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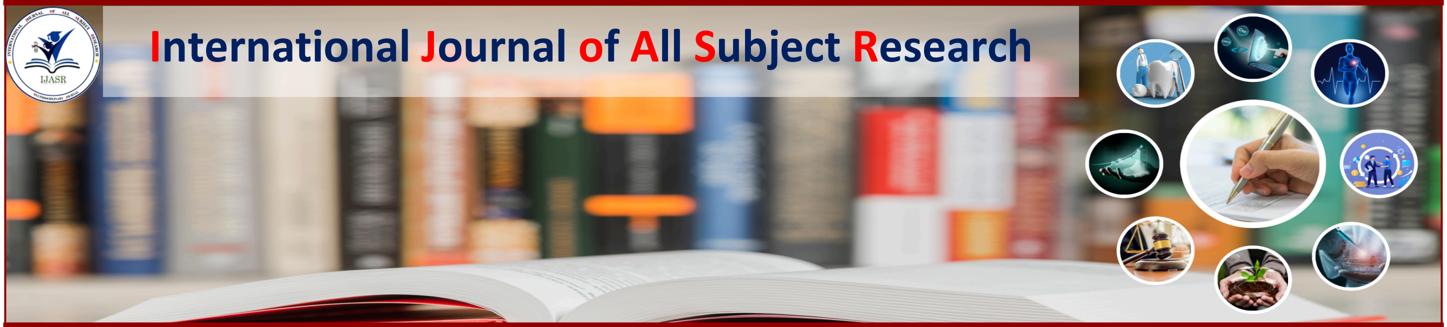

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Ilorin, North Central, Nigeria: The Physicochemical Status, Heavy Metal Content, and Possible Ecological Risk of Irrigated Peri-Urban Gardens

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Abstract

Using common analytical techniques, the physicochemical characteristics and a few chosen heavy metals of thirteen peri-urban garden soils in Ilorin, Kwara State, were examined, as well as the irrigation water. Analysis of the gardens' irrigation water and soils was done to look into any possible ecological risks. The findings demonstrated that, with the exception of turbidity (88.67 mg/l), which was greater than the advised standard limit, the examined physicochemical parameters for agricultural soils and water were within the WHO standard limits. Both seasons' worth of irrigation water samples contained lead and/or cadmium contamination, and the soils indicated possible high cadmium buildup. The eating of crops irrigated with water from these sources may provide a health risk, as suggested by this. Significant variations in the parameters across seasons and among sites were found, at $p<0.05$, according to analyses of the study's data. Overall, it was found that metals in soils across locations presented low to moderate potential ecological concerns. Significant variances and non-uniform distribution were observed in the physicochemical characteristics and heavy metal contents of the soils and irrigation water used in the gardens across different sites and seasons.

Keywords: Heavy metals, potential ecological risk, soils, irrigation water, peri-urban gardens, and physical variables

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Introduction

The possible risk to human life as well as the ecosystems has made the effects of human activity in peri-urban areas quite concerning. There have been reports that certain agricultural practices, urbanization, industrialization, and deforestation have increased the levels of hazardous chemicals in the environment, which has a major negative impact on the ecosystem, flora, and fauna as well as food webs (Afyuni, 2001; Afshariet al., 2016).

The physicochemical variability of soil and water has been significantly impacted by heavy metal contamination in peri-urban areas, which has been extensively reported to be caused by urbanization and other anthropogenic activities. According to a report, heavy metals' interactions with soil and water can alter their physicochemical characteristics, which can have detrimental impacts on humans, animals, and plants through the food chain (Moradiet al., 2016). The physical and chemical characteristics of irrigation water are related to its quality, according to Michael (1999). The researcher believed that if the readings are outside of the ranges that are acceptable for agricultural irrigation, it could have an impact on plant growth.

According to reports, water and soil serve as important natural storage spaces and reservoirs for pollutants (Hoodaji et al., 2012). These contaminants pose serious health concerns through the food chain and significantly disrupt the agro-ecology, soil biological system, and ecosystem (Moradi et al., 2016). According to Qing et al. (2015), exposure of soils and water to potentially toxic heavy metals may have negative impacts on human health through the food chain. Furthermore, certain ecosystems may be seriously contaminated by operations including waste disposal, mining, burning coal, urbanization, industrial operations, and others (Liu et al., 2013).

Sampling and Analysis of Soils

Using a stainless steel shovel, three to five subsoils were removed from the topsoil (0–15 cm) at each sampling location. Each site yielded one (1) kilogram of topsoil. To create a composite sample, these subsamples were thoroughly combined. After being carefully labeled, each sample was put into a zipped-lock plastic bag and brought into the lab. To exclude unwanted elements or particles, the soil samples were sieved through a 2 mm nylon mesh and oven-dried at 80°C for 72 hours in the lab. After being put through 63 µm sieves, the dried soils were refrigerated pending additional tests.

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Table 1: GPS Coordinates of Sampling Sites in Ilorin, Kwara State, Nigeria

	Garden/ Sampling site	Irrigation water source (Stream)	LGA	Activities in/around the sampling sites	Latitude (N)	Longitude (E)
1	Otte vegetation	Renge/ Otte Alalubosa stream	Asa	Near the road, vehicular emission.	8^{0}18’50. 0”	4^0 22’ 59”
2	Budo-Egba	Asa stream	Asa	Near the road, vehicular emission	8^0 19’ 0”	4^{0}24’ 00”
3	Budo- Abio	Budo-Abio stream	Asa	Less anthropogenic, far from the road	8^0 30’10”	4^{0}53’ 00”
4	Mubo	Asa Dam Mubo Stream	Ilorin East	Near a major dumpsite	8^{0}30’ 16.2”	4^{0}34’ 20”
5	Oyun	Oyun Stream, Oyun	Ilorin East	Near the road, vehicular emission	8^0 30’ 0”	4^{0}32’ 60”
6	Oja-gboro	Asa Dam, Ojo-gboro Stream	Ilorin East	Near a major dumpsite	6^{0}27’29.8”	3^0 23’09”
7	Ola-olu	Agba Stream, Ola-olu	Ilorin South	Near the road, vehicular emission, near mechanic workshops	8^{0}29i 47.90”	4^{0}32’31.70”
8	Eroomo	Yaalu Stream, Offa Garraga	Ilorin South	Far from the road, less anthropogenic activities	8^0 26’25.5”	4^0 35’29”
9	Oke – Odo	Ogan Stream, Off Unilroin Road	Ilorin South	Near the road, vehicular emission	8^0 28’49.0”	4^0 37’41”
10	Coca-Cola veget ation	Asa Stream, Coca-cola Road	Ilorin East	Near the road, vehicular emission, around industries, mechanic workshops	8^0 26’59.6”	4^{0}31’ 58”
11	Isale Aluko	Isale Aluko Stream, Isale Aluko	Ilorin West	Near a major dumpsite	8^{0}29’ 34.9”	4^0 54’05”
12	Odo-ore	Asa Stream, Odo-ore Egbejila	Ilorin West	Far from anthropogenic activities	8^0 23’05”	5^0 05’37”
13	Botanical garden(Reference site)	Oyun- University Stream	Ilorin south	Less human activities	8^0 28’54.3”	4^0 38’13”

Physicochemical Analysis of Soil

In order to calculate the bulk density, the Cresswell and Hamilton (2002) approach was used; Brady and Weil (1999) method was used to determine the pH; and soil texture was determined both qualitatively by touching and quantitatively by using a hydrometer. With Jenway 4010 Conductivity, electrical conductivity was measured according to Brady and Weil's (1999) approach; The total nitrogen content was determined using the method of Bremner and Mulvaney (1982); exchangeable cations (Ca2+, Mg2+, Na+, and K+) were determined using the method of Thomas (1983); available phosphorus (AP) was spectrophotometrically analyzed using UV/V's Spectrophotometer model 721N with the method of Dickman and Bray (1999); soil moisture content was determined using the method of Brady and Weil (1999); the method of Shailesh et al., 1997 was adopted to determine the total acid value; organic matter was determined using the Ignition method by Reddy (2002); and all of these methods were used to determine the total nitrogen content.

Analysis of Heavy Metals in Soil and Water Samples

Utilizing a wet digestion method of 3:1 and applying 65% nitric acid and 37% hydrochloric acid for extraction, heavy metal analysis was performed (Burt et al., 2003).Using a PerkinElmer Analyst 200 Atomic Absorption Spectrophotometer, the amounts of three specific heavy metals—copper, cadmium, and lead (Cd, Cu, and Pb)—in the soil and water samples were examined.

Physicochemical Analysis of Water

The pH of the water was measured on-site using a pH meter that had been previously calibrated using the Yidana et al. (2011) method; the electrical conductivity was evaluated using a calibrated EC 214 HANNA (Yidana et al. 2011); the chloride ion content was determined using the titrimetric method of Skoog (1996); the turbidity test was conducted using the Ulrich and Bragg (2003) method; the total acid values were determined using the Shailesh et al., 1997 method; and the total hardness (calcium ion plus magnesium ion) of the water samples was examined using the titrimetric method of Skoog et al. (2007)

Analytical Statistics

Using the Statistical Package for Social Sciences (SPSS) version 20.0, the obtained data were subjected to inferential statistics (Analysis of Variance) and descriptive statistics (mean, maximum, minimum, and standard deviation). To distinguish means based on substantial differences in the means at the 5% probability level, the Duncan Multiple Range Test was employed. Using the approach of Håkanson, 1980 (2.6), the concentrations of heavy metals in the soils were calculated to assess the possible ecological risk indices of the heavy metals in the research areas. Carl Pearson's Correlation Analysis in SPSS version 20.0 was used to determine the relationship between the samples' physicochemical characteristics and heavy metal content.

Model

The following was used to assess each metal's possible ecological risk index (RI) in the soil:

RI = £(Ti Ci)~~~

The natural hazards that the research location may face from heavy metal contamination in the soil are depicted above. Where Ti is the heavy metal toxicity response factor based on Hakanson's (1980) findings; Li et al. (2020) found that Cd = 30, Cu = 5, and Pb = 5. In this case, RI is the monomial potential ecological risk factor.For heavy metals, the background value is Bi, and the practical or current concentration is Ci in soil.

Results

In the dry and wet seasons, the physicochemical characteristics, heavy metal concentration of soils and water, and potential danger index of the chosen heavy metals in the study locations (twelve study sites) and the control site. the samples of soil collected during the dry season, including its physical, chemical, and heavy metal components. The findings indicate that the soil texture ranged from sandy loamy to loamy-sandy; the moisture content was found to be between 10.13±0.04% in Coca-cola soil (site 10) and 18.95±0.02% in Eroomo soil (site 8). With the exception of the soils from Okeodo, Coca-Cola, and Isale Aluko, all soils exhibited higher moisture contents than the Control site; the pH range for the soils was 6.62±0.04 for Budo Egba (site 2) to 7.18±0.03 for Mubo soil (site 4). The pH of the Control soil was lower than that of all the other soils, with the exception of the soils of Budo Egba and Odoore, and it was rated as slightly acidic to slightly alkaline.

Table 2: The physicochemical characteristics and concentrations of heavy metals in soil samples during the dry season

Paramater//Sites	**Budo Egba**	**Oyun**	**Otte**	**Okeodo**	**Mubo**	**Budo Abio**	**Olaolu**	**Eroomo**	**Ojagboro**	**Cocacola**	**Isale Aluko**	**Odoore**	**Botanical Garden**	**Permisible Limit**
ST	**LS**	**SL**	**LS**	**SL**	**LS**	**SL**	**LS**	**LS**	**SL**	**SL**	**SL**	**SL**	**LS**	**SL**
SM(%)	12.85±0.03f	17.73±0.03c	14.96±0.04e	10.45±0.03k	15.57±0.02d	11.74±0.02h	18.47±0.03b	18.95±0.02a	10.87±0.01i	10.13±0.04l	10.38±0.02g	10.58±0.02j	10.57±0.02j	21-80
pH	6.62±0.04h	7.05±0.04b	6.93±0.10c	6.85±0.01e	7.18±0.03a	6.88±0.01d	6.81±0.01f	6.69±0.01f	6.63±0.04hg	7.08±0.04b	6.94±0.01c	6.68±0.01f	6.67±0.01fg	6.5-8.0
BD(g/cm3)	2.12±0.01h	1.82±0.01k	2.21±0.01g	2.56±0.01c	2.10±0.01i	2.47±0.01d	1.96±0.01j	1.96±0.01j	2.59±0.01b	2.41±0.01e	2.31±0.01f	2.69±0.01a	2.69±0.02a	1.0-1.6
TAV (mg/l)	0.45±0.01bc	0.11±0.06i	0.35±0.01f	0.36±0.02ef	0.18±0.01h	0.31±0.01g	0.38±0.02ef	0.47±0.01b	0.53±0.01a	0.08± 0.03i	0.35±0.01ef	0.43±0.01cd	0.41±0.01ed	NF
OM (%)	3.07±0.02c	3.20±0 .02b	2.23±0.01i	2..97±0.04d	3.50±0.05a	2.47±0.05g	2.77±0.02e	2.46±0.03g	2.53±0.02f	2.05±0.02j	2.36±0.02h	2.09±0.01j	2.56±0.03f	2.0 -7.5
AP (mg/l)	4.25±0.04b	2.17±0.02g	0.96±0.01d	2.33±0.03f	2.46±0.01e	2.15±0.02g	3.81±0.02c	2.07±0.01h	2.17±0.01g	0.93±0.02i	2.19±0.01g	0.79±0.01j	3.72±0.02d	5.0-8.0
CEC(Cmolc/kg)	5.56±0.01e	5.43±0.02f	6.51±0.09bc	6.55±0.01b	5.93±0.04cd	5.04±0.03h	5.21±0.03g	4.05±0.01j	5.89±0.01d	5.84±0.06d	3.68±0.02k	8.63±0.03a	4.83±0.03i	10
N (%)	1.06±0.01a	0.95±0.01d	1.04±0.01b	0.81±0.01h	0.89±0.01f	0.96±0.01d	0.77±0.01i	0.92±0.01e	1.01±0.01d	0.91±0.01e	1.02±0.01c	0.86±0.02g	0.69±0.01j	4.6
EC mS/cm	194.83±0.50d	188.92±0.20g	189.75±0.50f	198.50±0.10b	172.65±0.05k	195.20±0.50c	172.50±0.10k	184.93±0.10i	192.27±0.54e	174.73±0.12j	199.10±0.10a	185.80±0.10h	171.85±0.51l	250
Cd	0.67±0.14 a	0.33±0.38 a	0.42±0.38 a	0.67±0.14 a	0.25±0.25 a	0.33±0.14 a	0.67±0.14 a	0.67±0.29 a	0.75±0.66 a	0.58±0.14 a	0.50±0.50 a	0.50±0.50b a	0.25±0.25 a	0.80
Cu (mg/kg)	2.00±0.90 a	2.58±0.14 a	2.42±0.80a	4.42±3.25 a	3.67±1.61 a	3.00±1.52 a	2.33±1.61 a	4.50±4.02 a	4.42±3.00 a	3.08±2.02 a	3.42±1.84 a	2.08±2.00 a	2.33±2.16 a	5.0-30
			3.58± 6.21 a	5.08±7.54 a	Pb(mg/kg)	3.92±5.15 a	3.42±3.64 a	5.08±4.69 a	5.17±4.47 a	2.25±0.43 a	85			

The soil bulk density varied as well, with the highest value being 2.69 ± 0.03 g/cm3 recorded for the Botanical garden (Control site 13) and the lowest value being 1.82 ± 0.01 kg/cm3. The acid values ranged from 0.18±0.03 mgKOH/g to 0.53± 0.01 mgKOH/g, highest value being Mubo soil (site 4) and lowest value being Ojagboro (site 6). With the exception of the soils at Budo Egba Oloaolu, Eroomo, and Odoore, all other sites had soils with higher acid values; the range of soil organic matter was 2.05 ± 0.02% for Coca-Cola soil (site 10) to 3.50 ± 0.05% for Mubo soil (site 4); with the exception of the soils at Budo Egba, Mubo, and Oyun, all other sites had higher organic matter than the Control soil; The cation exchangeable capacity (CEC) of the soils ranged from 3.68 ± 0.02 cmol/kg to 8.63 ± 0.03 cmol/kg, with the soils of all the sites having higher CEC than the soils of the Control site; the soil nitrate content nitrogen was between 0.69 ±0.01 mg/kg at the Control (site 13) and 1.06 ±0.01 mg/kg at Budo Egba (site 2), showing the lowest value recorded in the Control site; the soil available phosphorus of the soils ranged from 0.79±0.01 mg/kg to 4.25±0.04 mg/kg, showing the Control soil having higher available phosphorus than other soils, with the exception of the soils of Budo Egba and Olaolu. Between 171.85 ± 0.51 I mS/m and 199.10 ±0.10 mS/m, the soil electrical conductivity was measured; the soil at the Control site had the lowest value while the soil at the Isale Aluko site had the highest. The copper content of the soil during the dry season ranged from 2.00±0.90 to 4.50±4.02 mg/kg, with the Control site having lower concentration than all other soils except for the soils of Otte, Budo Egba, and Odoore; the lead (Pb) concentrations of the soils between sites ranged from 1.58 ±1.63 mg/kg to 11.67±15.12 mg/kg, with the Control site soil having the lowest Pb concentration than soils of other sites except for the soils of Odoore.

Discussion

The physical, chemical, and heavy metal contents of the soil samples collected during the two seasons revealed that the soils' textures ranged from sandy loamy to loamy-sandy, indicating that their parent soils are similar. This study's findings are comparable to those of Jones and Wild (1975), who claimed that loamy sand to sandy loam naturally occurs in most cultivated soils in the West African savannah region. The study's soils exhibit low to moderate moisture content across locations and seasons, with higher moisture content during the rainy season than during the dry, demonstrating seasonal variations in soil moisture content. According to Udo et al. (2007), the moisture content of the soils at the locations was below the acceptable range (21–80%) for agricultural soils in both seasons. This may be brought about by variations in the colloidal characteristics and soil quality aggregation of the soils. Both seasons' soil pH ranges (6.59–7.18) fell within the acceptable pH range for agricultural soil (6.5–8.0) (Njoyim et al., 2016), classifying the soils as slightly acidic to slightly alkaline, with the rainy season's soils being somewhat more acidic than the other season's. The reason for this could be that during the rainy season, there is a higher amount of organic matter decomposing in the soil, which produces more carbon dioxide and hydrogen ions (H+). The organic matter may have also reacted with soil water to make weak acids known as carbonic acid (Tematioet al., 2004). The pH range of 8.0 to 10.0 recorded in the Hayatu et al. (2020) report is lower than the pH of this investigation. Significant variations were observed in the bulk density of soils across locations and seasons. Specifically, the dry season soils were rated higher (1.82 ± 0.01 to 2.69 ± 0.03 g/cm3) than the rainy season soils (2.19±0.08g/cm3 to 2.47±0.16g/cm3). The packing arrangement of soil between sites and seasons and the higher density of soil minerals (sand, silt, and clay) may be to blame for this. The bulk density of the soils in this study exceeded Mofor et al. (2017)'s reported allowed value for agricultural soil (1.0 g cm-3–1.6 g cm-3). This suggested that the soils in this study had a greater clay mineralogy (Tabi and Ogunkunle, 2017). There was a noticeable variation in the peri-garden soils' acid values between sites and seasons, with the rainy season soils being rated as rather acidic. Variations in parent materials and soil organic matter degradation between sites and seasons may be related to this (Mzuku et al., 2005). The rainfall-induced soil organic matter ranged from 2.28 ±0.22% to 3.01 ±0.20% during the rainy season. This was greater than the dry-season values, but it was still within the acceptable range for agricultural soil (20.–7.5%). The variation may be due to low moisture content, variations in soil texture, acidity, and organic matter between locations and times of year. The overall variance with a negative loading for organic matter was displayed by this range of low moisture, suggesting a negative correlation between the organic components and the sites' soil particle sizes. All soils were found to have less accessible phosphorus in their soils during both seasons than the recommended range of 5.0-8.0 mg/l for agricultural soil. High soil heterogeneity in the amount of accessible phosphorus was noted by other researchers. According to reports from other studies, this may be related to the loss of organic matter content in the soil as a result of ongoing farming and phosphorus fixation from fertilizers that include phosphorus (Silva and Uchida, 2002). In the dry season, the range of soil electrical conductivity was somewhat higher (171.85 ± 0.51 and 199.10±0.10 mS/m) than in the wet season (178.66±17.15 and 194.33±4.60 mS/m). In both seasons, the soil electrical conductivity measurements were within the 250 mS/m safe limit for agricultural soil. The study sites' soils had low levels of effective nutrients, as demonstrated by their low electrical conductivity. Given that all values of the study sites' soils were below the acceptable level of 2 dSm-1 or 200 mS/m for agricultural soil, the soils could be classified as non-saline. It had been stated that soils with 2.5 dSm-1 or 250 mS/m (≤2 dSm-1 or 250 mS/m) were good or acceptable for agriculture. There were not many soil samples that had levels of Cd contamination over the 0.8 mg/kg acceptable limit for agricultural soil. Due to the abundance of Cd found in particular soils, certain sites are vulnerable to contamination if the activities surrounding the sites are not properly supervised. Soil seasonal heavy metal speciation was noted, with a greater concentration of Cd in soils during the rainy season compared to the dry season. Copper and lead concentrations in all soils from both seasons were within the permissible limits (5–30 and 85 mg/kg, respectively) for agricultural soils (USEPA, 2006). The study sites' irrigation water was found to have higher levels of selected heavy metals and other physicochemical properties than the safe limit for water used for irrigation or agricultural purposes (WHO, 2008). These findings suggest that irrigation water is likely to be the primary source of contamination for plants. The study's irrigation water pH results showed that it was somewhat acidic, with rainy season irrigation water sources being somewhat more acidic than samples from the dry season, but still below the permissible range of 5.5–7.5 for agricultural water. This was in contrast to Moses et al.'s (2019) investigation, which found a larger pH range of 7.57 to 7.96, but it was similar to the report of Joshua et al. (2015). This might be the result of organic wastes being introduced into the body of water, which would have caused an oxidation reaction and an increase in the amount of hydrogen ions released into the water. The partial breakdown of organic materials by bacteria and fungi may also have contributed to the problem, as they can produce a variety of organic acids that can reduce the pH of an aqueous solution during the rainy season (Fakayode, 2005). The range of total acid values was lower during the rainy season (2.17±0.00 mg/l to 2.57±0.53 mg/l) than during the dry season (1.57±0.02 to 3.97±0.02), suggesting that irrigation water during the rainy season was slightly more acidic than during the dry season. This could lead to corrosion in plant tissues when used for plant cultivation. According to the results, all irrigation water turbidity values throughout the rainy season were marginally higher than the turbidity limit that is allowed for agricultural water (WHO (2008), 5.0 NTU). This may be because the water seems foggy because of debris that falls into it from the wind, rain, microorganisms, and other suspended particles (Shabalala et al., 2013). There have been reports that this can harm humans through the food chain. The results of this study's turbidity analysis were in line with those of Adefemiet al. (2007), Wakawa et al. (2008), and Ololade and Ajayi (2009). This study found that irrigation water's total hardness and chloride content varied seasonally. In both seasons, the values obtained from irrigation water sources were below the WHO's (2006) acceptable limits for agricultural water (30–60 mg/l and 2.5 mg/l, respectively). The electrical conductivity of the irrigation water was found to be higher than the WHO's (2008) suggested threshold of 120 mS/cm, making it unsuitable for irrigation in both the rainy and dry seasons. Since there was more water evaporating from the irrigation source during the dry season, the concentration of dissolved salts may have increased and the electrical conductivity readings were higher than the recommended value. The results of this study were less than those of Fakayode's (2005) investigation of the Alaro River in Ibadan. The study found that irrigation water's electrical conductivity varied seasonally between sites. The Cd contents in all irrigation water sources were greater than the 0.003 mg/l allowable limit for irrigation. Since all of the irrigation water sources were contaminated with cadmium, they were unsuitable for use during irrigation in both seasons, but particularly during the rainy one. Due to the fact that all irrigation water sources had Cu values below the allowable limit of 1.74 mg/l for agricultural water, the irrigation water was free of copper. Pb concentrations in irrigation water were greater in all sources than in the allowable limit (0.01 mg/l) for agricultural irrigation water.

Conclusion

Based on experimental observations, the majority of soil samples in both seasons had physicochemical parameters that fell between FAO and WHO permissible limits for agricultural soils. However, some water samples had values that were higher than safe limits for irrigation or agricultural use. The interaction of elements that affected the productivity of irrigation water and the quality of the soil was discovered by this study. Seasons and locales differed significantly in the physicochemical characteristics of irrigation water. A comparison of the parameters with acceptable standards for agricultural purposes was found to be favorable, although some parameters in certain soils and irrigation water of the sites or gardens and seasons showed levels above tolerable limits. The study also revealed that there were minor variations in the parameters analyzed between sites and seasons at $p < 0.05$. Therefore, in order to prevent the bioaccumulation of heavy metals by plants, it is crucial to advise against actions that could lead to a deviation from the parameters' permissible levels for adequate water for irrigation. Although the irrigation water sources were heavily contaminated with lead and mercury, the chosen heavy metals displayed low to moderate potential ecological harm in the soils during both seasons. As a result, crops fed with these types of water sources typically become contaminated by irrigation water. Therefore, the study recommends routine evaluation of agricultural soils and irrigation water quality, appropriate disposal of waste, and appropriate oversight of operations at agricultural locations. These will lessen the negative impacts on health from agronomy, eliminate potential risks from heavy metals in certain places, safeguard the environment for improved sustainability, and help avoid high values of physicochemical qualities of the soils and water over allowable limits.

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