RESEARCH ARTICLE

ENVIRONMENTAL ASSESSMENTS OF HEAVY METALS CONCENTRATION AND PHYSICOCHEMICAL PROPERTIES IN SOIL AND WATER SAMPLES AT THE KANAWA IRRIGATION SITE, YAMALTU DEBA L.G.A., GOMBE STATE. NIGERIA

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Abstract

Background: The concentration of heavy metals and the physicochemical characteristics of soil and water samples from the Kanawa irrigation site were evaluated in this study.

Methods: The physicochemical parameters were analyzed using standard methods, whereas the heavy metal content of the soil and water samples was measured using an atomic absorption spectrophotometer.

Results: The allowable limit and the mean average of all the physical parameters are: Salinity value was (1.02%) and Permissible Limits PL were 2–5, turbidity value was (14.798m) and PL were 1–5, pH value was (6.46) and PL were 6.5–8.5, electric conductivity value was (463.798 μS/cm) and PL are 100–500, total dissolve solid (230.332 mg/l) and PL were 250–500, The overall hardness value was 184.4 mg/l $caco_3$ eqv, the total suspended solid value was 179 mg/l, and the PL was 500. The mean average values of the principal anions' chemical characteristics are: Lead (Pb) was measured at 0.0232 mg/l and the PL was 0.005, chromium (Cr) at 0.0433 mg/l and the PL was 0.005, Nickel (Ni) at 0.09918 mg/l and the PL was 0.1, Cadmium (Cd) at 0.00396 mg/l and the PL was 0.005, Copper (Cu) at 0.05338 mg/l and the PL was 1.5, Iron (Fe) at 0.33146 mg/l and the PL was 0.3, and aspartic (As) at 0.00986 mg/l and the PL was 0.005. In soil samples, the mean average values were compared to the PL as follows: the PL was 73.3 for copper (Cu) and 0.46518 mg/kg for cadmium (Cd); the PL was 0.2 for cadmium (Cd) and 0.24381 mg/kg for chromium (Cr); and the PL was 100 for nickel (Ni).

Conclusion: The findings indicate that the physiochemical characteristics and heavy metal levels in soil and water samples at the Kanawa irrigation site do not affect farmlands or the safety of the water for human use.

Keywords: AAS, Heavy metals, pH, Soil, Water.

INTRODUCTION
Background

An assortment of metals and semimetals (metalloids) that have been linked to environmental contamination and possible toxicity to different types of creatures are collectively referred to as heavy metals in broad usage. The earth's crust is known to naturally contain them, and their specific gravities are larger than 5 g/cm³ or at least five times that of water (Dufus, 2002).

Natural elements with atomic numbers higher than 20 have been added to the concept more recently (Ali *et. al.,* 2019). Elements that are necessary and non-essential make up the bulk of heavy metals. Iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), cobalt (Co), nickel (Ni), molybdenum (Mo), and selenium (Se) are among the most important ones. The reason for their name is that they are necessary for basic metabolic processes in living things. For many different kinds of life, a large number of them act as co-factors that are crucial to the structural and functional integrity of enzymes and the biochemical activities that they catalyze. However, organisms experience harmful physiological effects when these essential metals are present more than a particular threshold (Tchounwou, *et. al.,* 2012).

Many of the non-essential heavy metals are hazardous at low concentrations and have no known beneficial effects on living systems. The following heavy metals are considered non-essential: lead (Pb), cadmium (Cd), mercury (Hg), arsenic (As), tin (Sn), aluminum (Al), silver (Ag), gold (Au), antimony (Sb), bismuth (Bi), vanadium (V), tellurium (Te), titanium (Ti), Uranium (U), and chromium (Cr), especially the hexavalent form (Cr VI) (Tchounwou, *et. al.,* 2012).

In nature, soil and plants, plants and animals, and animals and soil all participate in the irreversible mineral-nutrient cycle (Adelekan and Abegunde 2011).

These minerals' homeostasis is preserved by strictly controlled processes of absorption, storage, and secretion. Animal health and production may be impacted by the breakdown of mineral homeostasis, which can result in a mineral deficit or toxicity (López-Alonso, 2012, Mehri 2020). One of the biggest issues facing the world today is heavy metal contamination, which puts people, animals, and the ecosystem at risk (Tchounwou, *et. al.,* 2012). Similar to this, one of the biggest issues that have drawn attention is the presence of specific heavy metals in various water sources from plain areas due to their toxicological significance in ecosystems and influence on human health (Abalaka *et. al.,* 2020, Eldaw *et. al.,* 2020). Due to both natural and man-made factors, the amounts of heavy metals in soils, water, river sediments, and plants vary, even in the Arctic region (De Oliveira Ribeiro *et. al.,* 2002, Tang *et al.,* 2014). However, industrialization is frequently blamed for water contamination in the majority of developing nations, including India, as a result of improper waste management and the leaching of certain heavy metals from the parent materials, which are poisonous to human and animal populations (Giri *et, al.,* 2020). Additionally, irrigating crops and forage plants in contaminated areas with this water may allow the crops to absorb harmful metals from the soil and irrigation water, which could then deposit in the crop yield and pose a risk to human and animal health (Singh and Kalamdhad, 2011).

As a result, blood samples from animals that ate forages produced on contaminated soil that were irrigated with tainted water were shown to contain high levels of heavy metals (Chang *et, al.,* 1996, Centeno *et, al.,* 2006). Higher concentrations of heavy metals are hazardous to the body and cause a variety of cellular and tissue damage as a result of oxidative stress, the production of free radicals, and the suppression of immunity (Tchounwou *et, al.,* 2012, Chang *et al.,* 1996, Ali, Khan and Ilahi, 2019). Recently, neurological illnesses, colon cancer, and gallbladder cancer have all been linked to Pb, Cd, as, and other elements (Tchounwou *et, al.,* 2012, Singh, and Kalamdhad, 2011, Chang *et al.,* 1996).

Therefore, biomagnifications in the food chain may also be present in settings such as soil, plants, and food that is produced from animals and plants exposed to high levels of heavy metal exposure. Thus, to prevent diseases brought on by heavy metals, it is necessary to monitor all environmental sources, including water (Tchounwou *et, al.,* 2012, Ali, Khan and Ilahi, 2019, Srivastava *et, al.,* 2017).

According to earlier research, the Romi River's high concentration of heavy metals raises the risk of cancer, neurological conditions, and organ damage in local residents, all of which could lower production and raise the death toll. Before being released into a river, effluent must be suitably treated, tested, and certified by law, which must be strictly enforced (Usman *et, al.,* 2020).

The Study Area

The Kanawa Irrigation Site is situated between latitude 10⁰16'31.9" N and longitude 11⁰20'21.3"E. Its total size is 1,981 km² (765 m²), with

an approximate land mass of 105 km² and an average temperature of 31 ⁰C. The research area is located 19 km from Gombe and has a tropical savanna environment. The area has two distinct seasons: the rainy season, which lasts from April to October and has an average rainfall of 850 mm, and the dry season, which runs from November to March.
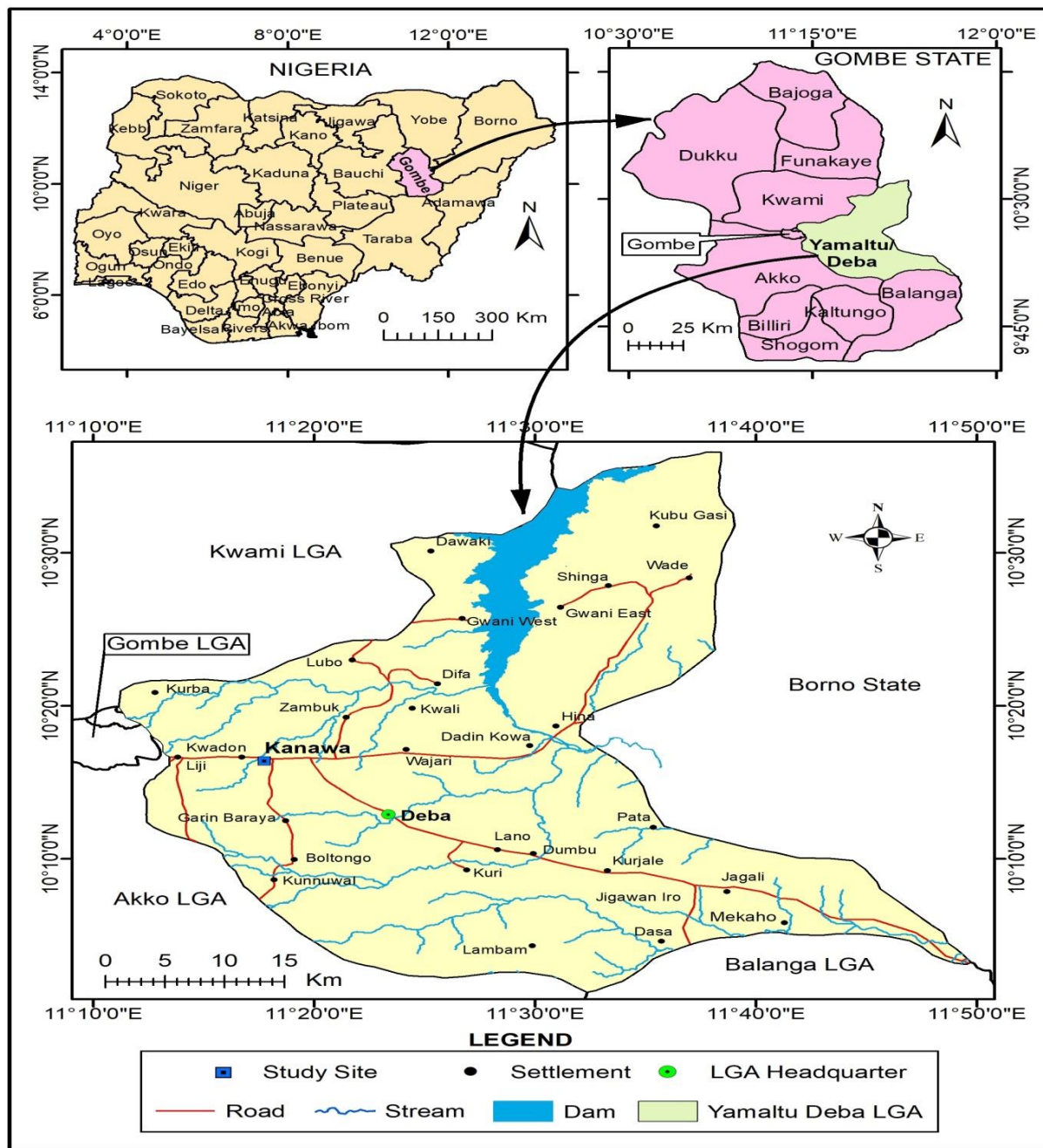

Fig 1.　A map of the Kanawa Irrigation Site

Study Aim:

This study investigated whether physiochemical characteristics and heavy metal levels in soil and water samples at the Kanawa irrigation site could affect farmlands or the safety of the water for human use.

Materials and Methods:

Materials

The following tools are used for soil sampling: an auger; bags, containers, and gloves for collecting soil; bottles and containers for sampling water; a pH meter and probes.

Lab Equipment: Equilibrium balances, electrodes, conductivity meters, pH meters, spectrophotometers or atomic absorption spectrometers (for heavy metal analysis), and analytical balances

Reagents and Chemicals: Acid solutions and standard solutions are used as reagents for heavy metal analysis. The physiochemical analysis reagents include conductivity standards and pH buffers.

Methods
The Atomic Absorption Spectroscopy (AAS) method is the analytical technique used to determine the presence of heavy metals in soil and water samples because of its affordability, accessibility, specificity, and wide range of applications. It also has a low detection limit. The heavy metal content of soil and water samples was measured with a Perkin Elmer 400ASS atomic absorption spectrophotometer (AAS).

Sample Collection and Preparation (soil and water samples)
Soil Samples
Random soil samples were taken from farms in each of the four study areas. A hand trowel made of clear plastic was used to remove the surface soil. Large stones, earth fragments, or plant components were extracted from composite samples of this kind of randomly selected soil from each site. After that, the samples were sun-dried and sieved through a 2-mm mesh to extract lump-free, extremely fine grains. After being dried, the tiny soil particles were put into plastic containers, given labels, and transported to the lab for examination.

Water Samples
Five water samples in all were taken in the region. The lake water samples were carefully taken from the Kanawa irrigation site, which is located in Juggol Funa Kanawa, from various farms in the vicinity, keeping a gap of 250 meters between each sample in the area. For the analysis, samples were taken using a 1 dm³ pet bottle from these key areas. Prior to use, 1 dm³ liter flasks were cleaned with water, diluted with HN0₃, and repeatedly rinsed with distilled water. The sample polythene bags were appropriately labeled at each sampling location and thoroughly cleaned twice with water prior to being collected. each sample that was taken were labels, including the location, date of collection, and serial numbers.

Sample analysis (digestion)
The first step in determining the amount of metal in water is to extract the metal in a concentrated form and isolate it from as many sources of interference as possible. This is typically done by employing a process known as digestion. Five centiliters of concentrated HNO^3 were added to 100 cm³ of each of the typical

water samples that had been put into beakers. The contents-filled beaker was set on a heated plate. After being gradually brought to a boil, the samples evaporated to a minimum volume of 20 cm³ on the hot plate. After letting the beakers cool, 5 cm³ more of concentrated HNO^3 was added. After being covered with a watch glass, the beakers were put back on the hot plate. The solution was heated further and HNO^3 was added as needed until it clarified and took on a light tint, indicating that the digesting process was finished. To get rid of any insoluble contaminants that can clog the atomizer, the watch glass and beaker walls were cleaned with distilled water and then filtered. After being transported to 100 cm³ volumetric flasks, the filtrates were diluted with distilled water to the appropriate level. The analysis (i.e., determining the concentration of each metal) was then conducted using these solutions. Akan *et al.*, 2007

Statistical Analysis
The SPSS statistical software (version 16; SPSS, Chicago, IL) was used to conduct the statistical analyses. The one-way analysis of variance (ANOVA) was employed to confirm that there were notable variations in the quantities of trace elements in the water samples. Micrograms per liter were used to express the concentrations of trace elements.

Determination of the Physicochemical Properties of water
PH: A pH meter was used to determine the pH value, in accordance with Jackson M. L. 2005. For this, a 1:2 ratio of 5 g of sieved soil sample and 10 ml of distilled water was used. After an hour of intermittent stirring with a glass rod, the suspension was allowed to settle. The pH was measured after the combination electrode was added to the supernatant.

Electric Conductivity (µs/cm): A digital electrical conductivity meter was used to measure the EC, and for that purpose, 5 g of a sieved sample were weighed, combined with 20 ml of distilled water (1:4), and constantly swirled for 30 minutes using a glass rod. After allowing it to calm down, the conductivity probe was added to the mixture in order to obtain a reading.

Total Dissolve Solid (TDS): TDS measures the concentration of dissolved ions in a solution. It's calculated by measuring the conductivity of the solution and then converting it to TDS using a conversion factor. Reference: Standard Methods for the Examination of Water and Waste Water.

Salinity: Salinity is the concentration of salt in water. It can be estimated using methods like titration, gravimetric analysis, or refractometry Kester D.R. et al., 1967

Turbidity (NTU - Nephelometric Turbidity Units): are a measure of a fluid's cloudiness or haziness brought on by a high

particle count. A turbidimeter, which scatters light by shining light through the sample, is used to measure it. Standard Operating Procedures for Water and Wastewater Analysis.

Total Suspended Solids (T.S.S): (T.S.S.) refers to the mass of suspended solids in a sample of water. A known volume of water is filtered through filter paper, dried, and then weighed to estimate the amount. Standard Operating Procedures for Water and Waste Water Analysis.

Total Hardness (mg/l CaCo₃): This indicator shows how much calcium and magnesium ions are present in water. It is ascertained by titrating a standardized chelating agent solution, such as EDTA. Standard Operating Procedures for Water and Waste Water Analysis.

2.8 Determination of the Concentrations of Major Anions (mg/l)

Phosphate Determination using the Ammonium Molybdate Method: This technique uses the interaction of phosphate ions with ammonium molybdate to produce a yellow complex that is spectrophotometrically detected at a certain wavelength. In an acidic environment, phosphate and ammonium molybdate combine to generate a heteropolyacid complex. The distinctive yellow hue of this compound can be measured with a UV-visible spectrophotometer. Riley, J. P., and Murphy, J. 1962.

Sulfate Determination using Turbidimetry with Barium Chloride: creates insoluble barium sulfate when combined with sulfate ions, subsidizing the solution. A turbidity meter is used to measure the turbidity. Light is scattered and turbidity is produced when barium sulfate precipitate is created when barium chloride and sulfate combine. A turbidity meter is used to measure turbidity, which has an inverse relationship with the sulfate content. Alpha et al., American Public Health Association 2017.

Chloride Determination using Mohr's Method: Using a chromate indicator, a chloride solution is titrated with a silver nitrate solution in this titrimetric technique. The terminus is indicated by a reddish-brown precipitate of silver chromate. A white precipitate of silver chloride is created when silver ions from silver nitrate combine with chloride ions. The solution turns from colorless to reddish-brown at the endpoint when a chromate indicator is added Vogel, A. I., 2012.

Determining Chloride Using Mohr's Method

Nitrate Determination using the Cadmium Reduction Method: This technique uses cadmium metal to reduce nitrate ions to nitrite, and then uses Griess reagent to quantify the nitrite ions colorimetrically. In an acidic media, nitrate is reduced to nitrite by

cadmium. Griess reagent and nitrite ions combine to generate a reddish-purple azo dye, which can be measured using spectrophotometry. Alpha. *et. al.,* 2017.

Assessment of Heavy Metals in Soil

A 5 g sample of soil was weighed into a clean porcelain crucible and cooked over a hot plate for the heavy-metal analysis. After that, the residue was heated to 5500 °C in a muffle furnace until the organic matter's carbon content was carefully and entirely oxidized (this took about an hour). The remaining residue was diluted with distilled water after being dissolved in a few drops of aqua-regia (3 parts concentrated HCl + 1 part concentrated HNO_3). A standard volumetric flask was filled with the filtrate after the solution was filtered and thoroughly washed. Following digestion, the solution was sucked into the Perkin Elmer Analyst 200 atomic absorption spectrophotometer (AAS) using an air acetylene flame to analyze the metal content against reference metallic remedies. Utilizing a certain hollow cathode lamp at a particular wavelength, each metal was identified. It was established what the total metal concentrations of heavy metals like Cu, Cd, Cr, Pb, As, and Fe were determined.

Assessment of Heavy Metal Content in Water

An atomic absorption spectrophotometer was used to quantify the amount of heavy metals present in water samples. This approach identified the elements cobalt, zinc, lead, copper, and cadmium. After gathering and processing 100 cm³ of water, 5 cm³ of recently made HNO_3, 15 cm³ of concentrated H_2SO_4, and 0.3 cm³ of $HClO_4$ were added to the flask. For two hours, the mixture was cooked on a hot plate while being stirred. The mixture was heated while it was broken down in a fume cupboard. Yusuf et al., 2015. Diluted the filtrate with distilled water to the appropriate amount. Three concentrations of a standard solution of the specific metal to be examined were chosen, and the digested sample solution was added to a 100 cm³ volumetric flask. The blank solution was aspirated and set to zero. The prepared sample solution was obtained using a hollow cathode lamp for each element at the appropriate wavelength and slit width of 0.5 nm after each standard solution was sucked into a flame AOAC 2005.

Results:

The results of the environmental assessment for heavy metal concentrations and physicochemical properties in soil and water samples from the Kanawa Irrigation Site in Yamaltu Deba L.G.A., Gombe State, Nigeria, are presented as follows:

Table 1: Physical Parameters of Water Samples

Samples	Physical Properties	

	pH	E.C (µS/cm)	TDS (mg/L)	Salinity (%)	Turbidity (NTU)	T.S.S (mg/L)	T. hardness (Mg/L CaCO$_3$eqv.)
Sample A	6.73[c]	356.00[b]	178.00[c]	0.80[d]	15.65[g]	129.00[j]	114.00[k]
Sample B	6.44[d]	284.00[b]	142.33[c]	0.60[d]	8.13[f]	105.00[j]	95.00[k]
Sample C	6.26[d]	520.33[b]	258.33[c]	1.20[d]	18.45[g]	154.00[j]	239.00[k]
Sample D	6.33[c]	421.33[b]	208.33[c]	0.90[d]	12.42[f]	225.00[j]	153.00[k]
Sample E	6.54[b]	737.33[a]	364.67[c]	1.60[d]	19.34[g]	282.00[j]	321.00[l]
FAO/WHO [27/28]	6.5-8.5[a]	100-500[b]	250-500[c]	2.5[d]	1-5[e]	500[j]	300[k]

Every value is shown as the average of three measurements; values that have the same letter in the same row differ considerably (p<0.05) from the FAO 1985/WHO 2011 allowable limits.

Discussion:

PH: The samples' pH values fall just short of the lower end of the 6.5–8.5 FAO 1985/WHO 2011 allowable limit range. For samples A through E, every recorded value is between 6.26 and 6.73. Even though these pH values lean somewhat acidic, they are still within a reasonable range for the majority of environmental and agricultural uses. It's crucial to remember that pH levels can affect the availability of nutrients, microbial activity, and the general health of the soil. Although the pH numbers you gave do not greatly differ from the acceptable range, it may be wise to think about any particular plants or crops you plan to produce and how pH might impact their development. Should you observe any patterns of falling pH over time, you may want to look into possible causes and think about suitable soil management techniques.

Electric Conductivity: According to the results, Samples A, B, and D are within the FAO/WHO-recommended range of 100–500 µS/cm for allowable EC values FAO 1985/WHO 2011. Samples C and E, however, fall outside of this range, indicating a greater dissolved solids concentration. This might have an impact on the water's quality for specific purposes. It might need more investigation to ascertain the precise ramifications for every sample.

Total Dissolved Solids (TDS): Samples A and B's TDS values show comparatively low quantities of dissolved solids, falling below the FAO 1985/WHO 2011 acceptable range of 250–500 ppm. This range is likewise occupied by samples D and E. Sample C, on the other hand, surpasses the upper limit, indicating a greater concentration of dissolved solids. This might have an impact on the

water's suitability for different uses, and more research might be needed to identify any possible effects.

Salinity: All of the samples' salinity readings (A, B, C, D, and E) are significantly lower than the 2.5% FAO 1985/WHO 2011 acceptable limit. This suggests that the samples are suitable for a variety of uses without raising issues with excessive salinity content due to their comparatively low salinity levels.

Turbidity (NTU): All of the samples' turbidity findings (A, B, C, D, and E) are higher than the FAO 1985/WHO 2011 allowable limits of 1–5 NTU. Elevated turbidity levels may suggest the existence of silt or suspended particles in the water, thereby influencing its transparency. If the water is going to be used for drinking or other sensitive purposes, it is best to look into the causes of turbidity and possibly take action to improve the quality of the water.

Total Suspended Solid (TSS): The TSS values for samples A, B, C, D, and E are all significantly lower than the 500 mg/l FAO/WHO [27/28] acceptable limit. This indicates that the samples' suspended solids contents are comparatively low, which is good news for the water's quality. TSS concentrations should ideally be lower because larger values may be a sign of sedimentation or contamination. The findings show that the samples' TSS content satisfies the required thresholds.

Hardness total (mg/l caco$_3$eqv): The total hardness levels of Samples A, B, and D are below the FAO 1985/WHO 2011 permitted limit of 300 mg/l CaCO$_3$ equivalent, according to the results. Samples C and E, on the other hand, surpass this threshold, indicating greater concentrations of minerals like calcium and magnesium. Water naturally has a certain amount of hardness, but too much hardness can cause problems for a variety of applications, including increased scaling in pipes and appliances. Higher-hardness water sources may need to be monitored and/or treated to guarantee the best possible water quality for a given application.

Table 2: Major Anions (Chemical Properties) of Water Samples

Samples	Concentration of Major Anions (mg/L)			
	Phosphate	Sulphate	Nitrate	Chloride
Sample A	17.99a	54.04c	28.49e	126.30i
Sample B	12.00a	34.13c	24.19e	107.86i
Sample C	27.46a	47.15c	62.62e	183.43i
Sample D	23.38c	18.52c	33.94e	0.90i
Sample E	47.03a	53.23c	82.21e	331.26h
FAO/WHO	0.1-1.0a	200-400b	45-100e	250-1000i

Every value is shown as the average of three measurements; values that have the same letter in the same row differ considerably (p<0.05) from the FAO 1985/WHO 2011 allowable limits.

Phosphate: All of the samples' phosphate results—A, B, C, D, and E—significantly surpass the 0.1–1.0 mg/l FAO/WHO [27/28] acceptable limits. Water with high phosphate concentrations can become eutrophic, which can cause aquatic plants to flourish out of control and possibly disturb the ecology. The causes of phosphate pollution must be addressed since they are frequently connected to wastewater discharge and agricultural runoff. To protect the ecosystem and the quality of the water, mitigation steps must be taken to bring these levels within the advised range.

Sulfate: All samples (A, B, C, D, and E) had sulfate readings that were significantly lower than the 200–400 mg/l FAO 1985/WHO 2011 permitted limits. This suggests that the samples' sulfate content is comparatively low, which is good news for the water's quality. In certain cases, elevated sulfate levels can give water a bitter taste, and in very high quantities, they may even have laxative properties. There shouldn't be any major issues with the sulfate level of these samples because the values are within the allowable limit.

Nitrate: Samples A, B, and D's nitrate readings are within the 45–100 mg/l FAO 1985/WHO 2011 permitted range. Samples C and E, on the other hand, show higher nitrate amounts as they fall outside of this range. Drinking water with high nitrate levels can be dangerous, especially for young children who may develop methemoglobinemia or blue baby syndrome. To guarantee safe consumption, it is imperative to identify the sources of nitrate pollution, which are frequently associated with agricultural runoff or wastewater, and implement mitigation measures to lower nitrate levels in water sources.

Chloride: Samples A, B, and D's chloride readings are far below the 250–1000 mg/l FAO 1985/WHO 2011 acceptable limits. Samples C and E, however, have larger quantities of chloride since they are above the maximum limit. When used for irrigation, water with high amounts of chloride can occasionally taste salty or brackish and can also affect the health of the soil and plants. It's critical to look into the causes of the contamination, which may include industrial discharges, natural processes, and road salt runoff. If necessary, regulate and lower the amounts of chloride.

Table 3: Heavy Metal Analysis of Water Samples

Samples	Concentration of Elements (mg/L)						
	Pb	Cr	Ni	Cd	Cu	Fe	As
Sample A	0.0115d	0.0013j	0.0325j	0.0000a	0.0652x	0.3169w	0.0064z
Sample B	0.0065d	0.0135j	0.0216j	0.0000a	0.0485x	0.1505w	0.0000z
Sample C	0.0251d	0.0729j	0.1467j	0.0073e	0.0553x	0.3346w	0.0149z
Sample D	0.0205d	0.0435j	0.0785j	0.0000d	0.0323x	0.2625w	0.0105z
Sample E	0.0524b	0.0853j	0.2166j	0.0125d	0.0656x	0.5928w	0.0175z
FAO/WHO	0.05d	0.05f	0.1j	0.005m	1.5z	0.3w	0.05z

Every value is shown as the average of three measurements; values that have the same letter in the same row differ considerably (p<0.05) from the FAO 1985/WHO 2011 allowable limits.

Lead (Pb): According to the results, the levels of lead (Pb) in the water samples are significantly lower than the 0.05 mg/L FAO 1985/WHO 2011 permitted limit. According to FAO 1985/WHO 2011 guidelines, all of the reported values for samples A through E are well below the limit, indicating that the lead contamination in these samples is within safe limits. In terms of human health and water quality, this is a favorable result.

Chromium (Cr): All of the water samples, except Sample E, have chromium (Cr) concentrations below the FAO 1985/WHO 2011 allowable limit of 0.05 mg/L. Sample E is marginally over the limit, containing 0.0853 mg/L of chromium. The amounts in the other samples, A through D, are far lower than the allowable level. To make sure that the chromium levels in Sample E stay within safe

ranges, it's critical to keep an eye on the levels and take into account any possible sources of contamination.

Nickel (Ni): All of the water sample concentrations of Ni are under the FAO 1985/WHO 2011 acceptable limit of 0.1 mg/L. For samples A through E, every recorded value is much below the upper bound. In terms of water quality and possible health effects, this shows that the nickel contamination in these samples is below safe limits per FAO/WHO [27/28] FAO 1985/WHO 2011 guidelines.

Cadmium (Cd): The majority of the water samples have cadmium (Cd) concentrations that are under the 0.005 mg/L FAO 1985/WHO 2011 acceptable limit. Samples C and E, on the other hand, marginally surpass this limit at 0.0073 mg/L and 0.0125 mg/L, respectively. Even though the exceedance is small, it's crucial to continue tracking these samples and looking into possible cadmium contamination sources. Most of the samples are under allowable limits overall, however, Samples C and E need to have their cadmium levels closely monitored.

Copper (Cu): The FAO 1985/WHO 2011 permitted limit of 1.5 mg/L is significantly exceeded by the amounts of copper (Cu) in the water samples. According to FAO 1985/WHO 2011 guidelines, the copper contamination in samples A through E is within safe limits because all of the observed values are much below the limit. This shows that the amount of copper in the water and its possible effects on human health are both good.

Iron (Fe): The majority of the water samples have iron (Fe) levels that marginally surpass the 0.3 mg/L FAO 1985/WHO 2011

acceptable limit. The iron concentrations in Samples A, C, and D are 0.2625 mg/L, 0.3346 mg/L, and 0.3169 mg/L, respectively, which are marginally above the limit. It's critical to address these high iron levels since extended exposure to high iron in drinking water can have negative health effects as well as change the taste and appearance of the water. Sample B is within the allowable limit with an iron content of 0.1505 mg/L. Your data appears to repeat itself for Sample E. To make sure that iron levels are within acceptable ranges, monitoring, and potential therapy are advised.

Arsenic (As): Because arsenic is a poison, samples A, C, D, and E are below the FAO/WHO [27/28] acceptable limit, which is typically set at a very low level. This implies that the amounts of arsenic contamination in these samples are safe under FAO 1985/WHO 2011 guidelines. All of the recorded results for samples A, B, C, D, and E are within the FAO 1985/WHO 2011 permitted limit for arsenic, except Sample B, which has an arsenic (As) level of 0.0000 mg/L. According to FAO 1985/WHO 2011 guidelines, this shows that the amount of arsenic contamination in these samples is well under permissible limits, which is good news for human health and water quality.

Table 4: Heavy Metal Analysis of Soil Samples

Samples	Concentration of Elements (mg/Kg)						
	Cu	Cd	Cr	Ni	Pb	As	Fe
Sample 1A	0.4753^c	0.0645^n	0.1528^u	2.2098^i	0.0764^o	0.0184^k	2.6529^e
Sample 1B	0.2964^m	0.0532^n	0.2155^l	1.4669^p	0.1136^o	0.0128^h	3.2199^o
Sample 1C	0.1932^v	0.0828^n	0.2745^k	1.1523^e	0.055^o	0.0253^l	2.6264^i
Sample 1D	0.7348^d	0.0314^n	0.1871^a	3.3482^t	0.9526^o	0.0635^p	4.4569^a
Sample 1E	0.3034^t	0.0113^n	0.2428^d	1.9647^k	0.0739^o	0.0419^l	3.5286^j
Sample 2A	0.5152^f	0.0849^n	0.1741^c	2.8236^j	0.0834^o	0.065^y	3.8136^y
Sample 2B	0.6837^s	0.0732^n	0.2352^s	5.6323^h	0.0421^o	0.0829^w	5.491^t
Sample 2C	0.2753^r	0.0419^n	0.3856^p	3.4316^g	0.0257^o	0.0552^d	3.4426^p
Sample 2D	0.3181^e	0.073^n	0.2143^z	3.2198^f	0.0731^o	0.0672^c	2.0869^h
Sample 2E	0.8564^q	0.0523^n	0.3562^y	4.7362^l	0.0782^o	0.0918^b	4.6205^m
FAO/WHO	73.3^k	0.2^n	100^x	67.9^r	0.3^o	0-32^z	425.5^n

Every value is shown as the average of three measurements; values that have the same letter in the same row differ considerably (p<0.05) from the FAO 1985/WHO 2011 allowable limits.

Copper (Cu): The FAO 1985/WHO 2011 permitted limit of 73.3 mg/kg is much exceeded by the quantities of copper (Cu) in the soil

samples. For both Sample Set 1 and Sample Set 2, every recorded value is far below the limit. This suggests that by FAO 1985/WHO 2011 guidelines, the copper content in these soil samples is well below safe limits. Regarding the quality of the soil and its possible effects on the environment, this is a positive discovery.

Cadmium (Cd): The FAO 1985/WHO 2011 acceptable limit of 0.2 mg/kg is significantly exceeded by the amounts of Cd in the soil samples. For both Sample Set 1 and Sample Set 2, every recorded value is far below the limit. This indicates that by FAO 1985/WHO 2011 guidelines, the cadmium content in these soil samples is well within safe limits. Regarding soil quality and any effects on the environment and agriculture, this is good news.

Chromium (Cr): The FAO 1985/WHO 2011 permitted limit of 100 mg/kg is significantly exceeded by the chromium (Cr) values in the soil samples. For both Sample Set 1 and Sample Set 2, every recorded value is well below the limit. Based on FAO 1985/WHO 2011 criteria, this indicates that the chromium content in these soil samples is well below permissible limits. Since the levels are considerably below the allowable limit, this is good for the quality of the soil as well as any potential effects on the environment and agriculture.

Nickel (Ni): With a few notable exceptions, the amounts of nickel (Ni) in the soil samples are often lower than the 67.9 mg/kg FAO 1985/WHO 2011 permitted limit. With nickel values of 5.6323 mg/kg and 4.7362 mg/kg, respectively, Samples 2B and 2E surpass the limit. The amounts of nickel in the other samples in Sample Sets 1 and 2 are within safe limits based on FAO 1985/WHO 2011 guidelines. It's critical to look into the causes of the higher-than-average levels in Samples 2B and 2E and to think about ways to control nickel exposure in those particular locations.

Lead (Pb): For every sample in Sample Sets 1 and 2, the levels of lead (Pb) in the soil samples are less than the FAO 1985/WHO 2011 permitted limit of 0.3 mg/kg. This indicates that by FAO 1985/WHO 2011 guidelines, the lead content in these soil samples is well within safe limits. With lead levels much below the allowable limit, this is a good result for soil quality and possible effects on agriculture and the environment.

Arsenic (As): The amounts of arsenic (As) in the soil samples are within the 0-32 mg/kg FAO 1985/WHO 2011 permitted limit range. This range includes all of the recorded values for Sample Sets 1 and 2. This suggests that by FAO 1985/WHO 2011 guidelines, the amount of arsenic in these soil samples is well below acceptable bounds. In terms of soil quality and any effects on agriculture and the environment, this is comforting because the arsenic levels are far within the defined range of allowable limits.

Iron (Fe): The amounts of iron (Fe) in the soil samples are far lower than the 425.5 mg/kg FAO 1985/WHO 2011 permitted limit. For both Sample Set 1 and Sample Set 2, every recorded value is far below the limit. According to FAO 1985/WHO 2011 criteria, this shows that the iron content in these soil samples is well within safe limits. Since the amounts of iron are considerably below the allowable limit, this is good news for the quality of the soil as well as any potential effects on the environment and agriculture.

Conclusion:

Analyses of the physiochemical properties and heavy metal concentrations in soil and water samples around the Kanawa irrigation site yield positive results. The physical properties of the water samples indicate that they are fit for human and agricultural use, highlighting their potential to support sustainable activities. There were a few minor problems with the amounts of nitrate, phosphate, and chloride, but overall chemical characteristics, including major anions, were judged to be acceptable. However, the overall evaluation of the water and soil samples in the research region yields positive findings, suggesting that these resources are safe for use in agriculture and human consumption. Concentrations in all soil and water tests were within the FAO/WHO permitted limit, meaning that ingestion is safe.

Acknowledgment

Competing Interests

The author declares that there are no conflicts of interest related to this study.

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