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PHYSIOCHEMICAL QUALITY ASSESSMENT OF IRRIGATION WATER AND FARM SOILS FERTILITY AROUND KOZA AND SABKE DAMS IN MAI'ADUA LOCAL GOVERNMENT AREA, KATSINA STATE, NIGERIA

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ABSTRACT

Irrigation water and farm soil are crucial for agriculture, as their quality impacts crop growth and ecosystem sustainability. This study assesses the physicochemical quality of irrigation water and farm soil in the vicinity of the Koza and Sabke dams in Mai'adua, Katsina State, Nigeria, to determine whether the water and soil meet the acceptable standards for safe agricultural use. Standard sampling techniques and laboratory analyses, as outlined by the American Public Health Association, were employed to measure water and soil parameters across both wet and dry seasons. Results revealed that water temperatures ranged from 27.16±0.89 °C in the wet season to 29.00±0.65 °C in the dry season for Sabke Dam, and from 26.24±1.30 °C in the wet season to 29.52±1.15 °C in the dry season for Koza Dam, exceeding the WHO standards and promoting microbial growth. Turbidity levels ranged from 303.58 ± 5.47 in the wet season to 290.60 ± 11.49 in the dry season for Sabke Dam, and from 290.36 ± 8.58 in the wet season to 263.89 ± 13.07 in the dry season for Koza Dam, both of which were far above the WHO limit of 5 NTUs. Nitrate values ranged from 14.543±0.44 in the wet season to 13.09±0.42 in the dry season for Sabke Dam and 17.90±0.82 in the wet season to 16.18±0.42 in the dry season for Koza Dam, remaining within permissible limits. Soil analysis revealed slightly acidic pH values, moderate moisture levels, and a high organic matter content, with adequate levels of nitrogen, phosphorus, and potassium supporting plant growth. The study recommends the need for sustainable water and soil management practices to mitigate risks and enhance agricultural productivity in the region.

Keywords: Mai'adua, Irrigation water, Farm soil, Physicochemical.

INTRODUCTION

Irrigation water and farm soil are fundamental components of agricultural ecosystems, playing critical roles in crop growth, productivity, and overall food security (Hurni *et al*., 2015). The quality of irrigation water and the physicochemical properties of irrigation farm soil significantly influence agricultural outcomes, environmental sustainability, and human health (Khalid *et al*., 2018). Irrigation water is crucial for supplementing natural rainfall, especially in arid and semi-arid regions where water availability is limited. It is sourced from various reservoirs such as dams, rivers, or lakes (Seth, 2003). The quality of irrigation water is determined by its chemical composition, physical characteristics (such as turbidity and temperature), and biological content (including microorganisms and pathogens). Contaminants in irrigation water, such as heavy metals, pesticides, and microbial pathogens like bacteria and parasites, can affect crop health and soil fertility and pose risks to human health through direct consumption or contact with contaminated produce (Bouaroudj *et al*., 2019).

Farm soil, on the other hand, serves as the medium for plant growth, providing physical support, nutrients, and water uptake for crops. Its physicochemical properties, including soil texture, pH level, soil moisture, soil electrical conductivity, organic matter content, and nutrient availability (such as nitrogen, phosphorus, and potassium), play crucial roles in determining soil fertility and crop productivity (Tale & Ingole, 2015). Soil quality influences microbial activity, nutrient cycling, and the presence and persistence of contaminants, including parasites such as helminths and protozoa (Nieder *et al*., 2018).

Understanding the interplay between irrigation water quality and soil health is essential for sustainable agriculture. Effective management practices, informed by comprehensive physicochemical analysis of irrigation water and soil, can mitigate contamination risks, optimise nutrient use efficiency, and promote crop resilience to environmental stresses. This approach not only enhances agricultural productivity but also supports ecosystem health, water conservation efforts, food safety, minimising environmental impact, and ensuring the safety and quality of agricultural products for consumers in the region.

Study Area

The study was conducted around the irrigation areas of Koza and Sabke dams in Mai'adua, a Local Government Area in Katsina State, Nigeria, located at a latitude of 13°11'66" N and a longitude of 8°31'05" E. meanwhile Sabke is situated at a latitude of 13°03'12" N and a longitude of 8°16'19" E, encompassing the dams, which borders the Republic of Niger. Mai'adua spans an area of 528 km² and had a population of 201,178 according to the 2006 census (Mimiko, 2006). (Sources?). The area is known for its significant historical urban and rural market, which operates on Sundays (Maiwada & Hassan, 2019). The market is international, serving as an exchange point between Nigeria and Niger Republic. Livestock, including cattle, sheep, goats, camels, donkeys, and horses, are the primary commodities, primarily sourced from Niger. In contrast, grains such as maize, sorghum, millet, and soybeans are mainly sourced from Nigeria. Maiadua has a semi-arid climate, characterised by an average annual temperature of 37°C, 653 mm of rainfall, and a relative humidity of 30%. The area features a dendritic drainage pattern system of small rivers and streams, which can lead to flooding during periods of heavy rainfall. The area predominantly has sandy loam soils, which support a variety of crops (Usman *et al*., 2018).

Materials and Methods

Sample processing of physicochemical parameters of water

During this study, Dam visits for sample collection were conducted monthly, both during the dry and wet seasons. In the dry season, visits were made in August, September, and October 2023. In the wet season, visits were conducted in January, February, and March 2024. Three visits were made each month, resulting in a total of 18 visits across both seasons. Water samples were collected from three points per visit, totalling 54 sampling points for each sample type.

Water samples were randomly collected in accordance with standard sampling guidelines and methods as described by the American Public Health Association. Within the Koza and Sabke dams, the sampling points were selected using a random sampling method from various locations around the dam banks to ensure a representative distribution. Two seasonal samplings were conducted between August 2023 and March 2024, encompassing the wet season (August to October 2023) and the dry season (January to March 2024). Water samples were collected in well-labelled

500 ml plastic polyethene bottles that had been previously rinsed three times. The samples were then transported to the laboratory and maintained in cooler boxes with ice for further analysis. Twelve physicochemical water quality parameters were selected for analysis. All the parameters were analysed as described in the standard methods of the American Public Health Association (APHA, 2012

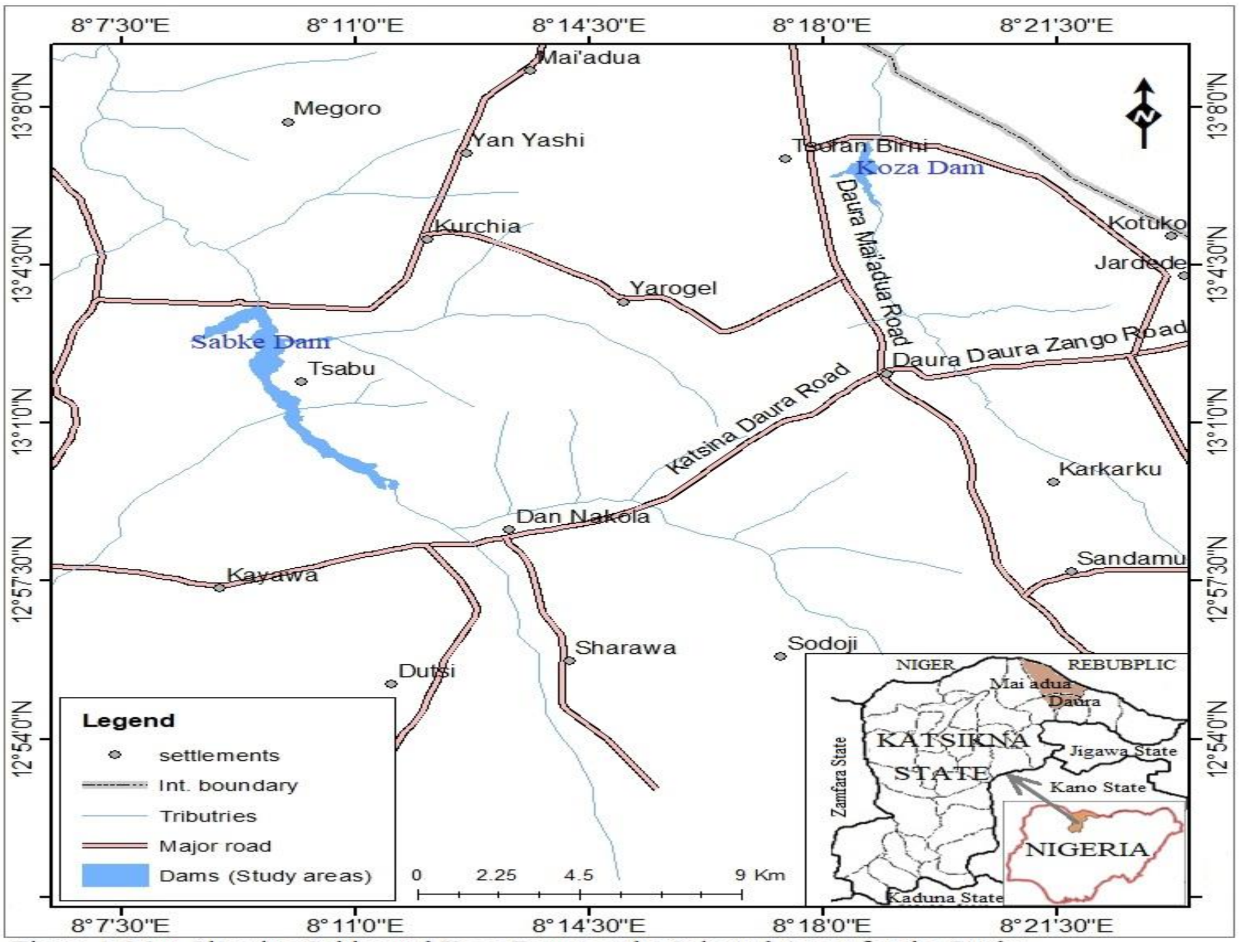

Figure 1: Map Showing Sabke and Koza Dams as the Selected Areas for the Study.
Source:- National Aeronoutic and Space Administration Spot Image 2025.

Figure 1: Map showing the study areas

Physicochemical Analysis of Soil Determination

A random sampling method was adopted. Approximately 200 grams of soil, collected from the surface to a depth of 3 cm using a small hand shovel, was placed in sterile, sealed plastic bags and transported to the laboratory. The soil was then sieved through a 2 mm sieve. The soil physicochemical parameters were analysed using established methods.

Soil pH was measured with the help of a digital pH meter (Hanna PH211 model), soil moisture content was calculated by weighing wet and dry soil methods by Gardner, (2000), Electrical Conductivity was measured using a soil-to-water suspension (Rayment *et al*., 2011), Soil Texture was analyzed using the hydrometer method by Stroke's law Rowell, (2014), Total Organic Matter (TOM) was measured using Potassium dichromate method as described by Souza *et al*. (2016), Nitrogen (N) was determined using Kjeldahl flask (Sáez-Plaza *et al*., 2013). The method of Twum (2015) was employed for Phosphorus (P) determination, and Potassium (K) was determined using the method of Tan (2005). All were measured using various chemical instruments and standard methods.

Table 1: Water Quality Parameters and Analytical Methods

Parameters	Methods	Source
Temperature	Mercury-in-glass thermometers	APHA (2012)
pH	Digital pH meter (PH-009(I) model)	APHA (2012)
Turbidity	Turbidity tube	APHA (2012)
Electrical Conductivity (EC)	Conductivity meter (Hanna EC215 model)	APHA (2012)
Dissolved Oxygen (DO)	DO-meter probe (Hanna HI9147-04 model)	APHA (2012)
Biological Oxygen Demand (BOD)	Five days (BOD_5) incubation methods	Jouanneau *et al.* (2014)
Total suspended solids	Drying and weighing filter papers	APHA (2012)
Total dissolved solids	Drying and weighing crucibles	APHA (2012)
Hardness	Ethylene Diamine Tetraacetic Acid (EDTA) titration methods	APHA (2012)
Chloride	Silver nitrate ($AgNO_3$) titration methods	APHA (2012)
Nitrate	Phenol disulfonic spectrometric methods	Thangiah (2019)
Phosphate	Stannous chloride spectrometric methods	Jagessar *et al.* (2011).

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Statistical Analysis

Statistical analysis was carried out using GraphPad statistical software version 3.01, and analysed by T-test; means and standard deviation were calculated for each parameter.

The mean ($\overline{X}$) was calculated as:

$$\overline{X} = \frac{\sum X_i}{n}$$

Where:

- X_i = individual data points
- n = total number of observations

The standard deviation (SD) was computed as:

$$SD = \sqrt{\frac{\Sigma(X_i - \overline{X})^2}{n - 1}}$$

The t-statistic for the two-sample t-test was determined using:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{s_p^2(\frac{1}{n_1} + \frac{1}{n_2})}}$$

Where:

- $\overline{X}_1 - \overline{X}_2$ = means of the two groups
- n_1, n_2 = sample sizes of the groups
- s_p^2= pooled variance, given by:

$$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$

A p-value $p<0.05$ was considered statistically significant.

Results and discussion

The physicochemical parameters obtained for water samples taken throughout the wet and dry seasons at Sabke Dam are shown in Table 2—the mean and standard deviation values, as well as their comparison to WHO and SON standards.

Table 2: Physicochemical Parameters of Water Samples from Sabke Dam during Wet and Dry Seasons

Site	Sabke			
Parameter	WHO (2018)	SON (2007)	Wet season	Dry season
Temperature (^{0}C)	25		27.16 ± 0.89^a	29.00 ± 0.65^b
Ph	6.5-8.5	6.5-8.5	6.51 ± 0.19^a	6.56 ± 0.28^a
DO (mg/L)	>5.0		7.78 ± 0.205^a	7.44 ± 0.25^b
Turbidity (NTU)	< 5	< 5	303.58 ± 5.47^a	290.60 ± 11.49^b
EC (µS/cm)	<400	<1000	84.03 ± 1.81^a	92.72 ± 1.82^b
TDS (mg/L)	< 500	< 500	126.44 ± 2.40^a	164.78 ± 3.27^b
TSS (mg/L)	< 500	< 500	134.67 ± 1.87^a	133.11 ± 1.05^a
BOD (mg/L)			2.98 ± 0.19^a	2.62 ± 0.47^a
Hardness (mg/L)	<150	<150	154.48 ± 8.37^a	157.81 ± 1.66^a
Phosphate (mg/L)	0.1	0.5	3.44 ± 0.64^a	0.05 ± 0.02^b
Nitrate (mg/L)	45	50	14.543 ± 0.44^a	13.09 ± 0.42^b
Chloride (mg/L)	< 250	< 250	117.93 ± 2.20^a	134.20 ± 3.40^b

Key: DO Dissolved Oxygen, EC Electric Conductivity, TDS Total Dissolved Solids, TSS Total Suspended Solids, BOD Biological Oxygen Demand, WHO World Health Organisation, SON

Standard Organisation of Nigeria. Values with the same superscript along rows indicate no significant difference (*P < 0.05*).

The physicochemical parameters obtained for water samples collected throughout the wet and dry seasons at Koza Dam are presented in Table 3, including the mean and standard deviation values, as well as their comparison to WHO and SON standards.

Table 3: Physicochemical Parameters of Water Samples from Koza Dam during Wet and Dry Seasons

Site	**Koza**			
Parameters	**WHO (2018)**	**SON (2007)**	**Wet season**	**Dry Season**
Temperature (^{0}C)	25		26.24±1.30^a	29.52±1.15^b
pH	6.5-8.5	6.5-8.5	6.86±0.30^a	6.39±0.26^b
DO (mg/L)	>5.0		7.68±0.19^a	6.87±0.40^b
Turbidity (NTU)	< 5	< 5	290.36±8.58^a	263.89±13.07^b
EC (µS/cm)	<400	<1000	88.09±1.37^a	94.39±0.91^b
TDS (mg/L)	< 500	< 500	97.33±1.41^a	113.67±2.00^b
TSS (mg/L)	< 500	< 500	104.00±2.24^a	87.33±1.50^b
BOD (mg/L)			2.84±0.29^a	2.60±0.22^a
Hardness (mg/L)	<150	<150	167.70±2.11^a	184.83±2.55^b
Phosphate (mg/L)	0.1	0.5	2.88±0.38^a	0.05±0.02^b
Nitrate (mg/L)	45	50	17.90±0.82^a	16.18±0.66^b
Chloride (mg/L)	< 250	< 250	110.97±5.08^a	155.70±1.82^b

Key: DO Dissolved Oxygen, EC Electric Conductivity, TDS Total Dissolved Solids, TSS Total Suspended Solids, BOD Biological Oxygen Demand, WHO World Health Organisation, SON Standard Organisation of Nigeria. Values with the same superscript along rows indicate no significant difference (*P*<0.05)

The mean and standard deviation of physicochemical parameters of soil samples collected throughout the wet and dry seasons around Sabke Dam, Mai'adua, are shown in Table 4.

Table 4: Physicochemical Parameters of Cultivated Soil Samples during Wet and Dry Seasons from Sabke Dam

Site	**Sabke**	
Parameter	**Wet season**	**Dry season**
Soil type	S-L	S-L
pH	6.32±0.19^a	6.62±0.29^a
EC (dS/m)	0.35±0.18^a	0.13±0.04^b
TOM (%)	2.73±0.18^a	1.89±0.17^b
N (mg/100g)	0.48±0.06^a	0.46±0.08^a
P (mg/100g)	14.66±0.79^a	13.55±0.22^b
K (ppm)	1.46±0.72^a	1.18±0.20^a
Moisture (%)	13.63±0.36^a	11.89±0.68^b

Key: S-L Sandy loamy, EC Electric conductivity, TOM Total Organic Matter, N Nitrogen, P Phosphorus, K Potassium. Values with the same superscript along rows indicate no significant difference (*P < 0.05*).

The mean and standard deviation of physicochemical parameters of soil samples collected throughout the wet and dry seasons around Koza Dam, Mai'adua, are shown in Table 5.

Table 5: Physicochemical Parameters of Cultivated Soil Samples during Wet and Dry Seasons from Koza Dam

Site	**Koza**	
Parameters	**Wet season**	**Dry season**
Soil type	S-L	S-L
pH	6.23±0.49[a]	6.40±0.41[a]
EC (dS/m)	0.25±0.14[a]	0.18±0.02[a]
TOM (%)	2.67±0.09[a]	1.21±0.30[b]
N (mg/100g)	0.75±0.12[a]	0.37±0.08[b]
P (mg/100g)	13.13±0.48[a]	12.95±0.45[a]
K (ppm)	0.99±0.46[a]	1.45±0.08[b]
Moisture (%)	13.19±1.46[a]	12.59±1.10[a]

Key: S-L Sandy loamy, EC Electric conductivity, TOM Total Organic Matter, N Nitrogen, P Phosphorus, K Potassium. Values with the same superscript along rows indicate no significant difference ($P < 0.05$).

Discussion

The Physicochemical Quality of Irrigation Water

The results show that water temperatures range from 27.16±0.89 to 29.00±0.65 °C and from 26.24±1.30 to 29.52±1.15 °C across both sites throughout the seasons, surpassing the WHO standard of 25 °C. High water temperatures promote the growth of microorganisms and can lead to issues with taste, odour, colour, and corrosion (Bernard & Ayeni, 2012). The results indicate that water temperature is a significant determinant in determining waterborne concentrations, with variable effects on waterborne infections. Several factors, including seasonal changes, geographic location, time of day, weather conditions, human activities, vegetation, shade, and water pollution, influence temperature variations observed in this study. These factors contribute to differences in water temperature.

The pH of water indicates its acidity or alkalinity, with the WHO recommending a range of 6.5 to 8.5 for human consumption. As per Tables 2 and 3, the pH values of the tested water fell within the WHO permissible range, indicating suitability for vegetable cultivation with irrigation water from the dam. Chapman *et al*. (2013) argue that these pH values are positive as they have no adverse effects on water systems, agriculture, the environment, or health.

Turbidity refers to the cloudiness of a fluid due to suspended particles, primarily measuring the concentration of colloidal solids (Alfred & Prosper, 2014). The WHO suggests water turbidity should range between 0 and 5 NTUs. However, our study recorded higher turbidity levels, exceeding the WHO limits, ranging from 303.58±5.47 to 290.60±11.49 and 290.36±8.58 to 263.89±13.07 NTU in the wet and dry seasons, respectively. This aligns with Chigor et al. (2012), who reported turbidity levels ranging from 14 to 547 NTU, indicating a high microbiological content in dam irrigation water. Irrigating with turbid water can compromise vegetable quality by facilitating the attachment and penetration of viruses and microorganisms through vegetables via solid particles. Runoff from farmlands, visitor activities, and natural debris contributes to the entry of soil particles into the dam. Total dissolved solids and total suspended solids were within the WHO-acceptable range for water quality.

During both wet and dry seasons, electrical conductivity (EC) in Sabke and Koza dams fluctuated between 84.03±1.81 and 92.72±1.82, and 88.09±1.37 and 94.39±0.91, respectively, which is below the WHO typical range of 400-500. The suspended contaminants change electric conductivity, which also depends on the ion concentration in water (Simeon *et al.*, 2019). High water electrical conductivity in irrigation can adversely affect parasite survival and development due to its impact on osmoregulation and water quality.

Biochemical oxygen demand (BOD) levels ranged from 2.98±0.19 to 2.62±0.47 and 2.84±0.29 to 2.60±0.22 mg/L in Sabke and Koza dams, respectively, during the wet and dry seasons, indicating low BOD levels. The study by Ashie et al. (2024) reported higher BOD levels, ranging from 17.27 to 3.56 mg/L. BOD levels can affect parasite survival and development; high BOD may indicate organic pollution, fostering conditions favourable for parasite proliferation, while low BOD suggests better water quality. In our study, the BOD level is low, which is within WHO standards and is considered acceptable. The hardness of the irrigation water pump from the dam ranged from 154.48±8.37 to 157.81±1.66 and 167.70±2.11 to 184.83±2.55 mg/L, with Koza dam samples exhibiting maximum hardness during both seasons. The WHO recommends a minimum hardness of 150 mg/L, with levels above this being considered high. In our study, water hardness is considered slightly elevated in the Sabke dam, while the Koza dam had high water hardness in both seasons. Hard water can compact soil, reducing pore space and limiting the availability of oxygen and water to plant roots, which can potentially hinder plant growth and production. Phosphorus levels in dam water varied from 3.44±0.64 to 0.05±0.02 and 2.88±0.38 to 0.05±0.02 mg/L across both sites. During the wet season, phosphate levels at both sites exceeded WHO standards and were deemed unacceptable. However, during the dry season at both sites, the phosphate concentration is within the typical range of the WHO criteria and is considered acceptable. High phosphate levels can lead to eutrophication, reducing plant growth and soil health. Excessive phosphate exposure in irrigation water can lead to reduced growth and increased susceptibility to parasitic diseases in plants (Hanjra *et al.*, 2012).

Nitrate (NO_3-) levels in Sabke and Koza dams varied from 14.543 ± 0.44 to 13.09 ± 0.42 mg/L and from 17.90 ± 0.82 to 16.18 ± 0.42 mg/L, respectively, across seasons. These levels were within the WHO maximum recommended limit of 45 mg/L for water quality. Also, the European Union's Water Framework Directive (WFD) regulates nitrate concentrations in irrigation water to 50 mg/L. The WFD aims to ensure the good ecological quality of all water bodies, particularly those used for irrigation, by reducing the levels of pollutants and toxins in water (Deviller *et al.*, 2020). Nitrate is an important nutrient for plant growth. However, high levels of nitrate in irrigation water from the dam that watered the vegetables can cause nitrogen pollution and eutrophication in water bodies. Vegetables irrigated with water containing high levels of nitrates may exhibit lower growth and increased susceptibility to parasite infections.

Chloride levels in Sabke and Koza dams ranged from 117 ± 2.02 to 134.20 ± 3.40 and 110.97 ± 5.08 to 155.70 ± 1.82 mg/L, respectively. Koza Dam exhibited high chloride levels during the dry season, exceeding WHO standards. While chloride is necessary for plant growth, excessive quantities can hinder growth and pose risks to sensitive plants (Colmenero *et al.*, 2019). Chloride levels in water can impact parasite development, as high chloride concentrations may exert osmotic stress on parasites, potentially affecting their survival and reproductive success. In contrast, low chloride levels are less likely to hinder parasite development. Careful irrigation management is crucial for maintaining chloride levels that are conducive to crop health while mitigating the risks of parasite development.

Physicochemical Properties of Farmland Soil

Soil physicochemical parameters play a crucial role in the survival and development of parasites, providing conditions conducive to their growth. Soil moisture content, total organic matter, and pH level are key determinants influencing the survival of parasites in soil. Soil texture also affects the survival and migration of larval stages of parasites.

The soil pH ranged from 6.32 ± 0.19 to 6.62 ± 0.29 and from 6.23 ± 0.49 to 6.40 ± 0.41 across both seasons, indicating acidic conditions. Acidic soil provides a favourable environment for microorganisms, which larvae feed on during their free-living stage, contributing to the prevalence of parasite species (Lambers *et al*., 2009). The soil type, categorised as sandy loam, favours the abundance of *Ascaris lumbricoides*. As its eggs develop optimally with increased survivability at greater soil depths (Ogden, 2015). The soil moisture content in this study fell within an acceptable moderate range, which promotes the development and survival of several parasites in contaminated soil. Soil electric conductivity ranged from 0.35 to 0.13 in Sabke and 0.25 to 0.18 in Koza, which is lower than the value reported by Abdulhamid et al. (2017) in Katsina, near the Dana Steel Industry Limited. (Where in the state, or does it apply for the whole state?). Soil electrical conductivity influences parasite development by impacting soil moisture levels, nutrient availability, and microbial activity, thereby affecting habitat suitability for parasites and their hosts (Usharani *et al*., 2019).

The total organic matter content ranged from 2.73 to 1.89 and from 2.67 to 1.21 in the wet and dry seasons, respectively, consistent with the findings by Goodhead et al. (2022) in rivers. Total organic matter influences parasite development by affecting soil microbial dynamics and habitat suitability, although its impact varies depending on soil management practices and biological interactions.

Nitrogen, phosphorus, and potassium levels were within an acceptable range. The presence and balance of Nitrogen, phosphorus, and potassium, derived from nitrogenous waste substances such as decaying plant and animal materials, are crucial for optimising plant growth in vegetable-cultivated soil. However, they can indirectly influence parasite development by affecting plant health, susceptibility to pests and diseases, and the interaction of soil microbial communities with parasites (Dordas, 2008).

Conclusion

The findings reveal that water quality is a critical factor for agriculture, directly impacting crop health and safety. Parameters such as water temperature and turbidity levels exceed WHO guidelines, with high water temperatures potentially promoting microbial growth, posing risks to crop quality and health. Turbidity levels are elevated, which may impact vegetable quality and increase the risk of pathogen contamination. However, other parameters, including pH, dissolved oxygen, electrical conductivity, total dissolved solids, total suspended solids, biological oxygen demand, hardness, phosphate, nitrate, and chloride, generally fall within acceptable standards despite seasonal variations, making the water suitable for irrigation. Soil analysis indicates slightly acidic pH, moderate moisture, and adequate nutrient content, supporting healthy plant growth and soil health. Regular monitoring of water quality parameters is essential to ensure compliance with standards for safe agricultural use. Additionally, farmer education programs are recommended to promote safe agricultural practices and effective water management techniques.

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