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# HEAVY METALS TOXICITY ASSESSMENT IN DIFFERENT TEXTURED SOILS HAVING WASTEWATER IRRIGATION

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## SUMMARY

Farmers are using municipal wastewater—either treated or untreated—for irrigation because of limited freshwater resources. The current study conducted a detailed survey of areas using consistent irrigation with wastewater. Soil and water samples collected from the selected sites include the suburbs of Sargodha, i.e., Chak No. 79, Raza Garden, Chak. No. 50Nb, Hameed Town, Istaqlalabad Colony, and underwent laboratory analysis. The maximum EC (3.64 dS $m^{-1}$) resulted in wastewater samples collected from Raza Garden and the highest SAR (7.04) and RSC (2.28 me $L^{-1}$) came from wastewater samples collected from Chak No. 79. Maximum lead, nickel, and arsenic analysis were 2.52, 0.15, and 0.06 mg $L^{-1}$, respectively, from wastewater samples collected from Chak. No. 50Nb, with a uniform concentration of cadmium (0.01 mg $L^{-1}$) in wastewater samples collected from all five mentioned sites e. The maximum pH (8.25), SAR (13.69), organic matter (0.68%), lead (11.56 mg $kg^{-1}$), cadmium (1.71 mg $kg^{-1}$), nickel (12.85 mg $kg^{-1}$), and arsenic (4.62 mg $kg^{-1}$) emerged from soil samples collected from the Raza Garden site. On the other hand, the highest EC (4.12 dS $m^{-1}$) occurred in soil samples of the Istaqlalabad Colony. Based on these results, an urgent advisory should reach the farming community not to use wastewater for irrigation in untreated form because it has ill effects on soil health, contaminating the plants.

**Keywords:** Heavy metals, wastewater, toxicity, soil and water properties

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**Key findings:** The untreated form of wastewater used for irrigation enriches the soil in toxic heavy metals (Pb, Cd, Ni, and As), which poses serious hazards. These heavy metals, exceeding their critical level, injure soils, plants, animals, and human health.

## INTRODUCTION

Water scarcity is critical to sustainable farming progress, particularly in dryland agricultural parts of the world (Smith *et al*., 2018). Now, farmers need to utilize urban wastewater in these areas for irrigation (Johnson and Thompson, 2019). As the global population continues to increase and the demand for food rises, water resources dwindle, and the long-distance transport of water substantially strains agricultural productivity (Brown *et al*., 2022). Utilizing treated urban wastewater for irrigation offers a potential solution by mitigating water shortages, enhancing water usage efficiency, and reducing water pollution. Optimal utilization of all available water resources, including treated urban wastewater, becomes crucial in dry and semi-arid climates due to the immense pressure on non-renewable water sources, prolonged drought periods, and rapid urbanization (White *et al*., 2017). Hence, the reuse of treated urban wastewater emerges as an unconventional yet promising water resource, alleviating water scarcity concerns to some extent (Garcia *et al*., 2020). As wastewater contains essential plant nutrients, it becomes imperative to establish proper guidelines for its utilization to minimize the adverse effects associated with wastewater irrigation and maximize its performance (Adams *et al*., 2021). Furthermore, this is indispensable to judge other impacts of wastewater, e.g., changes in soil and plant elemental composition, pollutants, and heavy metals accumulation (Lee *et al*., 2019).

On the contrary, wastewater is a good reservoir for agricultural purposes because it contains many nutrients beneficial in agriculture, aquaculture, and other activities (Hussain *et al*., 2002). The most common method is to dump municipal wastewater (untreated and treated) onto the land in developing or developed countries. Most wastewater irrigates the fiber, seed, and feed crops, and to some extent, vineyards, orchards, and other crops in developed countries by following environmental standards. Environmental beautification, groundwater replenishment, aquaculture, improving wildlife habitat, construction, industry, and dust removal are other practices for reusing wastewater. Enforcement of standards, successfully established in developing countries, is not always strict. In Mexico, India, and China, untreated wastewater release has been most common in aquaculture and agriculture for hundreds of years (Hussain *et al*., 2002).

Wastewater contains many types of pollutants. When using this wastewater for irrigation, these pollutants migrate to the soil. Plants growing from such soils uptake these pollutants. Subsequently, utilization of these plants transfers these toxic elements to animals and human beings, the ultimate end users. Hence, there is a dire need for time to address this crucial problem of agriculture directly linked to plants, animals, and human lives.

Given the above, there is much gap between the usage of wastewater in untreated and treated form. Farmers habitually use wastewater in an untreated form that is dangerous for soil, plants, animals, and human beings. However, when the same wastewater undergoes suitable treatment before application, it has a beneficial impact. Thus, it is about time to awaken the farming community from the peculiar wastewater usage in a scientific way to benefit from it rather than lose. Hence, the presented survey study commenced with the following hypothesis:

**H0**: Heavy metals may remain unpolluted when consistently irrigated with wastewater

**H1**: Those heavy metals may concentrate in soil which are found in wastewater

## MATERIALS AND METHODS

This study sought to explore toxicity types created due to different pollutants in the soil when irrigated with wastewater. This experiment included a thorough investigation of the region receiving regular wastewater irrigation. Soil samples came from five separate locations in the suburbs of Sargodha and sustained chemical analysis in the laboratory. Chemical properties (EC, pH, SAR), different heavy metals (lead, cadmium, nickel, and arsenic), soil texture, and organic matter underwent analysis in the samples.

### Treatments

Separate block sampling ensued on soil and wastewater of various industries producing and processing different products. Collecting five from each sample comprised Factor A (Sampling sites/locations), Factor B (Number of soil samples/sites), and Factor C (Wastewater sampling from each location).

### Methodology

For this purpose, five varied sites selected included i) Chak. No. 79, ii) Raza Garden, iii) Chak. No. 50Nb, iv) Hameed Town, and v) Istaqlalabad Colony, considering the varying sources of wastewater irrigation. From each site, five soil samples collected were random from a depth of 0–15 cm, with a sample of wastewater used as a source of irrigation. The collected soil samples received analysis for EC, pH, SAR, organic matter, soil texture, and selected heavy metals (lead, cadmium, nickel, and arsenic). Similarly, five wastewater samples collected from each site also underwent analysis for the above parameters.

### Protocols and analysis for soil, plant, and water samples

All laboratory analyses for soil and water samples followed the methods written in Handbook 60 of the U.S. Laboratory Staff (1969) or otherwise mentioned.

### Soil texture

The hydrometer method usage determined the soil textural class. The International Textural Triangle, which offers a categorization system based on the proportions in the soil's sand, silt, and clay (Moreno *et al*., 2022), helped identify the soil textural class.

### Residual sodium carbonates (RSC) measurement (meL$^{-1}$)

Applying Eaton's (1950) equation computed the RSC:

$$RSC = (CO_3^{-2} + HCO_3^{-}) - (Ca^{++} + Mg^{++}).$$

All appeared as me L$^{-1}$.

### Soil organic matter (%)

The method of Walkley and Black (1934) aided in calculating the total soil organic carbon content.

### Heavy metals measurements (Pb, Cd, Ni, and As)

After the digestion of soil and plant samples, determining heavy metals (Pb, Cd, Ni, and As) used the atomic absorption spectrophotometer (Smith *et al*., 2018).

### Statistical analysis

According to the procedure outlined by Steel *et al*. (1997), significant differences between treatment effects' identification employed the LSD test at a 1% probability level, with these differences marked by various letters (a, b, c, etc.).

## RESULTS

### Characterization of wastewater of Chak. No. 79, Sargodha

The standard deviations (SD) for each parameter provide insights into the

**Table 1.** Analysis of wastewater of Chak No. 79, Sargodha (Site: 72.62997-32.05458).

| Parameters | $EC_{ww}$ (dS $m^{-1}$) | pH | SAR | RSC (me $L^{-1}$) | Pb (mg $L^{-1}$) | Cd | Ni | As |
|---|---|---|---|---|---|---|---|---|
| Means | 2.37 | 7.20 | 7.04 | 2.28 | 2.51 | 0.01 | 0.12 | 0.05 |
| SD | 0.111 | 0.158 | 0.419 | 0.164 | 0.148 | 0.002 | 0.035 | 0.021 |
| Range | 0.26 | 0.4 | 1.04 | 0.4 | 0.4 | 0.006 | 0.09 | 0.05 |

Means: Means of five wastewater samples, SD: Standard Deviation, Range: Ranges of various parameters

inconsistency or spread of data about the mean (Table 1). Mean values of various parameters like EC, pH, SAR, and RSC appeared as 2.37 dS $m^{-1}$, 7.20, 7.04, and 2.28 me $L^{-1}$, respectively. Similarly, mean values for the concentration of four heavy metals were 2.51, 0.01, 0.12, and 0.05 mg $L^{-1}$ for Pb, Cd, Ni, and As, respectively. These mean values for all eight parameters represented the average of five wastewater samples. The standard deviation for EC, pH, SAR, RSC, Pb, Cd, Ni, and As is 0.111 dS $m^{-1}$, 0.158, 0.419, 0.164 meq $L^{-1}$, 0.148, 0.002, 0.035, and 0.021 mg $L^{-1}$, respectively. The range for EC, pH, SAR, RSC, Pb, Cd, Ni, and As is 0.26 dS $m^{-1}$, 0.4, 1.04, 0.4 meq $L^{-1}$, 0.4, 0.006, 0.09, and 0.05 mg$L^{-1}$, respectively.

**Analysis of soil samples of Chak. No. 79, Sargodha**

The average values of EC, pH, SAR, organic matter, Pb, Cd, Ni, and As reached scores of 2.77 dS $m^{-1}$, 7.26, 8.75, 0.66%, 5.63, 0.73, 5.76, and 2.64 mg $kg^{-1}$, respectively (Table 2). The standard deviation values for soil EC, pH, SAR, organic matter, Pb, Cd, Ni, and As remained at 0.257 dS $m^{-1}$, 0.084, 0.751, 0.067%, 0.471, 0.131, 0.938, and 0.674 mg $kg^{-1}$, respectively. The rate for EC, pH, SAR, organic matter, Pb, Cd, Ni, and As were 0.81 dS $m^{-1}$, 0.3, 1.97, 0.2%, 1.23, 0.37, 3.01, and 1.99 mg $kg^{-1}$, respectively.

**Characterization of wastewater of Raza Garden, Sargodha**

The standard deviations (SD) for each parameter provide insights into the inconsistency or spread of data about the mean (Table 3). Mean values of various parameters like EC, pH, SAR, and RSC resulted in 3.64 dS $m^{-1}$, 7.07, 6.12, and 1.1 me $L^{-1}$, respectively. Similarly, mean values for the concentration of four heavy metals were 2.44, 0.01, 0.14, and 0.06 mg $L^{-1}$ for Pb, Cd, Ni, and As, respectively. These mean values for all eight parameters represented the average of five wastewater samples. The standard deviation for EC, pH, SAR, RSC, Pb, Cd, Ni, and As is 0.086 dS $m^{-1}$, 0.079, 0.297, 0.2 meq$L^{-1}$, 0.304, 0.004, 0.023, and 0.016 mg $L^{-1}$, respectively. The range for EC, pH, SAR, RSC, Pb, Cd, Ni, and As is 0.2 dS $m^{-1}$, 0.2, 0.64, 0.5 meq $L^{-1}$, 0.7, 0.001, 0.06, and 0.04 mg $L^{-1}$, respectively.

**Analysis of soil samples of Raza Garden, Sargodha**

The average values of EC, pH, SAR, organic matter, Pb, Cd, Ni, and As, as determined, were 2.95 dS $m^{-1}$, 8.25, 13.69, 0.68%, 11.56, 1.71, 12.85, and 4.62 mg $kg^{-1}$, respectively (Table 4). The standard deviation values for soil EC, pH, SAR, organic matter, Pb, Cd, Ni, and As remained at 0.534 dS $m^{-1}$, 0.108, 1. 045, 0.082%, 0.496, 0.139, 0.911, and 0.646 mg $kg^{-1}$, respectively. The range for EC, pH, SAR, organic matter (%), Pb, Cd, Ni, and As was 1.55 dS $m^{-1}$, 0.3, 2.99, 0.21%, 1.16, 0.41, 2.98, and 1.92 mg $kg^{-1}$, respectively.

**Characterization of wastewater of Chak. No. 50Nb, Sargodha**

The standard deviations (SD) for each parameter provide insights into the inconsistency or spread of data about the mean (Table 5). Mean values of various parameters like EC, pH, SAR, and RSC were at 3.56 dS $m^{-1}$, 7.14, 6.69, and 1.12 me $L^{-1}$, respectively. Similarly, mean values for the concentration of four heavy metals were 2.52,

**Table 2.** Analysis of soil in Chak No. 79, Sargodha (Site: 72.62997-32.05458).

| Parameters | Texture | EC ($dS\ m^{-1}$) | pH | SAR | OM (%) | Pb | Cd | Ni | As |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | ($mg\ kg^{-1}$) | | | |
| Means | Sandy Clay | 2.77 | 7.26 | 8.75 | 0.66 | 5.63 | 0.73 | 5.76 | 2.64 |
| SD | Loam | 0.257 | 0.084 | 0.751 | 0.067 | 0.471 | 0.131 | 0.938 | 0.674 |
| Range | | 0.81 | 0.3 | 1.97 | 0.2 | 1.23 | 0.37 | 3.01 | 1.99 |

Means: Means of five soil samples, SD: Standard Deviation, Range: Range of various parameters

**Table 3.** Analysis of wastewater of Raza Garden, Sargodha (Site: 72.386 -32.341).

| Parameters | $EC_{ww}$ ($dS\ m^{-1}$) | pH | SAR | RSC ($me\ L^{-1}$) | Pb | Cd | Ni | As |
|---|---|---|---|---|---|---|---|---|
| | | | | | ($mg\ L^{-1}$) | | | |
| Means | 3.64 | 7.07 | 6.12 | 1.1 | 2.44 | 0.01 | 0.14 | 0.06 |
| SD | 0.086 | 0.079 | 0.297 | 0.2 | 0.304 | 0.004 | 0.0230 | 0.016 |
| Range | 0.2 | 0.2 | 0.64 | 0.5 | 0.7 | 0.01 | 0.06 | 0.04 |

Means: Means of five wastewater samples, SD: Standard Deviation, Range: Range of various parameters

**Table 4.** Analysis of soil in Raza Garden, Sargodha (Site: 72.386 -32.341).

| Parameters | Texture | EC ($dS\ m^{-1}$) | pH | SAR | OM (%) | Pb | Cd | Ni | As |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | ($mg\ kg^{-1}$) | | | |
| Means | Clay Loam | 2.95 | 8.25 | 13.69 | 0.68 | 11.56 | 1.71 | 12.85 | 4.62 |
| SD | | 0.534 | 0.108 | 1.045 | 0.082 | 0.496 | 0.139 | 0.911 | 0.646 |
| Range | | 1.55 | 0.3 | 2.99 | 0.21 | 1.16 | 0.41 | 2.98 | 1.92 |

Means: Means of five soil samples, SD: Standard Deviation, Range: Ranges of various parameters

**Table 5.** Analysis of wastewater of Chak. No. 50Nb, Sargodha (Site: 72.72242-32.05202).

| Parameters | $EC_{ww}$ ($dS\ m^{-1}$) | pH | SAR | RSC ($me\ L^{-1}$) | Pb | Cd | Ni | As |
|---|---|---|---|---|---|---|---|---|
| | | | | | ($mg\ L^{-1}$) | | | |
| Means | 3.56 | 7.14 | 6.69 | 1.12 | 2.52 | 0.01 | 0.16 | 0.06 |
| SD | 0.072 | 0.058 | 0.281 | 0.164 | 0.334 | 0.005 | 0.030 | 0.022 |
| Range | 0.17 | 0.15 | 0.66 | 0.4 | 0.8 | 0.014 | 0.07 | 0.06 |

Means: Means of five wastewater samples, SD: Standard Deviation, Range: Range of various parameters

0.01, 0.16, and 0.06 mg $L^{-1}$ for Pb, Cd, Ni, and As, +respectively. These mean values for all eight parameters represented the average of five wastewater samples. The standard deviation for EC, pH, SAR, RSC, Pb, Cd, Ni, and As is 0.072 dS $m^{-1}$, 0.058, 0.281, 0.16 meq $L^{-1}$, 0.334, 0.005, 0.030 and 0.022 mg $L^{-1}$, respectively. The range for EC, pH, SAR, RSC, Pb, Cd, Ni, and As are 0.17dS $m^{-1}$, 0.15, 0.66, 0.4 meq $L^{-1}$, 0.8, 0.014, 0.07, and 0.06mg $L^{-1}$, respectively.

**Analysis of soil samples of Chak. No. 50Nb, Sargodha**

The average values of EC, pH, SAR, organic matter, Pb, Cd, Ni, and As occurred as 2.90 dS $m^{-1}$, 7.56, 8.67, 0.67%, 5.56, 0.71, 6.42, and 3.28 mg $kg^{-1}$, respectively (Table 6). The standard deviation values for soil EC, pH, SAR, organic matter, Pb, Cd, Ni, and As remained at 0.223 dS $m^{-1}$, 0.096, 0.901, 0.063%, 0.496, 0.135, 1.332, and 0.804 mg $kg^{-1}$, respectively.

**Table 6.** Analysis of soil in Chak. No. 50Nb, Sargodha (Site: 72.72242-32.05202).

| Parameters | Texture | EC ($dS\ m^{-1}$) | pH | SAR | OM (%) | Pb | Cd | Ni | As |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | ($mg\ kg^{-1}$) | | | |
| Means | Sandy | 2.90 | 7.56 | 8.67 | 0.67 | 5.56 | 0.71 | 6.42 | 3.28 |
| SD | Clay | 0.223 | 0.096 | 0.901 | 0.063 | 0.496 | 0.135 | 1.332 | 0.804 |
| Range | Loam | 0.69 | 0.3 | 2.82 | 0.17 | 1.16 | 0.44 | 4.03 | 2.11 |

Means: Means of five soil samples, SD: Standard Deviation, Range: Ranges of various parameters

**Table 7.** Analysis of wastewater of Hameed Town, Sargodha (Site: 72.65069-32.08014).

| Parameters | $EC_{ww}$ ($dS\ m^{-1}$) | pH | SAR | RSC ($me\ L^{-1}$) | Pb | Cd | Ni | As |
|---|---|---|---|---|---|---|---|---|
| | | | | | ($mg\ L^{-1}$) | | | |
| Means | 3.23 | 7.07 | 5.63 | 1.34 | 2.44 | 0.01 | 0.14 | 0.06 |
| SD | 0.148 | 0.079 | 0.363 | 0.207 | 0.304 | 0.004 | 0.023 | 0.015 |
| Range | 0.38 | 0.2 | 0.92 | 0.5 | 0.7 | 0.01 | 0.06 | 0.04 |

Means: Means of five wastewater samples, SD: Standard Deviation, Range: Range of various parameters

**Table 8.** Analysis of soil in Hameed Town, Sargodha (Site: 72.65069-32.08014).

| Parameters | Texture | EC ($dS\ m^{-1}$) | pH | SAR | OM (%) | Pb | Cd | Ni | As |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | ($mg\ kg^{-1}$) | | | |
| Means | Clay Loam | 3.73 | 7.54 | 11.56 | 0.67 | 5.81 | 0.73 | 6.81 | 2.56 |
| SD | | 0.560 | 0.096 | 1.773 | 0.111 | 0.590 | 0.118 | 1.043 | 0.637 |
| Range | | 1.46 | 0.2 | 4.63 | 0.35 | 1.96 | 0.32 | 3.39 | 1.93 |

Means: Means of five soil samples, SD: Standard Deviation, Range: Ranges of various parameters

The EC, pH, SAR, organic matter (%), Pb, Cd, Ni, and As ranges were 0.69 $dS\ m^{-1}$, 0.3, 2.82, 0.17%, 1.16, 0.44, 4.03, and 2.11 $mg\ kg^{-1}$.

**Characterization of wastewater of Hameed Town, Sargodha**

The standard deviations (SD) for each parameter provide insights into the inconsistency or spread of data about the mean (Table 7). Mean values of various parameters like EC, pH, SAR, and RSC were at 3.23 $dS\ m^{-1}$, 7.07, 5.63, and 1.34 $me\ L^{-1}$, respectively. Similarly, mean values for the concentration of four heavy metals were 2.44, 0.01, 0.14, and 0.06 $mg\ L^{-1}$ for Pb, Cd, Ni, and As, respectively. These mean values for all eight parameters represented the average of five wastewater samples. The standard deviation for EC, pH, SAR, RSC, Pb, Cd, Ni, and As is 0.148 $dS\ m^{-1}$, 0.079, 0.363, 0.20 $meq\ L^{-1}$, 0.304, 0.004, 0.023, and 0.015 $mg\ L^{-1}$, respectively. The range in EC, pH, SAR, RSC, Pb, Cd, Ni, and As is 0.38 $dS\ m^{-1}$, 0.2, 0.92, 0.5 $meq\ L^{-1}$, 0.7, 0.01, 0.06, and 0.04 $mg\ L^{-1}$, respectively.

**Analysis of soil samples of Hameed Town, Sargodha**

The average values of EC, pH, SAR, organic matter, Pb, Cd, Ni, and As were at 3.73 $dS\ m^{-1}$, 7.54, 11.56, 0.67%, 5.81, 0.73, 6.81, and 2.55 $mg\ kg^{-1}$, respectively (Table 8). The standard deviation values for soil EC, pH, SAR, organic matter, Pb, Cd, Ni, and As remained at 0.560 $dS\ m^{-1}$, 0.096, 1.773, 0.111%, 0.590, 0.118, 1.043, and 0.637 $mg\ kg^{-1}$, respectively. The range in EC, pH, SAR, organic matter (%), Pb, Cd, Ni, and As was 1.46 $dS\ m^{-1}$, 0.2, 4.63, 0.35%, 1.96, 0.32, 3.39, and 1.93 $mg\ kg^{-1}$.

**Characterization of wastewater of Istaqlalabad Colony, Sargodha**

The standard deviations (SD) for each parameter provide insights into the inconsistency or spread of data about the mean (Table 9). Mean values of various parameters like EC, pH, SAR, and RSC resulted in 3.38 $dS\ m^{-1}$, 7.2, 5.94, and 0.58 $me\ L^{-1}$, respectively. Similarly, mean values for the concentration of four heavy metals were 2.52,

**Table 9.** Analysis of wastewater of Istaqlalabad Colony, Sargodha (Site: 72.64151-32.06997).

| Parameters | $EC_{ww}$ (dS $m^{-1}$) | pH | SAR | RSC (me $L^{-1}$) | Pb | Cd | Ni | As |
|---|---|---|---|---|---|---|---|---|
| | | | | | (mg $L^{-1}$) | | | |
| Means | 3.38 | 7.2 | 5.94 | 0.58 | 2.52 | 0.01 | 0.13 | 0.05 |
| SD | 0.098 | 0.158 | 0.361 | 0.258 | 0.148 | 0.002 | 0.035 | 0.020 |
| Range | 0.21 | 0.4 | 0.88 | 0.6 | 0.4 | 0.006 | 0.09 | 0.05 |

Means: Means of five wastewater samples, SD: Standard Deviation, Range: Range of various parameters

**Table 10.** Analysis of soil in Istaqlalabad Colony, Sargodha (Site: 72.64151-32.06997).

| Parameters | Texture | EC (dS $m^{-1}$) | pH | SAR | OM (%) | Pb | Cd | Ni | As |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | (mg $kg^{-1}$) | | | |
| Means | Sandy Clay | 4.12 | 7.52 | 12.77 | 0.68 | 6.15 | 0.66 | 6.12 | 2.60 |
| SD | Loam | 0.415 | 0.103 | 1.364 | 0.098 | 0.585 | 0.099 | 1.108 | 0.673 |
| Range | | 1.28 | 0.3 | 4.24 | 0.35 | 1.98 | 0.33 | 3.84 | 2.04 |

Means: Means of five soil samples, SD: Standard Deviation, Range: Ranges of various parameters

0.01, 0.13, and 0.05 mg $L^{-1}$ for Pb, Cd, Ni, and As, respectively. These mean values for all eight parameters represented the average of five wastewater samples. The standard deviation for EC, pH, SAR, RSC, Pb, Cd, Ni, and As is 0.098 dS $m^{-1}$, 0.158, 0.361, 0.258 meq $L^{-1}$, 0.148, 0.002, 0.035, and 0.020 mg $L^{-1}$, respectively. The EC, pH, SAR, RSC, Pb, Cd, Ni, and As ranges are 0.21dS $m^{-1}$, 0.4, 0.88, 0.6 meq $L^{-1}$, 0.4, 0.006, 0.09, and 0.05 mg $L^{-1}$.

**Analysis of soil samples of Istaqlalabad Colony, Sargodha**

The average values of EC, pH, SAR, organic matter, Pb, Cd, Ni, and As emerged as 4.12 dS $m^{-1}$, 7.52, 12.77, 0.68%, 6.15, 0.66, 6.12, and 2.60 mg $kg^{-1}$, respectively (Table 10). The standard deviation values for soil EC, pH, SAR, organic matter, Pb, Cd, Ni, and As remained 0.415 dS $m^{-1}$, 0.103, 1.364, 0.098%, 0.585, 0.099, 1.108, and 0.673 mg $kg^{-1}$, respectively. The EC, pH, SAR, organic matter, Pb, Cd, Ni, and As rates are 1.28 dS $m^{-1}$, 0.3, 4.24, 0.35%, 1.98, 0.33, 3.84, and 2.04 mg $kg^{-1}$.

## DISCUSSION

Wastewater is one of the serious environmental concerns because water quality criteria of surface water and groundwater set by the WHO bear frequent violations. About 380 billion $m^3$ of municipal wastewater attains global generation, estimated to increase 24% by 2030 and 51% by 2050. On the average, most of the cities of the developing countries discharge 30–70 mm3 of wastewater per capita per day. The freshwater availability declines daily. This situation worsens with time, with the major contributing factors being rapid urbanization, industrialization, population growth, increase in insecticides and pesticide use in agricultural activities, lack of proper waste treatment systems, and non-implementation of water management policies.

Many contaminants like organic matter, inorganic pollutants, nitrates and phosphate, fluoride, oil spillage, heavy metals, and water-soluble radioactive substances are polluting the world's water when disposed of in water bodies without any treatment. The sad reality around the globe is that only a minor portion of generated wastes undergo treatment, with the rest disposed of without adequate treatment. However, in some developing countries, this situation is worse than in others. The disposal of untreated wastes and uncontrolled water pollution poses economic and ecological effects. The prime goal of this review is to discuss the chief causes, significant sources, and impacts of untreated wastewater by giving an overview of the most affected areas worldwide (Tariq and Mushtaq, 2023).

Pakistan is a South Asian country with a population of about 243 million. It ranks fifth in the world's most populated countries. Similar to other developing countries worldwide, Pakistan also suffers from water contamination. It is also among the water-stressed areas, as it depletes freshwater resources caused by increased pressure for different water usage (Jabeen *et al*., 2015). The prime sources of contamination of water bodies are household sewage, rapid industrialization, rapid urbanization, poor management systems, and population increase (Ashraf *et al*., 2018).

Utilizing untreated wastewater poses significant risks to the environment and public health, as it often contains high concentrations of heavy metals and other contaminants. These heavy metals can accumulate in soils, leading to soil degradation, reduced crop yields, and potential health hazards when crops grown in contaminated soils reach consumption. Notably, untreated wastewater used for agricultural purposes contained alarmingly high heavy metals, becoming a severe threat to the environment and human health. High toxicity levels observed in water and soil samples underscored the urgent need for effective remediation measures to reduce heavy metal contamination and mitigate its adverse effects (Mahmood, 2014). The buildup of toxic metals in soil and crops is of concern because it can affect plant growth, food safety, and marketability. This experiment also estimated the impacts of various organic materials on the uptake of toxic metallic elements. Organic modifications had significant effects on all growth parameters and metal concentrations. This study found that vermicomposting was the most effective at reducing cadmium, chromium, and lead. However, using organic additives can help reduce its impact on plant growth, soil quality, and human health. Organic fertilizers, specifically, biological humus, can reduce the absorption of toxic metallic elements in plants and promote growth with reduced health risks. Generally, organic fertilizers are vital in restoring landmine-affected soils by providing nutrients, improving soil structure, and sequestering heavy metals. It indicated that organic amendments effectively reduced heavy metal concentrations in the wastewater, transforming it into a safer resource for irrigation (Bashir *et al*., 2021).

Results demonstrated significant decrease in heavy metal accumulation in treated soils over time compared with soils irrigated with untreated wastewater. Beyond reducing heavy metal concentrations, the research examined broader impact of wastewater treatment with organic amendments on soil quality. Soil health indicators, such as pH, organic matter content and nutrient levels incurred monitoring. Our findings indicated that treated wastewater improved soil quality, enhancing its fertility and overall health. This improvement translated into increased crop yields, crucial for food security in regions where untreated wastewater have often usage for irrigation (Gul *et al*., 2015; Ismaiel *et al*., 2022). According to Selim (2006), if wastewater utilization continues for a long time without proper treatment, an EC of 3.10 dS $m^{-1}$ could be sufficient to promote soil salinization. Soil sodicity may result from the prolonged usage of wastewater with high SAR and RSC levels.

With the widespread use of pesticides and higher concentrations of As in groundwater, a majority of wastewater tests in the Sargodha district revealed levels of As over the allowable limit. High As concentrations in wastewater were also evident (Kahlown *et al*., 2006) in specific cities of Punjab province. Another significant metal hazardous to plant development and quality is nickel. Ni is allowable up to 200 g $L^{-1}$. Some wastewater samples had greater Ni contents, and if used improperly, especially for food crops, this wastewater might transmit Ni to the food chain. Cadmium can be present in amounts up to 10 g $L^{-1}$. Cadmium concentration in all wastewater samples was greater. The primary causes of elevated Cd levels in wastewater may be the phosphate fertilizer use, metallurgical industries, and ore processing. Chromium needs for human health are 200 g per day, and deficiencies can lead to cardiovascular problems and decreased glycogen stores. Permitted maximum for Cr is 100 g $L^{-1}$. Although it is typically below permitted limit, wastewater with a higher Cr content may indicate heavy usage of phosphatic fertilizers, metal plating, dyes, ceramics, glass, glues, wood preservation, textiles, and tanning (WHO, 1989).

Different cities in the country release an estimated 40 gallons of wastes into water bodies every day. The massive use of agrochemicals in agriculture is another significant source of water contamination. When applied to cropland, agricultural chemicals, such as fertilizers and pesticides with higher amounts of chemicals, such as nitrates, ammonia, phosphates, and sulfates mix with irrigation water and, eventually, leak into the soil to reach natural water supplies. In addition, some fertilizers contain heavy metals as by-product, and the extensive use of such fertilizers results in the accumulation of these toxic metals in soil and water (Azizullah *et al*., 2011).

Essential quality indicators for soil and its nutrients are soil EC and SAR, respectively, the salinity and sodicity index. High wastewater EC was an indicator of soluble salt accumulation in the soil, harming soil quality and plant growth. The accumulation of Na in the soil due to high SAR of wastewater could disrupt the soil structure and limit soil drainage. According to Mkhinini *et al*. (2018), continuous wastewater irrigation can result in a significant concentration of salts, especially Na, which may penetrate the soil, induce crusting, and limit soil porosity. Heavy metal content in wastewater left these metals in the soil, harming the soil's properties. According to Handa *et al*. (2019), wastewater use significantly increases the buildup of Cu, Ni, Cr, Zn, and Al in soils, especially when using wastewater in its untreated form.

Worldwide estimation of annual pesticide use is about 2.5 million tons, with continuous increases. Pakistan alone uses approximately 70,000 tons of pesticides annually, with a yearly increasing rate of about 6%. It is estimated that only about 0.1% of applied pesticides reach the targeted organisms, and the remaining portion is lost, thus causing environmental pollution. For Pakistan, this problem worsens due to improper storage, usage of outdated pesticides, and lack of awareness of its harmful effects (Azizullah *et al*., 2011).

Elevated levels of these nutrients in wastewater showed a linkage to the appropriate concentration of N, P, and K in vegetable plants. Lead and cadmium accumulation in vegetable plants appeared higher than the permitted limit for both heavy metals in all plant samples. According to Murtaza *et al*. (2010), wastewater had significant N, P, K, and heavy metal concentrations. If using this wastewater persisted regularly for a long time in agricultural activities without taking appropriate measures, plant nutrients, salt, and metal ions would transfer to the plants. Papaioannou *et al*. (2019) reported heavy metal buildup at hazardous levels in produced plants using wastewater.

## CONCLUSIONS

The study concluded that although using wastewater as a source of irrigation is unavoidable in current situations due to insufficient quantity of canal water, it harms soil, plants, and, ultimately, human health. Hence, treated wastewater can become a source of irrigation for growing maize crops without or with minimum hazards from heavy metals.

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