Characterization of Heavy Metal and Physico-Chemical Profiling of Sewage WaterSoil in Jaipur District, Rajasthan, India

ABSTRACT

Jaipur is the capital state of Rajasthan. During the year 2021, District Jaipur of 3 blocks (Chomu, Sanganer, and Shahpura) in 9 villages [Keshav Nagar (V_1), Morija (V_2), Nindola (V_3), Goner (V_4), Shrikishanpura (V_5), Durgapura (V_6), Shivpuri (V_7), Manoharpur (V_8), Nwalpura (V_9)] were selected for estimation of physico-chemical properties and Heavy metal contamination in severage channels. A total of 9 samples were collected from 9 villages sewerage channels. This study aimed to analyze the physico-chemical properties of agricultural soil and irrigation water in three blocks of Jaipur, Rajasthan. The findings revealed significant variations in the physico-chemical properties of the agricultural soil and water in Chomu, Sanganer, and Shahpura. Standard methods were employed to assess the physico-chemical characteristics of soil samples contaminated with sewerage effluents in these regions, which exhibited considerable diversity. The pH levels of the soil samples were predominantly slightly acidic and alkaline ranging from 6.22 to 7.31. Electrical conductivity values varied between 0.41 to 0.62 mmhos/cm. The percentages of organic matter and organic carbon in the soil samples ranged from 0.17% to 0.25% and 0.29% to 0.43%, respectively. Additionally, the analysis included heavy metals such as zinc (Zn), manganese (Mn), iron (Fe), and copper (Cu). The soil samples were found to contain elevated levels of heavy metals, surpassing the permissible limits. The discharge of sewerage effluent into the environment, primarily originating from the textile industry, house, etc. constitutes are major source of pollution that can adversely impact the local flora and fauna. Therefore, it is imperative to implement effluent treatment measures before their release into the environment.

Keywords: Jaipur district, sampling sites, physico-chemical properties, heavy metals, etc.

INTRODUCTION

Environmental contamination is a sewage ecological crisis that poses significant challenges to our planet today. Developing countries in South Asia, such as Pakistan, Nepal, Bangladesh, and India, particularly experience the detrimental effects of pollution resulting from urbanization, increased household and vehicular fuel usage, and industrialization (Karn and

Harada, 2001). The city of Jaipur in Rajasthan, situated in the central region, has witnessed rapid urban growth and industrial development in the past two decades. Numerous industrial areas have emerged throughout Jaipur and its neighbouring regions during this period. This industrialization has led to a prevalent issue of heavy metal pollution, referring to the presence of toxic metallic elements with high density and low concentration tolerance, including copper, manganese, lead, cadmium, iron, mercury, zinc, and nickel (Raikwar *et al.,* 2008). While heavy metals occur naturally in the Earth's crust, the majority of environmental contamination and exposure stem from human activities, such as mining, smelting operations, and industrial processes encompassing metal refinement, coal burning, petroleum combustion, nuclear power generation, and manufacturing in various sectors like plastics, textiles, microelectronics, wood preservation, and paper processing. Birds are particularly sensitive to environmental contaminants resulting from human activities and serve as vital indicators of ecological conditions in specific areas. Therefore, they are widely used in monitoring environmental changes (Medona *et al.,* 2015).The analysis of heavy metal excretion through bird fecal matter has gained attention due to the Wildlife Protection Act of 1972, which prohibits the capturing and killing of birds in India. Consequently, researchers in this field focus on analytical studies that utilize bird tissues and organs less frequently. Moreover, limited studies on heavy metal pollution in bird feces exist within the Indian context. Additionally, heavy metals possess the ability to bioaccumulate and biomagnify within food chains (Zhuang *et al.,* 2009). As a result, fecal matter serves as a valuable indicator of metal contamination, effectively reflecting the level of metal pollution in the environment. Therefore, the examination of bird feces provides an estimation of the adverse impact of trace metals on these organisms and their surrounding environment. This study aims to assess the concentration of heavy metals in bird fecal matter within industrial environments and explore the potential use of fecal matter as a non-invasive method for determining metal concentrations in the environment. Metals occur naturally in our environment, especially in the Earth’s crusts where they contribute to the balance of the planet. However, as a result of human activities they are distributed, concentrated and chemically modified, which may increase their toxicity (Mihaly *et al.,* 2005)The concentration of HMs tends to increase with soil development, its mobility can be changed by environmental conditions such as type of soil, agricultural input, climate change and saturation capacity of the soil (García-Carmona et al., 2019).

Treated sewage water, enriched with essential nutrients like nitrogen, phosphorus, and potassium, as well as organic matter, micronutrients, and beneficial microbial communities, offers a potential substitute for conventional irrigation water and chemical fertilizers. However, concerns arise regarding the introduction of contaminants such as heavy metals, pathogens, and organic pollutants, which could compromise soil fertility and ecosystem health over time. Furthermore, long-term irrigation with sewage water may alter soil physical properties, including structure, texture, and hydraulic conductivity, thereby affecting water infiltration, root growth, and overall crop productivity. Understanding the intricate interactions between sewage water application, soil properties, and crop responses is pivotal for devising effective management strategies that optimize agricultural productivity while safeguarding environmental and human health. Synthesizing existing literature on sewage water use in crop production, particularly its effects on soil physical and biological properties, is essential for informing policymakers, researchers, and agricultural practitioners about its sustainable utilization and implications across diverse agroecosystems. This approach not only reduces stress on freshwater resources, primarily utilized for human and industrial purposes but also addresses waste disposal concerns (Cheftez *et al.*, 2006; Hajjami *et al.*, 2012).Bacterial diversity distribution can be influenced by heavy metals concentrations in the environments (Gupta et al., 2022; X. Wang et al., 2021).

MATERIALS AND METHODS

Jaipur, the capital city and the largest city in the state of Rajasthan, is located at a geographical position of approximately 26.9124° N latitude and 75.7873° E longitude. The district of Jaipur covers a total geographical area of 11,06,148 hectares or 11,061.48 square kilometers (Government of Rajasthan, n.d.). In terms of agricultural land use, the Gross Cropped Area in Jaipur district is estimated to be around 8,48,313 hectares. Out of this, the Net Sown Area is approximately 6,63,167 hectares. However, it's important to note that only 3,02,428 hectares of the Net Sown Area are under irrigation. These figures provide an overview of the agricultural landscape in Jaipur district, highlighting the extent of cultivated land and the proportion that benefits from irrigation. These statistics are essential for understanding the agricultural potential and the distribution of agricultural activities in the region. (District Fact Book., 2019)

Nine samples were obtained from three different blocks (Figure 1) in the Jaipur district prior to the monsoon season. These samples included soil and sewage water effluent. The purpose was to assess the physico-chemical characteristics of the collected samples. The collection took place in the morning of June 2021, with temperature and pH measurements recorded in the field. To maintain sample integrity, acid-washed plastic bottles and sterilized plastic bags were used for collection, and the samples were stored at 4°C. The soil samples underwent analysis to determine various parameters such as pH, electrical conductivity (EC), percentage of organic carbon (OC), percentage organic matter (OM), and Heavy metals zinc (Zn), iron (Fe), copper (Cu), manganese (Mn). On the other hand, the effluent samples were analyzed for pH, electrical conductivity (EC), as well as cations and anions present. In summary, a total of nine samples consisting of soil and sewage water effluent were collected from different blocks in Jaipur district before the onset of the monsoon season. These samples were analyzed to assess their physico-chemical properties.

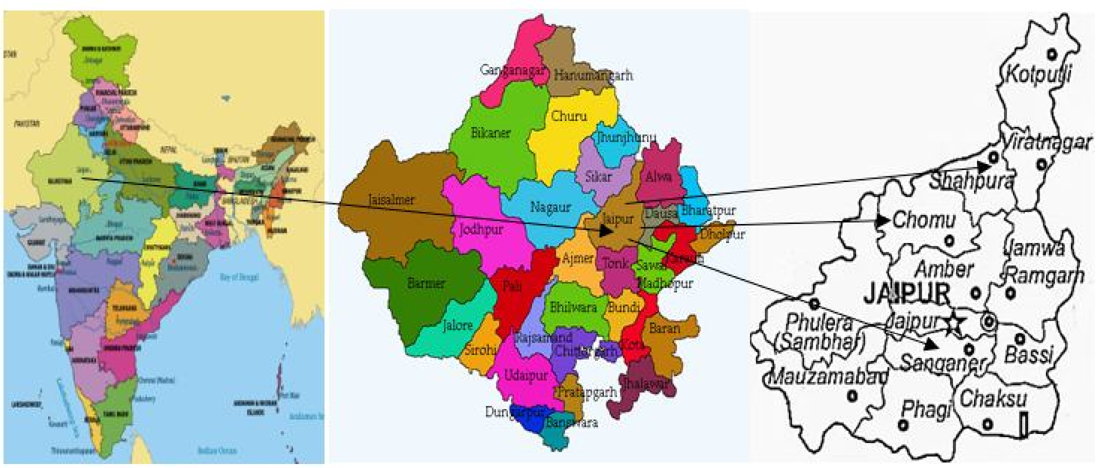

Figure 1 Soil sampling sites in 3 blocks from Jaipur district, Rajasthan, India

Processingofsoilsamples

Thesurfacesoilsampleswerekeptinshadeforairdrying,atroomtemperature and later taken to the laboratory for further processing. With the help of awoodenroller the dried samples were crushed and grounded. Later, the samples weresievedusing2mmmeshsieve.Thesampleswerethenstoredinawelllabelledpolythene bags where collection date and time were specified. The labelled sampleswerefinallyanalyzed for the physico-chemical properties.

PhysicalandChemicalanalysisof soilsamples

The collected soil samples were analyzed for various physical and chemicalproperties in laboratory. It includes pH, electrical conductivity and micronutrients (Zinc, Copper, Manganese,Iron).

DeterminationofsoilpH

Asuspensionintheratioof1:2.5(10gsoil+25mldistilledwater)wasprepared fordetermining soil pH usingpH meteridentified byJackson, 1973.

Table 1Classification of soilsamplesunderpHranges:

pHRange	SoilReactionRating
<4.6	Extremelyacid
4.6-5.5	Stronglyacid
5.6-6.5	Moderatelyacid
6.5-7.0	Neutral
7.1-8.5	Moderatelyalkaline
>8.5	Stronglyalkaline

Determinationofsoilelectricalconductivity

A suspensionof soil waterwasprepared inthe ratio of 1:2.5(10g soil and25mldistilledwater) in50mlbeaker for measuring soluble saltconcentrationbyusingconductivitymeteras illustratedbyJackson1973.

Table 2 Classification ofsoilsamplesunderECranges

Classification	ECdSm^{-1}

Nonsalinesoils	0-2
Slightlysalinesoils	2-4
Salinesoils	4-8
Stronglysaline soils	8-16
Extremelysalinesoils	>16

Determinationof organiccarbon

For estimation of organic carbon, Walkey and Black (1934) method of wetoxidation was acquainted.1g of soil sample was taken in a conical flask of 500mlcapacityand10mlofpotassiumdichromatesolutionfollowedby20mlofconcentrated sulphuric acid were added. The solution was swirled for a minute andkept aside for 30 minutes for redox reaction to be completed. Then, the solution wasdilutedwith200mlofdistilledwater.0.2gofsodiumflorideand1mlofdiphenylamine indicator was added to the solution. Titration of the solution was donewithferrous ammoniumsulphate till theviolet colorchanges togreen.

$$\%\text{Organiccarbon} = \frac{B-T \times 0.003 \times 100}{2 \times \text{wtofsoil}}$$

$$\%\text{organicmatter} = \text{organiccarbon} \times 1.724 (\text{VanBemmelenfactor})$$

Where,B= Volumeof0.5N FASsolutionusedforblank titrationT = Volumeof0.5NFASsolutionusedforsampletitration

Availablemicronutrient

Cationic micronutrient iron, copper, zinc and manganese in the soil sampleswere measured on atomic absorption spectrophotometer. 0.005 M DTPA

(DiethylineTriamine Penta Acetic Acid), 0.01M calcium chloride dehydrate and 0.1M triethanolamine buffered at pH 7.3 (Lindsay and Norvell, 1978) were used as extractant. 10 g ofsoil sample was taken and to that 20 ml DTPA solution was added in a 100 ml conicalflak. The contents were shaken on a rotatory shaker for 2 hours and filtered throughWhatman no. 42 filter paper. The concentration of micronutrients were then analyzedonAAS.

Table 3Shows, different locations of seweragechannel water soil samples

S.No.	Blocks	Villages	Latitude(^{0}N)	Longitude(^{0}E)
1.	Chomu(B_1)	KeshavNagar (V_1)	26.9039^0	75.7844^0
		Morija(V_2)	27.2068^0	75.7582^0
		Nindola(V_3)	27.3185^0	75.7081^0
2.	Sanganer(B_2)	Goner(V_4)	26.8865^0	75.8341^0
		Shrikishanpura(V_5)	26.7998^0	75.8582^0
		Durgapura(V_6)	26.8518^0	75.7862^0
3.	Shahpura(B_3)	Shivpuri (V_7)	26.9426^0	75.7526^0
		Manoharpur(V_8)	26.2994^0	75.9571^0
		Nwalpura(V_9)	26.8103^0	75.8365^0

RESULTS AND DISCUSSION

The study investigated soil samples taken from areas near sewage water effluent and agricultural lands around Jaipur, focusing on their physico-chemical properties.

The results showed that pH of the soil samples (Table 5 and Figure 2) ranged from 6.22 to 7.31, indicating a slightly acidic to alkaline nature. Such variation can be attributed to the impact of sewage water effluent, which often alters soil pH due to the presence of various ions and organic matter. The higher pH values observed could potentially lead to alkaline soil conditions, which may affect nutrient availability and soil health adversely. Similar results were also recorded byAshfaqand Ahmad (2014) in Agracity.

The electrical conductivity values ranged from 0.41 to 0.62 mmhos/cm. This variation suggests differences in the concentration of dissolved ions in the soil. High electrical conductivity in soil is often associated with elevated levels of dissolved salts, which can influence soil fertility and plant growth. The presence of sewage water effluent can contribute to increased E.C. due to the accumulation of salts and minerals. The Variation in electrical conductivity of water samples reflects the variation of total soluble salt concentration present in groundwater of the region and ultimately the salinity of the groundwater. samples. Similar results were also recorded by Prakash et.al (2020) in Faridabad district of Haryana.

The percentage of organic matter ranged (Table 5 and Figure 2) from 0.17% to 0.25%, while organic carbon ranged from 0.29% to 0.43%. These values indicate a moderate level of organic content in the soil samples. The increase in organic matter and carbon content is likely influenced by the discharge of organic waste with sewage water, which enriches the soil but can also affect its nutrient balance and microbial activity. The study also analysed the concentrations of heavy metals such as zinc, iron, copper, and manganese in the soil samples. The reported ranges were 1.10 to 1.81 ppm for zinc, 3.10 to 4.71 ppm for iron, 0.25 to 0.55 ppm for copper, and 2.90 to 4.70 ppm for manganese. These concentrations exceed standard limits, indicating contamination likely due to sewage water effluent, which is known to carry heavy metals from industrial and domestic sources. Such contamination poses risks of toxicity to soil organisms and can potentially affect crop quality and human health through food chain transfer. Recently, heavy metal pollution has attracted widespread attention as a result of its toxicity, numerous sources, and accumulative and non-biodegradable nature (Fajardo *et al*., 2019).

The findings of this study align with previous research conducted by Kumar *et al.* (2014), Rahi *et al.* (2018), Singh *et al.* (2010), and Singh et al. (2006), which also reported similar trends in soil properties and heavy metal contamination in areas affected by sewage water effluent. Soil is a substantive component of the biosphere and forms the major sink for metals released into the environment from a wide variety of anthropogenic activities such as transport, agricultural practices, municipal refuse, industrial activities and disposal of wastes (Wang *et al*., 2016; Jiang *et al*., 2018; Salem *et al*., 2020).

In summary, the soil samples analyzed near sewage water effluent areas in Jaipur exhibit notable variations in physico-chemical properties, including pH, electrical conductivity, organic matter, and heavy metal concentrations. These variations highlight the impact of sewage water on soil quality and underscore the importance of effective management practices to mitigate contamination and preserve soil health in such environments.

Parameters	**Critical limit**
pH	7-8.5
Electrical Conductivity mmhos/cm	0-1.5
Organic Carbon %	0.5-0.75
Organic Matter %	0.8-1.29
Zinc ppm	0.6
Iron ppm	4.5
Copper ppm	0.2
Manganese ppm	2.0

Table 4 Standard Critical limits of different parameters

Table 5 Results of analysis of Sewage water soil of different Villages

Sites	**pH**	**E.C. mmhos /cm**	**O.C. (%)**	**O.M. (%)**	**Zn (ppm)**	**Fe (ppm)**	**Cu (ppm)**	**Mn (ppm)**
V_1	7.17	0.51	0.20	0.34	1.15	4.35	0.30	3.10
V_2	7.24	0.60	0.18	0.31	1.10	3.65	0.31	3.50
V_3	7.10	0.53	0.17	0.29	1.45	3.10	0.52	2.90
V_4	6.76	0.41	0.19	0.32	1.57	4.28	0.46	3.78
V_5	6.35	0.57	0.24	0.41	1.42	3.50	0.44	4.55
V_6	7.31	0.61	0.18	0.31	1.68	4.69	0.37	2.92

V_7	6.37	0.53	0.21	0.36	1.32	4.71	0.55	4.10
V_8	7.25	0.62	0.19	0.32	1.81	4.00	0.38	4.70
V_9	6.22	0.51	0.25	0.43	1.62	3.85	0.40	2.98

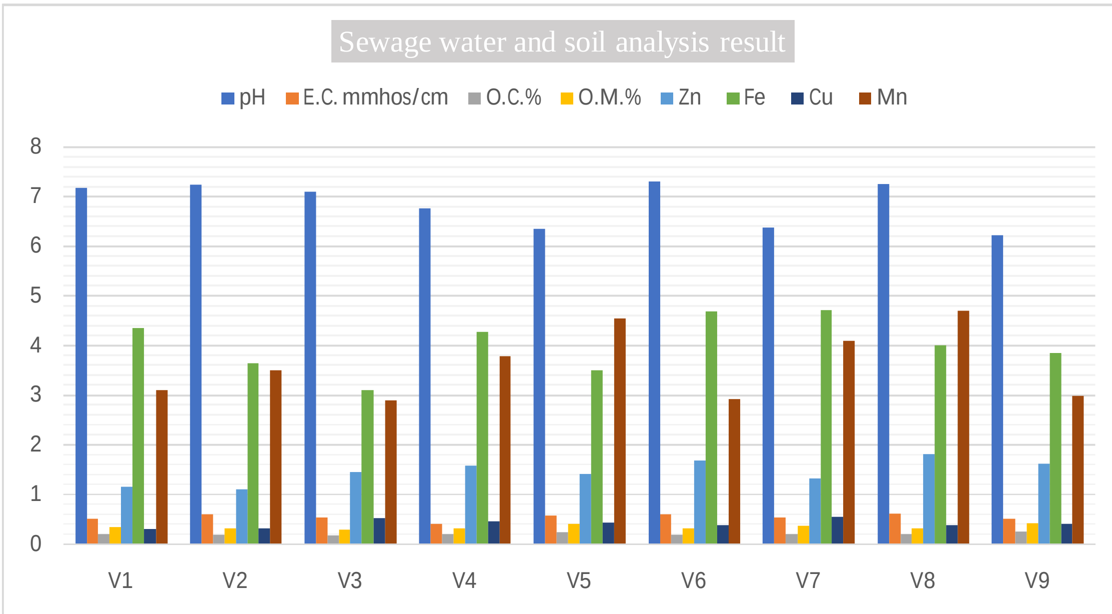

Figure 2: Results of analysis of Sewage water and soil of different Villages

Conclusion

This research has demonstrated that soil samples in Chomu, Sanganer, and Shahpura blocks have been affected by sewage water effluent, resulting in a noticeable increase in coloration, unpleasant odour, and a slightly acidic to alkaline pH. Furthermore, these soil samples contain trace amounts of metal ions at concentrations that do not meet the required standards. The study has also revealed that the effluent released from the sewage channel is significantly polluted. It is crucial to promptly implement appropriate methods for treating the effluent before it is discharged into surface water sources in order to mitigate the potential environmental risks it poses.

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