Industrial Engineering
2025, Vol. 9, No. 1, pp. 1-8
https://doi.org/10.11648/j.ie.20250901.11

Research Article

Impact of Textile Dyeing Effluent on Soil Quality Parameters

Nirma Dhaker, Preeti Mehta, Pankaj Sen*, Rajeev Mehta, Abhilasha Bhatt

Department of Chemistry, Sangam University, Bhilwara, India

Abstract

The presence of untreated textile effluents is a significant problem in urban areas. In the absence of treatment, complicated effluent that contains a number of colors, metallic pollutants, and a variety of organic chemicals that are necessary for softeing, printing, and heat stabilization can accumulate in natural sources, leaching into water and soil, and so deteriorating the quality of the soil. The primary purpose of this investigation is to investigate the influence that textile effluent has on the physicochemical characteristics of soil. The inquiry required the collection of soil samples from five different locations, each of which housed a textile dyeing business. A wide range of physicochemical characteristics, such as pH, electrical conductivity, cation exchange capacity, phosphorus, potassium, sodium, organic carbon percentage, acidity, moisture content, micronutrients (Fe, Cu, Mn, Zn), and SAR values, are evaluated in order to determine the quality of the soil. In the process of penetrating the food web, the high concentration of pollutants in the soil reduces the fertility and quality of the soil. It is of the utmost importance to take into account their direct or indirect impact on humankind. By monitoring many physicochemical parameters of polluted textile industry soil and comparing them with agricultural soil samples, the purpose of this study is to evaluate the impact that textile industries have on the quality of the soil in the Hamirgarh and Mandal RIICO industrial regions of Bhilwara.

Keywords

Heavy Metal, Sar, Dyeing Industry, Soil Qualities

1. Introduction

Soil plays a vital role in ecosystem. Soil provides ecosystem services critical for life: soil acts as a water filter and a growing medium; provides habitat for billions of organisms, contributing to biodiversity; and supplies most of the antibiotics used to fight diseases. In textile industries, fabrics were processed out through various processes such as sizing, desizing, weaving, scouring, bleaching, mercerizing, carbonizing, fulling, dyeing and finishing that merge extreme diversity in raw materials. The complex-colored textile industries effluents have considerable influence on soil feature. In worldwide scenario, about 15% of all the produced dyes are lost during the process of dyeing and finishing and released in the textile effluents that possess a strong color, fluctuating pH, high COD, and bio-toxicity [1] The city of Bhilwara's industrial expansion did not coincide with the development of its waste management infrastructure. Wastewater and ef-

*Corresponding author: pankajsunita2004@gmail.com (Pankaj Sen)

Received: 30 January 2025; **Accepted:** 11 February 2025; **Published:** 26 February 2025

fluent from almost all industries are released on land without being treated. One of the largest global industries is textiles. Industries that dye textiles have a great potential to harm the ecosystem and water supplies. According to estimates, industries use around 10,000 distinct types of dyes and pigments. The procedure employed depends on many variables, including the materials used, such as yarn, fabric, fiber, garments, and fabric construction, as well as the general kind of fiber, dye lot size, and quality requirements in the colored fabric. [2] Oil refineries, chemical complexes, fertilizer, and cement plants, soap and detergent manufacturers, tanneries for textile and dyeing paint, and light facilities in Bhilwara all discharge harmful effluents into the groundwater and soil untreated. [3, 4] During an investigation in May 2023–2024, soil samples at Bhilwara City's RIICO Industries sector were revealed. It contains a range of micronutrients and trace elements that are present in agricultural plants. Textile industries have played a significant role in Bhilwara's industrial sector tanks to the expansion of industrial and dying process houses. [5-7] Every day, almost 20 million gallons of untreated industrial wastewater are discharged near Bhilwara. To determine whether dyeing industry effluents are suitable for use as irrigation water and whether they are suitable for use in agricultural soil cultivation at various concentrations, this study aimed to characterize them in terms of their physicochemical properties and trace element contents macro & micronutrients. [8-10].

STUDY AREA: -The study was conducted in the Rico industrial area of Hamirgarh and the Mandal of Bhilwara. Rico industries road is located 15 km north and 20 km east of national highway 79. Selected from four to five industries in this area and most of the new bleaching and dying units operating in this area, soil samples were gathered in the summer of 2023- 24. This map of the Rico industrial area in Bhilwara includes many sites and locations. Site. Site. Site III. Site IV. Site V.

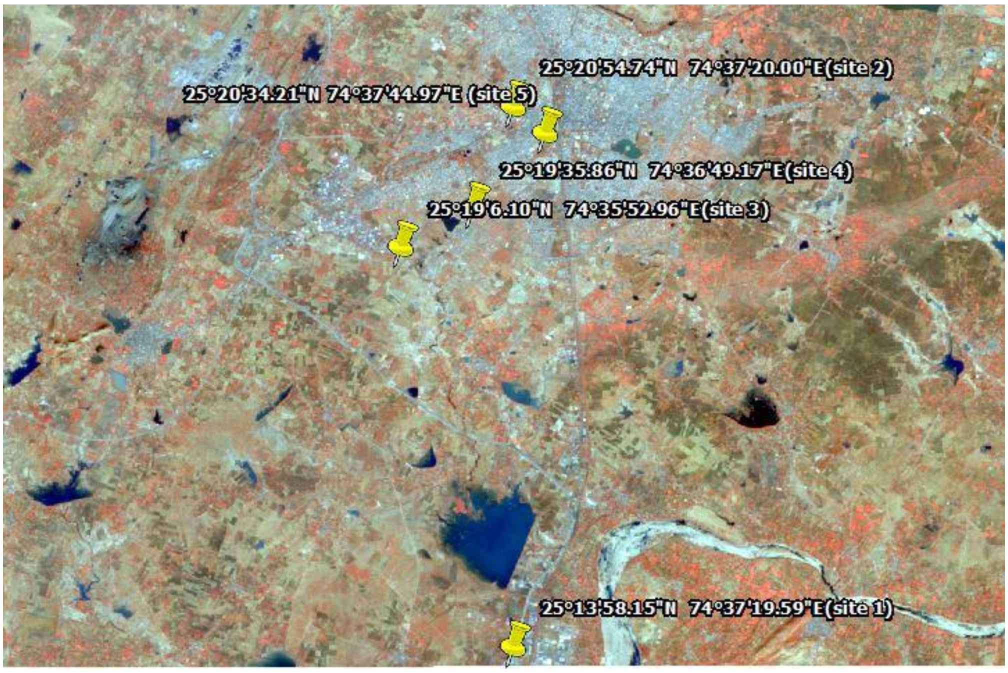

Figure 1. *Study area.*

MATERIALS AND METHODS: Soil samples were taken at five different locations: Rico Industries, Hamirgarh, and a Mandal near Bhilwara city. The effluent from Bhilwara dyeing and finishing companies was collected in 1 kg plastic containers during the summer seasons for irrigation of soil and crop cultivation. The soil for crop cultivation was taken from routinely cultivated agricultural land in the nearby industrial region, using soil sample collecting that included 9cm and 15cm depths at each site. The soil samples were gathered from all trenches and carefully mixed on the spot before being transported in large plastic bags. All the chemicals used were of analytical quality, followed by standard procedures. A similar Colour of the soil sample was recorded; the temperature was observed on the spot, pH and electrical conductivity were measured using a digital conductivity meter using 1:10 soil water suspension, and organic carbon was quantified using the "Walkley and Black's titration method. "Available In soil testing laboratories, phosphorus was measured using a stannous chloride colorimetric galvanometer, and potassium in soil K was determined using a variety of methods including volumetric, spectrographically, gravimetrically, potentiometrically, or calorimetrically, Sulphur in soil was measured using a flame photometer, and Sulphur in soil was measured using a colorimeter or spectrophotometer. The Atomic Absorption Spectrophotometer (AAS) method determines micronutrients in soil (Fe, Cu, Mn, or Zn) are determined using the Atomic Absorption Spectrophotometer (AAS) method [11].

2. Result and Discussion

Table 1 shows the values of physicochemical parameters in soil samples and industrial soil samples in each case throughout the summer season. The results were compared to the Indian Society of Soil Science's permitted standard (ISOSS). The site I; Site II; Site III; Site IV; Site V.

Dyes, bleaching chemicals, acid, metals, and micro, and macronutrients Cr, Cu, Fe, Pb, Zn, and Mn are all flown into the Bhilwara RIICO Industries region without being treated. This Nala's water is used to irrigate the neighboring crops. Metal levels fall and climb up to the allowed maximum for the parameters.

Table 1. Physicochemical parameters of soil samples.

Samples	Industrial soil	Agricultural soil	Industrial soil	Agricultural soil	Industrial soil	Agricultural soil	Industrial soil	Agricultural soil	Industrial soil	Agricultural soil	Permissible- limit (ISOSS)
Parameters	I	I	II	II	III	III	IV	IV	V	V	
Colour	Dark brown	Brown	Black	Black	Brown	Black	Black	Dark brown	Brown	Black	NA
Temperature (°C)	20.0	18.5	19.6	18.68	21.6	19.38	20.5	18.2	21.5	18.0	NA
pH	8.1	7.9	10.0	8.5	9.0	8.6	8.9	8.5	8.6	8.2	7.8.5
Electrical conductivity (µs/ms)	12.0	7.12	3.3	2.1	15.0	10.6	6.10	5.3	25.5	6.3	0-1
Organic carbon (%)	2.1	1.9	1.15	1.5	0.10	0.55	0.96	0.50	0.20	0.52	0.5-0.75
K (mg/l)	850	788	860	500	620	400	860	860	840	820	142-337
P (mg/l)	150	32	16	10	40	30	110	50	82	24	23-56
Fe (mg/l)	2.280	1.21	10.32	6.341	1.10	1.09	2.890	6.130	3.132	2.989	4.5
Cu (mg/l)	3.228	1.868	3.201	1.950	2.102	2. 247	2.122	1.978	4.326	2.214	0.20
Mn (mg/l)	0.520	0.321	1.252	0.904	1.201	0.120	0.780	0.234	3.040	4.160	2.0
Zn (mg/l)	0.912	0.403	2.524	1.103	3.020	2.976	1.582	0.978	1.439	2.112	0.6

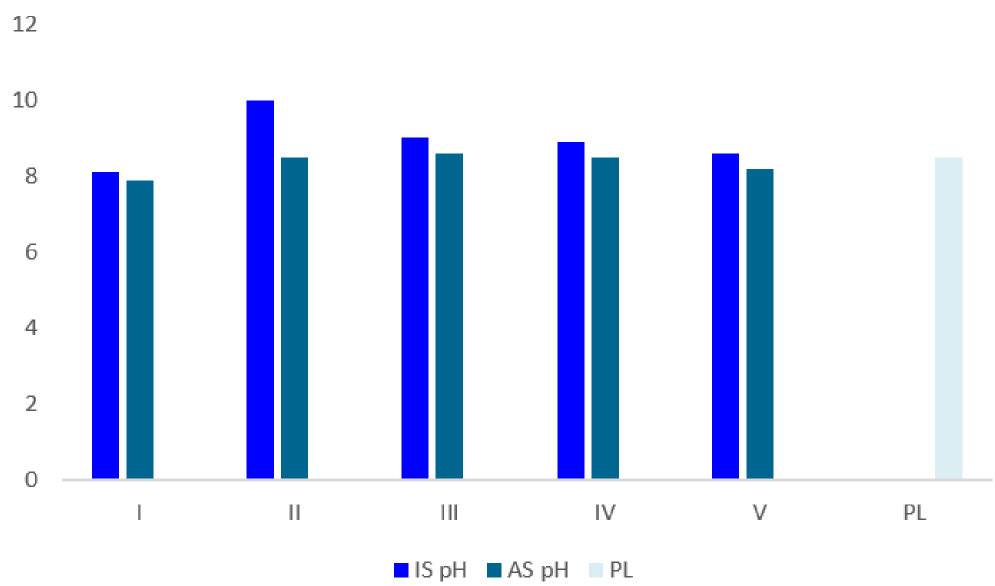

Figure 2. Compression of pH in selected study areas.

pH: The pH of the soil is a measurement of its acidity or alkalinity. ISOSS has defined a standard acceptable level of 7-8.5 for agriculture soil. The pH value ranged from 7.9 to 10.0 maximum pH at Site II in the current study, showing the discharge of alkaline effluents from the textile industry. [Figure 2]

Electrical conductivity (E. C.): The conductivity of the soil around the industry has increased due to ionic particles in the effluent. The E. C. values in this study ranged from 2.1 to 25.5 µs/ms for all samples. Its maximum speed is 0-1µs/ms. At Site V, the most significant value was recorded. [Figure 3]

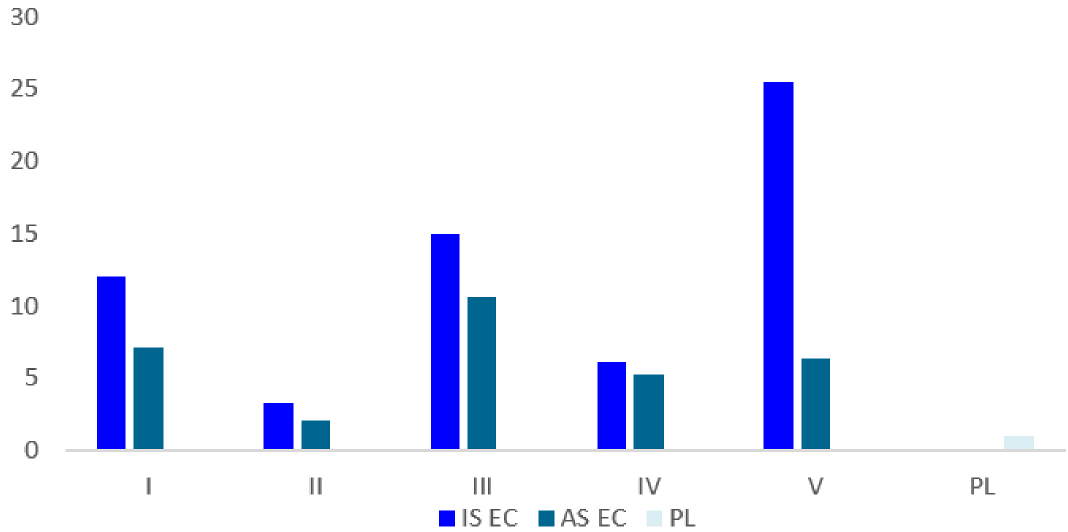

***Figure 3**. Compression of EC in selected study areas.*

Organic carbon (%): The readings are more significant than the agriculture soil at site one (1.3), showing more cation and anion availability in these places. In this study, the most effective value of Organic Carbon detected around the industry is 2.1 percent, while the lowest value is 0.10 % at Site I and Site III. [Figure 4]

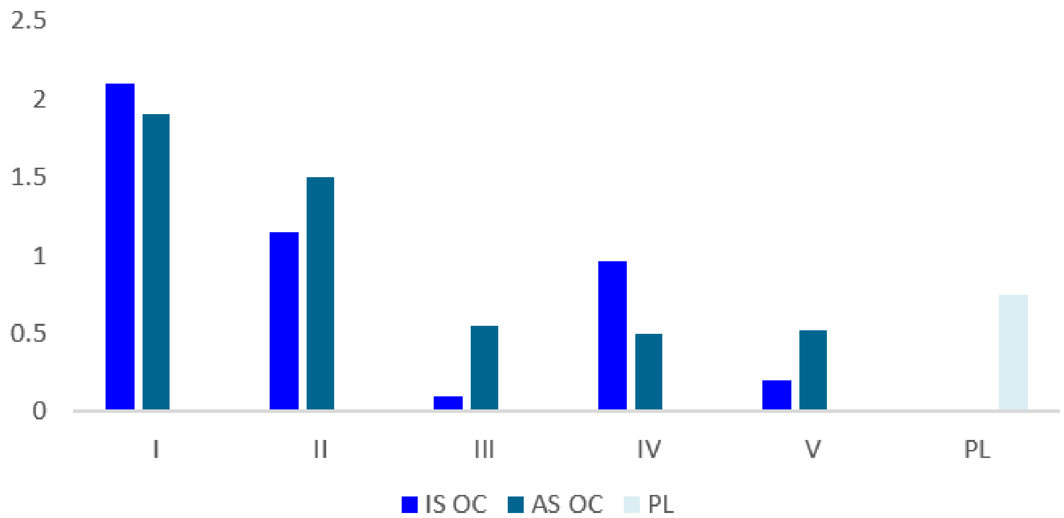

***Figure 4**. Compression of OC in selected study areas.*

Potassium (mg/l): The contamination concentrations in soil samples ranged from 400 to 860 mg/l, above the allowed limit of potassium in agriculture soil 142 to 337 mg/l. The maximum value 860 mg/l was observed in more than one site for the IV and II sites. [Figure 5]

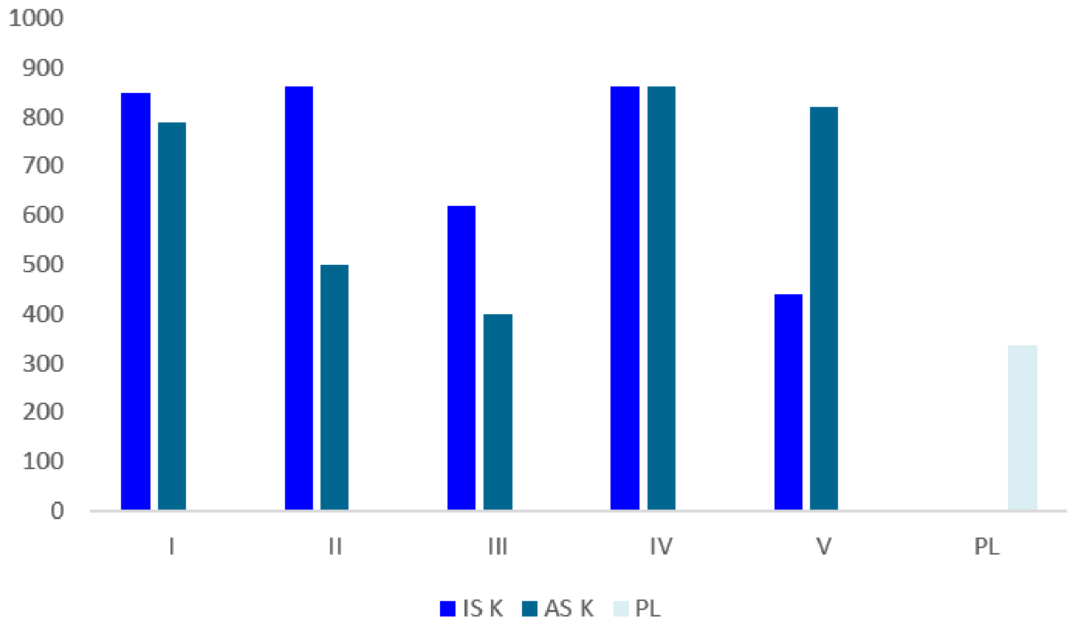

Figure 5. *Compression of K in selected study areas.*

Phosphorus (mg/l): Inorganic phosphate in contaminated soil was relatively high, with most samples falling below the recommended threshold of 10 to 150 mg/l. According to ISOSS, the acceptable limit is 23 to 56 mg/l. The maximum result reported for the I site was 150 mg/l. [Figure 6]

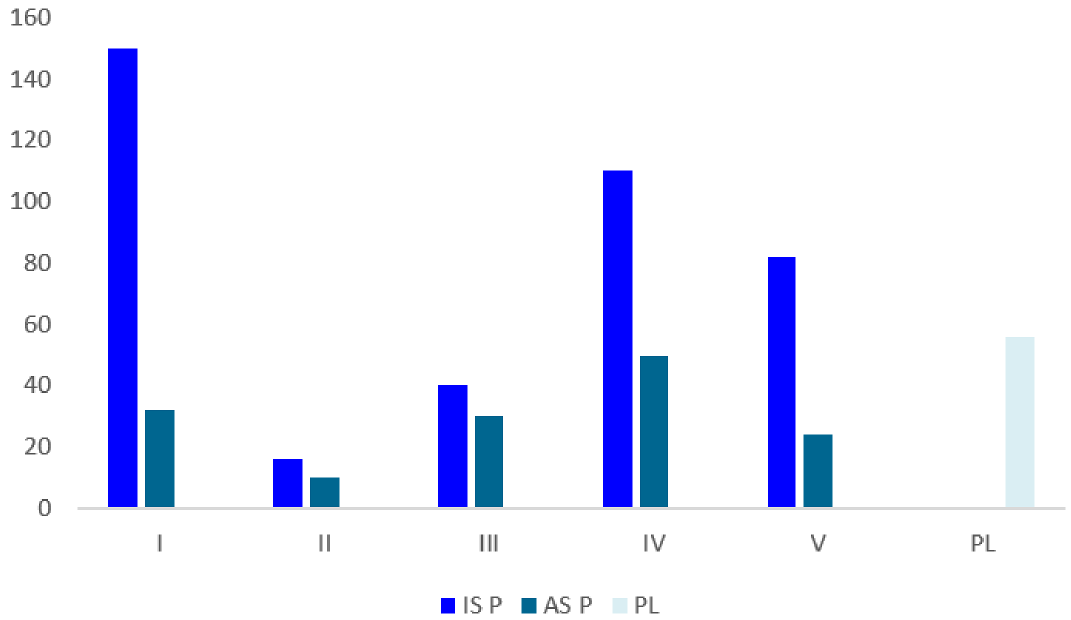

Figure 6. *Compression of P in selected study areas.*

Iron (mg/l): The iron levels in the research sites ranged from 1.09 to 10.32 mg/l. The maximum permissible concentration is 4.5 mg/l. The highest value was found at site II. [Figure 7]

Copper (mg/l): The concentration of copper ions in all samples. According to ISOSS, the permitted limit is 0.20 mg/l. Copper ion contamination varied from 1.868 to 4.326 mg/l. [Figure 8]

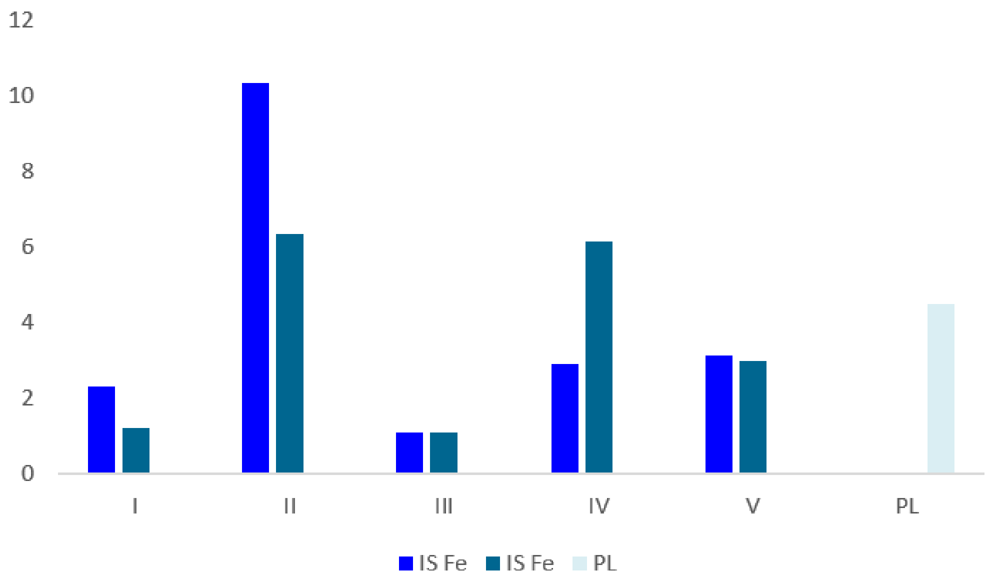

Figure 7. *Compression of Fe in selected study areas.*

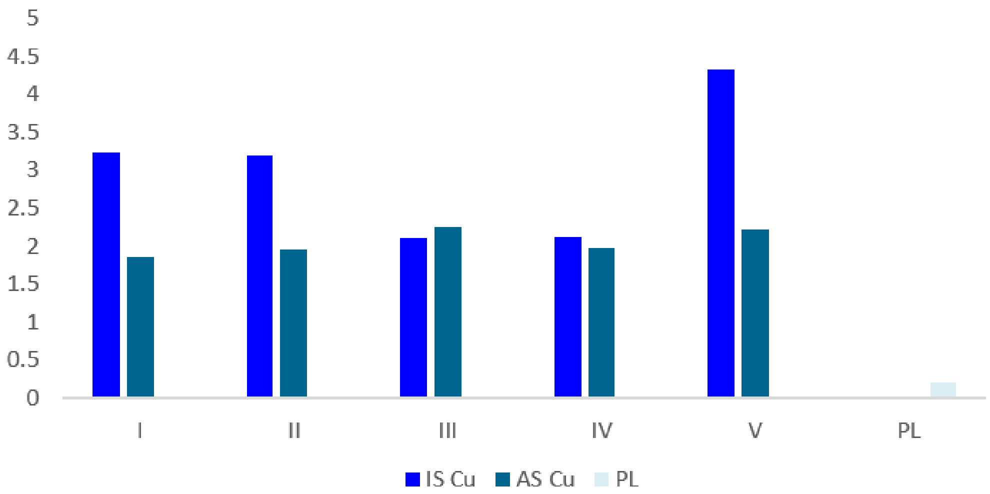

Figure 8. *Compression of Cu in selected study areas.*

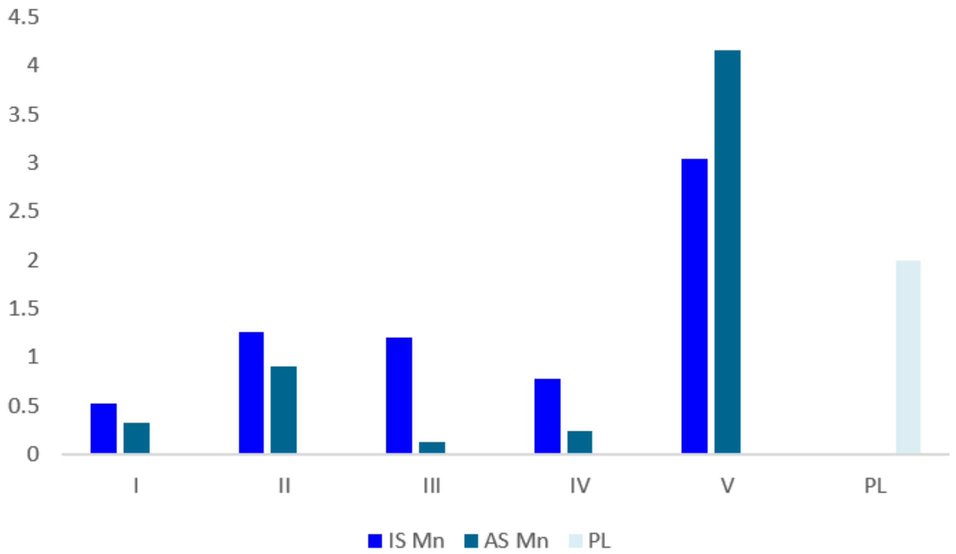

Figure 9. *Compression of Mn in selected study areas.*

Manganese (mg/l): In the concentration of manganese ions in the soil sample. ISOSS 2.0mg/l is the standard acceptable level for soil. The selection Mn in this investigation ranged in the concentration ranges from 0.120 to 4.160 mg/l. The highest value was found at location V. [Figure 9]

Zinc (mg/l): The ion of Zn has a standard allowed limit of 0.6 mg/l in soil ISOSS. The sample concentrations in this investigation ranged from 0.403 to 3.020 mg/l. At site III, the highest value was reported. [Figure 10]

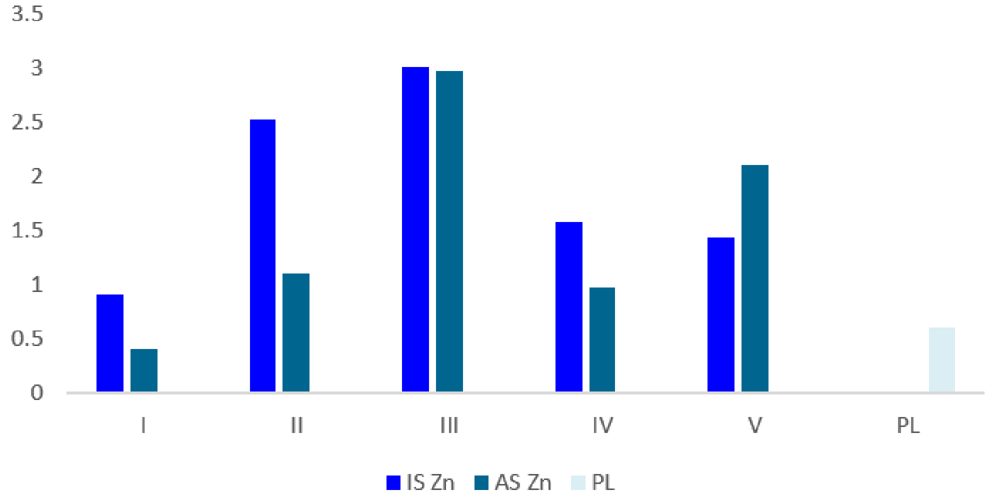

Figure 10. *Compression of Zn in selected study areas.*

3. Conclusion

This study aims to demonstrate the harmful effects of textile mill effluent on the soil. Textile mill effluents are complex because they contain a variety of dyes, metal contaminations, and other organic agents that can accumulate in natural sources under different operating conditions; soil and water after untreated disposal may be toxic to ecosystems and humans' life. The investigation has shown that toxic colors and significant levels of organic pollutants are present in the effluent produced by textile processing facilities in the RIICO Industries region of the Bhilwara district. According to the study, the soil contained the highest concentrations of O. C., E. C., and micronutrients as well as heavy metal contamination. what must be accomplished before the wastewater is discharged during treatment. Industrial enterprises are required to develop and maintain effluent treatment units. Industries are required to uphold the minimal standard specified in the ETP evaluation guide. High levels of industrial effluent contamination cause problems with the soil, water, and environment that influence plant fertility and yield in this area. The application of industrial effluent affected the soil's physicochemical characteristics, as well as its quality and fertility, which means that the quality of the soil is not acceptable for cultivation, according to the report's results.

Abbreviations

AAS	Atomic Adsorption Spectrophotometer
SAR	Specific Absorption Ratio
COD	Chemical Oxygen Demand
ISOSS	Indian Society of Soil Science's Permitted Standard
EC	Electrical Conductance
OC	Organic Carbon

Acknowledgments

The industrial region is unfit for use as a drinking area, and it generally harms irrigation water and agricultural production. Sangam University, Agriculture, and PHED labs are all located in Bhilwara. DFRS Arjiya Bhilwara, Bhilwara's sewage water treatment facility.

Author Contributions

Nirma Dhaker: Data curation, Methodology, Resources, Writing – original draft

Preeti Mehta: Methodology, Supervision, Validation

Pankaj Sen: Conceptualization, Investigation, Methodology, Supervision

Rajeev Mehta: Validation, Visualization

Abhilasha Bhatt: Formal Analysis, Methodology

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Markandeya, D. Mohan, and S. P. Shukla, "Hazardous consequences of textile mill effluents on soil and their remediation approaches," journal Cleaner Engineering and Technology vol. 7, pp 100434, 2022.

[2] P. K. Bharti, and C. Awnish, "Soil quality and contamination", Discovery Publishing House, Delhi, pp 186, 2013.

[3] S. Sumithra, and C. Ankalaiah, J. D. Rao, R. T. Yamuna, "Case study of physicochemical characterization of soil around the industrial and agricultural area of Yerraguntla, Kadapa District, A. P, India. Int. J. of Geology, Earth & Environmental Sciences, vol. 3, pp 8-34, 2013.

[4] S. K. Bajpai, et al., "Seasonal Analysis of Soil Sediment of Shahpura Lake of Bhopal", International Journal of Environmental Science and Development, vol. 1, no. 4, 2010.

[5] F. Degryse et al., "Soil management and fertilizer practices affecting crop production and human health. In The Nexus of Soils, Plants, Animals, and Human Health", Stuttgart, Germany: Schweizerbart, pp. 111-121, 2017.

[6] C. Barot. and V. Patel., "Comparative study of seasonal variation in Physicochemical Properties of selected wetlands of Mehsana district, North Gujarat", Jan. Indian Journal of applied research, vol. 4, no. 7, ISSN- 2249- 555X JULY 2014.

[7] Thesis: Verma, R, "A Chemical Study On Industrial Effluent On Soil and Water Around Bilaspur", Dr. C. V. Raman University Department of Chemistry, Completed the year 2015.

[8] Sen, P., Mehta, R. & Mehta, P. Water quality assessment of Banas River, eastern-south region of Rajasthan, using water quality index. Proc. Indian Natl. Sci. Acad. 89, 134–142 (2023). https://doi.org/10.1007/s43538-022-00145-7

[9] N. Dhaker, P. Mehta and R. Mehta, Impact of Dying Industrial Effluent on Physicochemical Parameters of Ground Water Quality of Industrial Area of Bhilwara, Rajasthan. Studies in Indian Place-Names. ISSN: 2394- 3114 vol. 40, Issue 68, 2020.

[10] L. Baskaran, et al., "Amelioration of Sugar Mill Effluent Polluted Soil and its Effect on Green gram (Vigna radiate L.)", Botany Research International, vol. 2, no. 2, pp. 131-135, 2009.

[11] N. Dhaker, P. Mehta, and R. Mehta, Impact of Dye Industrialeffluent on Soil Quality Parameters at Rico Industrial Area Bhilwara Rajasthan. Journal Biosci. Biotech. Res. Comm. Special Issue vol 13 No 10 Pp. 293-296, 2020.