment of sampling. Using a digital pH meter, the pH was measured on-site by submerging the electrode into 100 cm^3 of the water sample and noting the reading. A Sension5 conductivity meter was used to test electrical conductivity, and the electrode was submerged in the 25 cm^3 water sample until a stable reading was recorded (Rodríguez *et al.,* 2018).

Determination of total alkalinity of water

In the 250 cm^3 conical flask, 10 cm^3 of the sample was added, along with two drops of the phenolphthalein indicator solution. The phenolphthalein alkalinity is zero if the indicator in the sample is colorless, indicating that the water is acidic to the phenolphthalein. If the sample is pink in color, titrate it by adding 0.1N hydrochloric acid reagent until the pink color turns colorless. To continue the determination of methyl orange alkalinity using the same sample from the phenolphthalein alkalinity test, two drops of methyl orange indicator was added and titrated with 0.1N hydrochloric acid until a pink color first appeared. Then, the sample was boiled. If the color changes, another titration will be performed with 0.1N HCl (Haruna *et al*., 2020).

Determination of total hardness of water

2 cm^3 of the buffer solution was added to 50 cm^3 of the water sample in a conical flask, and the mixture was swirled to ensure homogeneity. After adding three drops of Eriochrome Black T indicator, the mixture turned pink. After that, 0.1 M EDTA was added to the sample and titrated until a blue hue developed. To express the total hardness in mg/L, the acquired titer value was multiplied by the authorized conversion factor of 44.892. For the remaining samples, this process was repeated (Sesugh *et al.,* 2019).

Determination of Turbidity

The test tube was cleaned with deionized water (turbidity-free), filled to the 10 cm^3 line with deionized water, placed into the colorimeter chamber, and scanned to calibrate the instruments (blanking). This process determines the turbidity. After being cleaned, the second tube was put into the chamber to scan the sample, filled with sample water to the 10 cm^3 mark, shaken to re-suspend particulate matter, and then inserted.

Suspended Solid (SS)

The total suspended solids (TSS) method is a gravimetric procedure in which a sample is filtered, dried, and weighed to determine the accurate TSS value. A Whatman filter paper, rinsed with distilled water, was dried in an oven at 105°C for one hour, then cooled in a desiccator. Its initial weight (W1) was measured using a digital balance. After filtering 100 cm^3 of the water sample through the paper, the filter paper with the residue was dried at 105°C for one hour. The final weight (W2) was recorded, and the total suspended solids were calculated using the formula in Equation 1 (Vyrides and Stuckey, 2009).

$$(W2 - W1) \times 100 \text{ mg/L} \qquad (1)$$

Determination of Total solid

Total solid (TS) was determined by Summation of Total Suspended Solid (TSS) and Total Dissolved Solid (TDS) (Hart, 2006).

Determination of Heavy Metals (Cr, Mn, Ni, Pb, Co, Cd):

Digestion of Water Sample

Fifty milliliters of each water sample were measured into a 100 cm^3 beaker, and concentrated acids were added: 6 cm^3 of nitric acid (HNO_3, 65%), 3 ml of hydrochloric acid (HCl, 35%), and 2 cm^3 of hydrogen peroxide (H_2O_2, 30%). The samples were then placed on a hot plate and heated slowly until the volume was reduced to approximately 20 cm^3. The walls of the beaker were rinsed with deionized water, and the mixture was filtered using Whatman filter paper. The filtrate was transferred to a clean, screw-capped 60 cm^3 polyethylene bottle. These digested samples were used to measure the concentrations of individual metals in the water using Flame Atomic Absorption Spectroscopy (FAAS). Blanks were prepared using the same procedure but without the samples (Karim *et al.,* 2015).

Digestion of Soil Sample

Three grams of the sieved soil sample was accurately weighed and transferred to a 250 cm^3 conical flask. Each sample received 10 cm^3 of aqua regia, a mixture of concentrated nitric acid and concentrated hydrochloric acid in a 1:3 ratio. The sample was then placed on a heating mantle in a fume cupboard until white fumes were observed. After digestion, the samples were cooled, and 50 cm^3 of deionized distilled water was added before filtering. The filtrate was then diluted to 100 cm^3 with deionized water and transferred to a screw-capped polyethylene bottle. Blanks were prepared using the same procedure but without the soil samples. The metal content of the samples was analyzed using Flame Atomic Absorption Spectroscopy (F.A.A.S) (Tsadilas *et al.,* 2005).

RESULTS AND DISCUSSION

The results of the physicochemical parameters and heavy metal concentrations studied in the sampling area are shown in Tables 2. 3, and 4. The concentrations of the heavy metals in the irrigation water samples (in mg/L) are presented in (Table 3) below, along with the WHO/FAO 2008 permissible limits for irrigation. The concentrations of the heavy metals in the irrigation soil samples (in mg/L) are presented in (Table 4) along with the WHO/FAO 2008 permissible limits for irrigation. The quality of a water body is determined by the interaction of its physical, chemical, and biological factors, all of which together affect its productivity.

Table 2: Physicochemical parameters of water sample compared with WHO (2008) permissible limit

sample	pH	Temperature (^{0}C)	Conductivity (μS/cm)	Turbidity (NTU)	TSS (mg/L)	TDS (mg/L)	Alkalinity (mg/L)
A	9±0.25	10.50±0.50	184.2±53.5	0.00±0.00	12.3±5.16	87.8±26.1	21.3±2.8
B	6.3±0.10	15.83±0.29	76.6±25.4	79.3±1.15	58.6±3.21	36.4±12.3	95.1±10.9
C	6.2±0.07	7.23±0.25	72.0±15.2	148.3±4.62	109.3±1.52	35.5±9.5	144.8±11.0
PL	6.5-8.5	-	1000	5	1700	1000	-

TSS: Total suspended solid, TDS: Total dissolved solid

Table 3: Concentration of heavy metals in a water sample (mg/L) compared to the WHO/FAO (2008) permissible limit for irrigation

Metals (mg/L)	Farm A	Farm B	Farm C	Permissible Limit
Cr	0.194±0.70	0.183±0.064	0.172±0.055	0.55
Mn	0.196±0.019	0.370±0.023	0.180±0.041	0.20
Ni	0.90±0.28	0.20±0.008	0.187±0.074	1.40
Cd	ND	ND	ND	ND
Pb	0.206±0.019	0.233±0.045	0.199±0.022	0.065
Co	0.016±0.011	0.024±0.013	0.199±0.022	0.05

Table 4: Concentration of heavy metals in a soil sample (mg/kg) compared to the WHO/FAO (2008) permissible limit for irrigation

Metals (mg/kg)	Farm A	Farm B	Farm C	Permissible Limit
Cr	0.00	4.20±0.014	0.00	100
Mn	3.16±0.086	4.22±0.010	5.70±0.010	2000
Ni	0.14±0.086	4.78±0.64	2.27±0.052	50
Cd	ND	ND	ND	ND
Pb	5.68±0.976	3.56±0.12	1.88±0.014	100
Co	0.22±0.020	0.36±0.042	0.24±0.010	50

pH

The pH values for all the farms are below the acceptable limit of 8.4 with Farm A at 7.90, Farm B at 6.30, and Farm C at 6.20, indicating that Farm A is slightly alkaline compared to the slightly acidic Farm B and Farm C (Figure 1). The acidity is due to increased organic materials, as the decay of organic matter produces carbon dioxide (CO_2), which reacts with water to form carbonic acid (HCO_3), lowering the pH. The pH values of the irrigation water samples range from 6.2 to 7.9, which is slightly acidic and below the WHO, 2008 recommended range of 6.5 to 8.5. (Bozorg-Haddad *et al.,* 2021). This low pH may indicate a high concentration of carbon dioxide gas and bacterial presence. Consuming water with a very low pH can harm body tissues. Lower pH also increases the solubility of toxic metals in water, making it harmful for consumption and farming (Lawson, 2011).

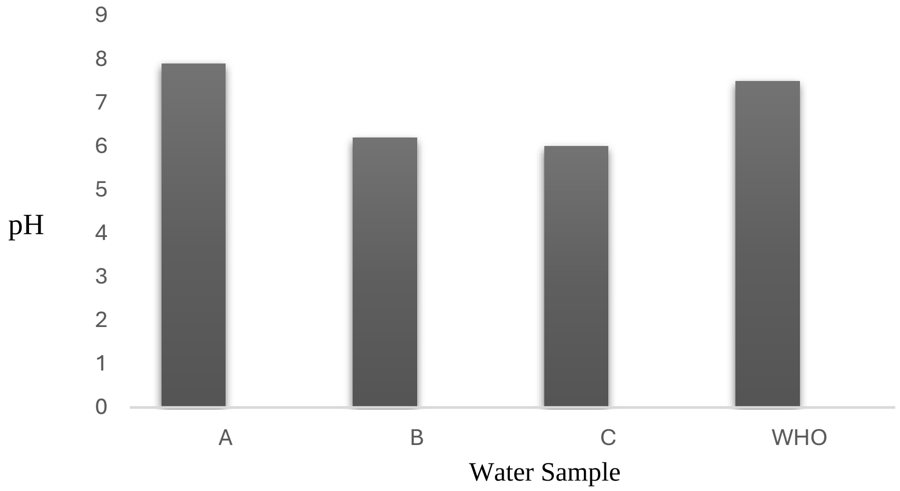

Figure 1: pH and WHO (2008) acceptable limit comparison

Temperature is the measure of how hot or cold a substance is; all the temperature readings obtained fall between 10.50 and 17.23 (C). In contrast, the respective values of farms A, B, and C are 10.50, 15.83, and 17.239 (°C). Based on the results, we can observe that farm A has a slightly higher temperature than farm B, mainly because all sample temperatures were taken right away and the water came from the dam, whereas farm A's temperature was lower because the water sample was taken from the groundwater used for irrigation. According to the Food and Agriculture Organization FAO (1989). and the World Health Organization (2008), there is no acceptable or allowed temperature.

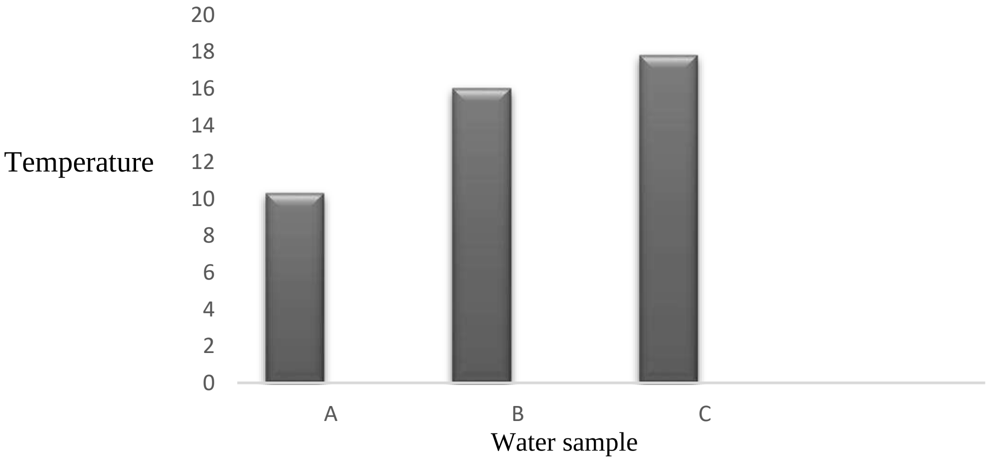

Figure 2: Temperature and WHO (2008) acceptable limit comparison

Conductivity

Electrical conductivity is a measure of water's ability to conduct electric current, primarily influenced by dissolved salts such as sodium chloride and potassium chloride (Rhoades, 1996). The electrical conductivity values obtained in this study ranged from 72.0 to 184.2 µS/cm, all below the WHO (2008) maximum limit of 1000 µS/cm (2008). The highest conductivity was recorded at Farm A, while the lowest was at Farm C, indicating higher dissolved mineral content in Farm A compared to the other farms. Although conductivity itself is not a direct health concern, it can indicate other water quality issues (Bhateria and Jain, 2016). Lower conductivity values, such as 72.0 µS/cm at Farm C and 76.6 µS/cm at Farm B, suggest lower dissolved salt content. In contrast, the higher conductivity at Farm A (184.2 µS/cm) suggests more dissolved salts, which enhances its ability to conduct electricity.

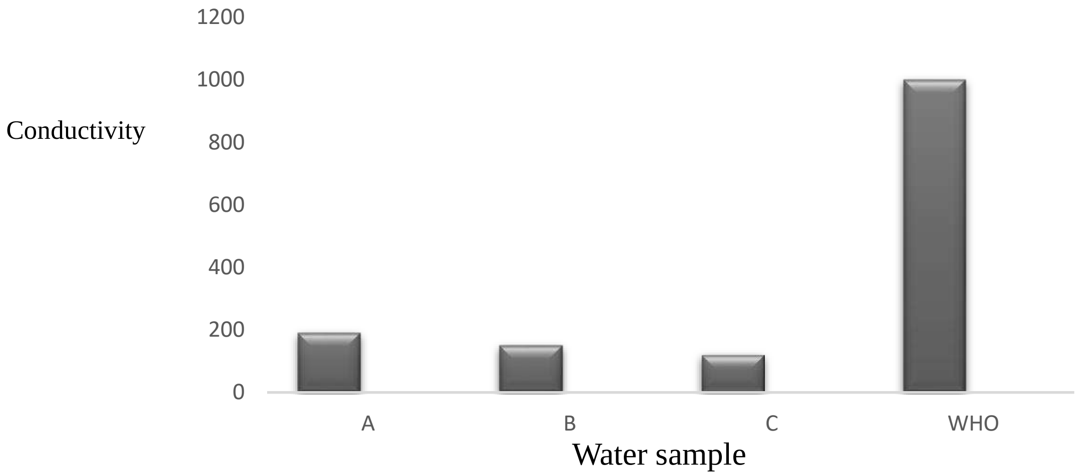

Figure 3: Conductivity against WHO (2008) acceptable limit

Turbidity

Measurements of turbidity, which depend on the amount and kind of suspended particulates in the water, are essential for assessing its quality. is a water clarity metric that evaluates how much suspended matter, such as dirt particles, algae, and plankton, obstructs light flow through the water. It suggests that there are particles present that scatter and absorb light, hence influencing the transparency of water (Muncy, 1979). In this study, Farm A showed low turbidity at 0.0 NTU, Farm B had moderate turbidity of 79.33 NTU, and Farm C exhibited high turbidity at 148.33 NTU. Higher turbidity values indicate increased interference, scattering, or absorption of light due to particulate matter, reducing water transparency. Farm A's low turbidity suggests high transparency, while Farm C's high turbidity indicates a higher density of suspended debris. Turbidity generally correlates with the concentration of total suspended solids in water and can also result from dissolved metals or organic matter (UNICEF 2008). According to the results, all turbidity values exceed the WHO (2008) permissible limit of 5.0 NTU.

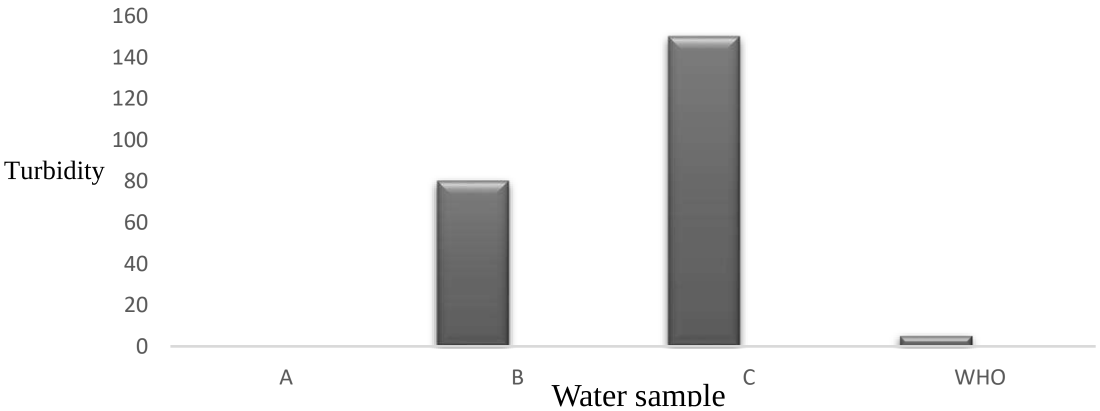

Figure 4: Turbidity against WHO (2008) acceptable limit

TOTAL SUSPENDED SOLIDS (TSS)

The total suspended solids of water samples were assessed using a DR/890 Colorimeter, revealing a range of 12.33-109.33 mg/L. The lowest value was recorded in Farm A at 12.33 mg/L. Total suspended solids (TSS) serve as a measure of water turbidity, with higher TSS values indicating increased water cloudiness. Farm C exhibited the highest TSS value at 109.33 mg/L, followed by Farm B at 58.67 mg/L. This trend parallels the turbidity levels, where higher TSS values correspond to greater water opacity. The elevated TSS in Farm C is attributed to factors like siltation, deterioration, heavy precipitation, runoff, and contributions from surrounding farmland, which transport mud, sand, and other materials (Adekola *et al.,* 2015)). Importantly, the TSS values observed in this study remained well below the permissible limit of 1700 mg/L set by WHO (2008).

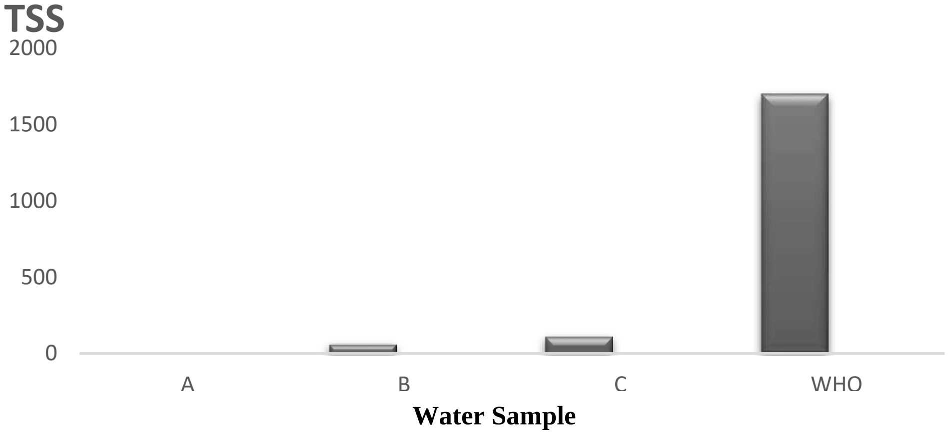

Figure 5: Total suspended solid against WHO (2008) acceptable limit

Total Dissolved Solid TDS

Due to its ability to depict water quality and, in particular, the impact of seawater intrusion, TDS analysis is crucial and highly significant (Rusydi, 2018). The presence of inorganic salts and trace amounts of organic materials in water is described by the TDS concentration. TDS can originate from natural causes, such as geological conditions, human activities, such as home and industrial waste, and agriculture. The Total Dissolved Solids (TDS) values at all sampling sites were below the WHO's permissible limits of 500 mg/L (2008), as shown in Table Figure 6. Elevated TDS levels can indicate potential concerns, often due to the presence of potassium, chlorides, and sodium, which generally have minimal short-term effects. However, toxic ions like lead, arsenic, cadmium, and nitrate can also dissolve in the water, leading to hard water with an undesirable salty, bitter, or metallic taste. High TDS can also suggest the presence of toxic minerals and may stem from organic sources such as leaves silt, plankton, industrial waste, and sewage (Lawson 2011). Farm A, B, and C had TDS values of 87.87, 43, and 35.5 mg/L respectively, all of which are below the WHO (2008) standard. Some treatments, like the addition of coagulants, may be necessary to make these waters suitable for domestic use.

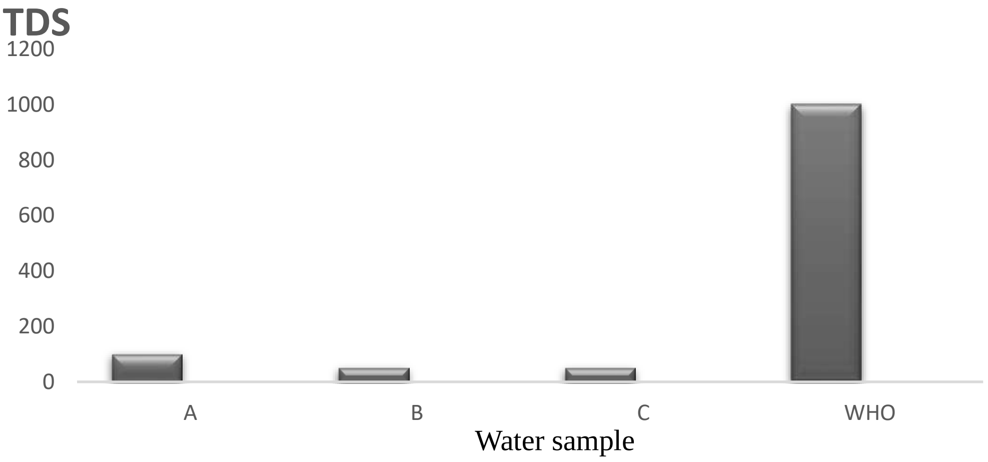

Figure 6: Total dissolved solid against WHO (2008) acceptable limit

Total Hardness

Water hardness leads to soap precipitation and is caused by various dissolved polyvalent metallic cations, primarily due to the presence of Ca^{2+} and Mg^{2+} ions (Shariati-Rad and Heidari, 2020). Additionally, other cations such as Ba^{2+}, Sr^{2+}, Fe^{3+}, and Zn^{2+} also contribute to water hardness. Traditionally, total hardness is measured as the combined concentrations of Ca^{2+} and Mg^{2+}, expressed in mg/L as $CaCO_3$ (Organization, 2010). As shown in figure 7, Farm A had the highest total hardness value at 109.24 mg/L, followed by Farm B at 43.39 mg/L, and Farm C with the lowest value at 37.41 mg/L. All values obtained in this study are below the WHO (2008) permissible limit of 500 mg/L. This measure reflects the total soluble magnesium and calcium salts in the water, expressed as $CaCO_3$. According to the WHO, the acceptable range for hardness (calcium and magnesium) in drinking water is 100-500 mg/L. Calcium and magnesium, essential components of total hardness, are crucial for dietary needs, contributing to bone health (Islam *et al*., 2016).

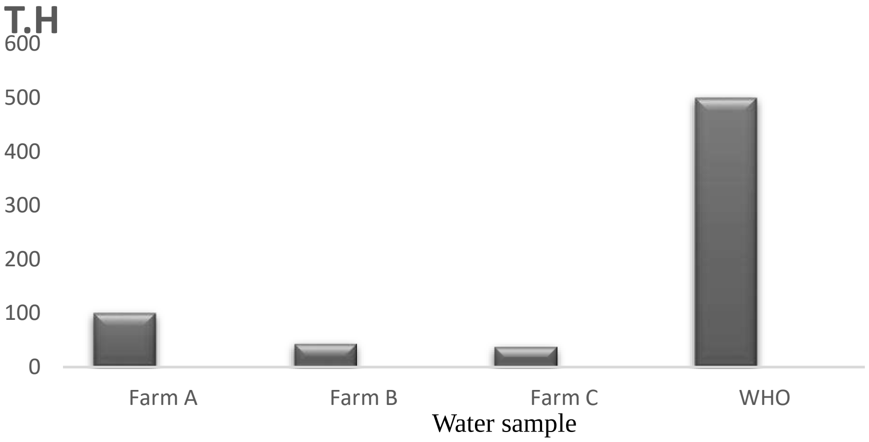

Figure 7: Total hardness against WHO 2008 acceptable limit

Heavy Metals

The analysis of heavy metals in the irrigated water samples indicates elevated lead (Pb) concentrations in Farms A and C, with average mean concentrations of 0.206±0.019 mg/L and 0.199±0.022 mg/L, respectively. These levels exceed the recommended maximum permissible limit of 0.065 mg/L. In contrast, cobalt (Co) concentrations in Farms A and C are low, with average means of 0.016±0.011 mg/L and 0.024±0.006 mg/L, below the recommended 0.05 mg/L limit. Farm B exhibits a high manganese (Mn) concentration, averaging 0.370±0.023 mg/L, which is above the permissible limit of 0.20 mg/L, and also has the lowest average mean Co concentration at 0.024±0.013 mg/L. Overall, the data shows high Pb concentrations in Farms A and C, elevated Mn levels in Farm B, and undetectable levels of cadmium (Cd) across all farms.

Farm A also has the lowest value with an average mean value of 0.14±0.086 mg/kg, below the recommended permissible limit of 50 mg/kg, and the highest average mean concentration of Pb in the soil samples, with a precise value of 5.68±0.916 mg/kg, which is below the recommended permissible limit of 100 mg/kg. Additionally, the Cr concentration in the same farm is below the detection limit. Farm C has the highest average mean concentration of Mn with *(5.70±0.010) and is also below the recommendable limit of (2000 mg/kg); the Chromium metal in farm C is also below the detectable limit, but it has the lowest average mean concentration of Co (0.24±0.010 mg/kg), which is also below the recommended allowable limit of (50 mg/kg). Farm B also has an average mean value of (4.78±0.064 mg/kg) and is below the recommended allowable limit of (50 mg/kg). Additionally, farm C has an average mean value of (4.20±0.014 mg/kg) for Chromium. Of all the farms' heavy metal Cd levels were often undetected, indicating that they are below the detection limit.

Similarly, based on the available data, the average mean amounts of lead in the soil sample (5.68±0.916 mg/kg) and water samples (0.206±0.019 mg/L and 0.199±0.022 mg/L) surpassed the suggested allowed limit of 0.065 mg/L. The potential health effects of lead exposure are determined by the individual's vulnerability and the total amount of lead present in their environment, not by the lead's presence in food, water, soil, dust, or air.(Brown & Margolis, 2012).However, Due to the unseen mechanism of heavy metal toxicity, the problem of heavy metals entering the food chain necessitates thorough assessments and prompt decision-making to prevent serious health effects (Chary *et al.*, 2008).

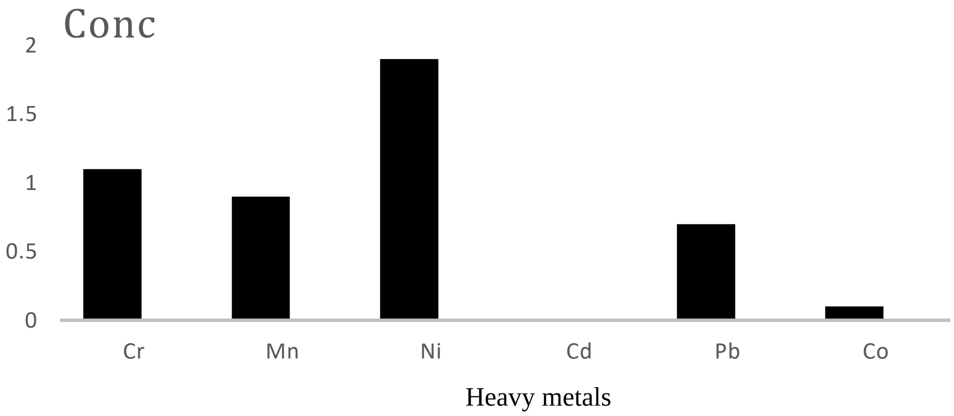

Figure 8: Average concentration of heavy metals in a water sample

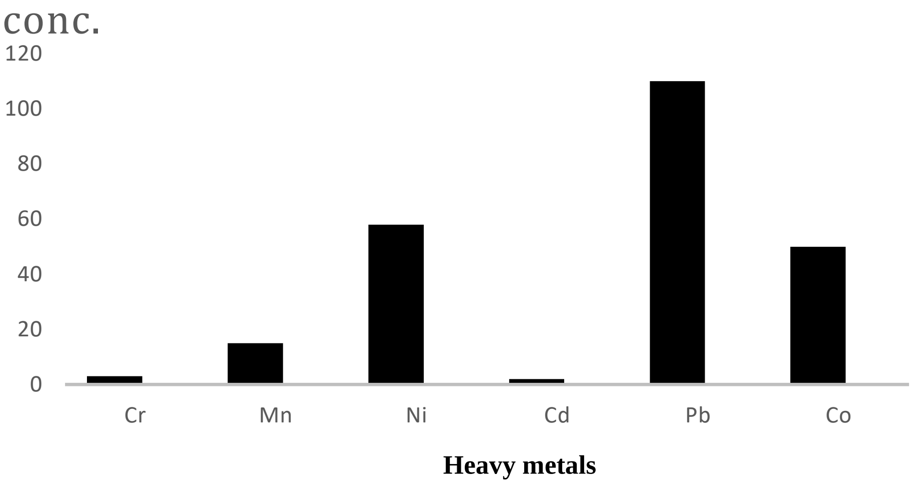

Figure 9: Average concentration of heavy metals in soil sample

CONCLUSION

There are noticeable differences in the concentrations of heavy metals and physicochemical parameters amongst sampling sites, as evidenced by the examination of a subset of heavy metals and the physicochemical characteristics of irrigation water and soil from Warwade Dam, Dutse LGA, Jigawa State. Certain water samples had lead and manganese concentrations that are higher than the permissible limit which could pose threats to public health and agricultural output. In addition, variations exist in pH, turbidity, and total dissolved solids, which indicate the impact of human activity and natural processes on the quality of the water. When compared to soil, irrigation water plays a major role in determining the amounts of heavy metals in vegetables because it typically causes the accumulation of heavy metals in soil, which then affects crops. The findings indicated that lead levels were found to be high in both soil and irrigation water. These results highlight how crucial it is to put in place efficient water management plans and pollution prevention techniques to safeguard the local public's health and the environment.

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