Metal Contamination of Canal Versus Sewage Water Irrigated Vegetables in Metropolitan Area of Sargodha, Pakistan

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Abstract

The reduction in the fresh water supply and increase in the domestic effluents with increase in population and urbanization in the Pakistan force the farmers to use untreated sewage water for the irrigation purposes. Besides high nutrient content Sewage water also have source of metal contamination in the food chain. The present field study was conducted to compare the nickel (Ni), copper (Cu) and lead (Pb) contamination in vegetables grown on soils irrigated with sewage water and canal water in Sargodha, Punjab, Pakistan. The Ni, Cu and Pb contamination was assessed using soil quality indices i.e., contamination factor (CF), metal translocation factor (MTF), pollution load index (PLI), geo-accumulation index (Igeo) and ecological risk index (ERI) were calculated in the collected samples. The physico-chemical properties of soil and water samples were determined. Based on the results, it was revealed that sewage irrigated areas were at higher risks of metals contamination compared to canal irrigated areas. From the studied metals, Pb showed highest contamination potential based on the soil quality indices. In sewage irrigated sites, metal concentrations were found higher in edible parts of the vegetables confirming that sewage water contains and supply more metals than canal irrigated water and pose more health and ecological risks.

Introduction

World's largest canal water irrigation exists in Pakistan which was built to compensate the growing needs of irrigational water for growing food demands in 1917. Canal irrigation water was mostly used for irrigational purpose but due to the climate change induced-water scarcity and reduced amount of precipitation, brackish water, and industrial and municipal wastewater (collectively called as sewage water (SW)) were also began to be used for irrigation (Sardar et al. 2020; Ullah et al. 2018). Generally, it is believed that canal irrigation water has less or no contaminants i.e., heavy metals and excessive nutrients pollution (Farsang et al. 2020; Fatunla et al. 2017). But due to the geogenic processes like parent material weathering (Xia et al. 2020; Zinn et al. 2020), urbanization, urban sprawl and industrialization, sewage water (SW) is also contaminated with metals and excessive nutrients (Eid et al. 2021). Now a days, the use of both canal as well as SW is common for the vegetable production is, and/but from the few decades it has been increasing due the freshwater scarcity (Navarro et al. 2015). Among water resources only 2.5% water is fresh with some salt's precipitations. Less than 3% of world's freshwater resources are present in the Mediterranean area in the region freshwater is distributed unequally, 72% in northern countries, 20% in eastern countries and 8% in southern countries (FAO 2007). SW irrigation is the most common practice in the arid and semi-arid areas of the world (Rossi 2015). High growth rate of population and rapid increase in the industrialization put high pressure on the land and water resources and ultimately producing a large quantity of SW that has been using in the urban and peri-urban areas for the irrigation purposes to supports the livelihood (Akhtar et al. 2018). About 1/10th population of the world consuming agricultural product produced from SW (Kauser 2007). According to an estimate, about 32,500 ha area in Pakistan use SW for irrigation purpose (Shahid 2017). About 46% of the farmers are using SW as sole application, 40% are using canal + ground water, 10% are using canal water and only 3% are using ground water for irrigation (Baig et al. 2011). The use of untreated SW has both positively and negatively affect the human health, agriculture production, soil fertility and environment (Scott et al. 2004; Shakir et al. 2017). Sewage water considered rich source of nutrients because of having high concentration of organic and inorganic materials (Perera et al. 2019), while concentration of trace elements and metalloids found to be higher than the safe limits (Shakoor et al. 2013; Milik et al. 2017).

Trace elements are the group of elements existing in small amounts that is less than 0.1% by volume (1,000 parts per million) (Bhattacharya et al. 2016). Excess amount of these elements causes toxic effects on the plant and human beings (Wada 2004). Soil is an important component of biosphere as it is geochemical sink for the contaminant and have buffering capacity to control the chemical elements to the atmosphere, hydrosphere, and biota. Trace elements originate from different sources reach to the soil surface their fate depends upon physicochemical properties. Many scientists revealed the behavior of various chemical pollutants in the soil (Hooda 2010). Trace element or metals are the serious threat because the persist in the soil for the longer period of the time (Farid et al. 2013) and can only be removed from the soil by leaching, erosion, and plant uptake. According to a research study these metals can persists i.e., zinc (Zn) persist in the soil from 70 to 135 years, cadmium (Cd) 13 to 1100 years, copper (Cu) 310 to 1500 years and lead (Pb) can remain for 740 to 5900 years (Banuelos et al. 1999).

Lead has been gaining attention of the researcher due to its strong environmental hazards and increasing concentration in the vegetables grown near the urban and industrial areas. Higher Pb concentration in the upper layer of the is potential threats for the crops (de Abreu et al. 1998). It is one of the most persistent elements in the soil having severely negative effects on plant and human health. It get accumulate in the roots and show very little mobility in the plant (Wozny 1995), and adversely affect the seed germination (Mishra et al. 2006), cause disruption in the mitosis (Liu et al. 1994; Wierzbicka 1994), induce leaf chlorosis (Verma and Dubey 2003), reduce photosynthetic and enzymes activities, and ultimately affect plant growth (Sharma and Dubey, 2005; Nas and Ali 2018). Along with Pb, nickel (Ni) is also a trace element required by the plant in minute quantity for the proper growth and development (Gerendás et al. 1999), and function as urease enzymes activator and nitrogen metabolon (Bhalerao et al. 2015). However, when its concentration gets high it become toxic and retarded faction of membrane and photosynthesis, lower the germination index, stunted growth and significantly decrease in crop yield (Moya et al. 1993; Boominathan and Doran 2002). Nickel added in the plant soil system through the anthropogenic activities in which ore smelting, electroplating and sewage sludge are the most prominent sources (Déportes et al. 1995; Cempel, and Nikel 2006). Copper (Cu) is an essential redox-active transition metal required by plants. Having multi oxidation states it involves in various physiological processes of the plant (Yruela 2009). It act as activator in many enzymes in plant (Li et al. 2018). While execs concentrations of Cu in the soil effects the developmental and physiological processes of plants (Al Naggar et al. 2018; Thounaojam et al. 2012; Ballabio et al. 2018). As many studies on the effects of heavy metals pollution in vegetables and associated health and environmental hazards due to canal water and sewage water are documented separately, but the comparison of both irrigation practices in a single study was lacking in the existing literature. Keeping in view the shortcomings, this study was planned to; a) investigate the Ni, Cu and Pb concentration and distribution in SW and canal water irrigated soils, b) study the transfer of these metals from soil to edible parts of the vegetables, and c) enumerate their source of pollution and health and ecological risks in Sargodha, Pakistan.

Materials And Methods

Study area and sampling sites

Sargodha is the 12th largest and 11th metropolitan city of Pakistan. It is an agriculture based city and famous in all over the world for its citrus varieties i.e., Kinnow, orange and lemon. It is located on the bank of river Jhelum at 32.5100 N and 72.4016 E. It has geographical area of about 5,864 km^2 and population of about 8.10 millions. There are numbers of sites in the surrounding (peri-urban areas) of Sargodha where farmers are using un-treated sewage water and canal water for the vegetables production. Different sewage and canal water irrigated sites were selected for the study (Fig. 1). Fourteen SW irrigated and 14 canal irrigated sites were selected for the study.

Water samples

Sewage and canal water were collected using random sampling method. Samples were analyzed for the pH and EC on the spot using pH (Hanna HI-83141) and EC (Lovibond SensoDirect con200) meters. After this, samples were filleted using Whatman filter paper No. 42, added 2-4 drops of conc. sulfuric acid, and stored for the further analysis at 4 °C. The concentration of the Ni, Cu and Pb were determined with the help of Atomic Absorption spectrophotometer (AAS) (Hitachi Polarized Zeeman AAS, Z-8200, Japan) (Radulescu et al. 2014).

Soil Samples

Samples were collected from 0-20 cm depth using soil auger. After collection, samples were stored in plastic zipper bags after washing bags with distilled water and tagging. Samples were grounded using wooden tool, sieved via 2-mm sieve, and kept in the shade for air drying, then shifted in an oven for the 24 hours at 105 °C. Ammonium bicarbonate-diethylenetriaminepentaacetic acid (AB-DTPA) methods Soil extract and metal concentrations were determined using method (Malathi and Stalin 2018).

Plant Sample

Available vegetables (tomato and apple gourd fruits, and leaves of cauliflower, and spinach) were collected from both sewage and canal irrigated areas. Vegetable samples were sun dried and then transferred into an oven at 65±5 °C until the constant dry weight was obtained. After this, samples were digested using aqua regia mixture 1:3 (HNO_3:$HClO_4$) and analyzed for Ni, Pb and Cu determination with Atomic Adsorption Spectrophotometer (AAS) (Uddin et al. 2016).

Contamination factor

Contamination factor (CF) is an important factor that is use monitor the metals contamination in the Soil (Hakanson 1980). Following equation is used to calculate the CF:

$$CF = \frac{Potential\ toxic\ element\ conc.\ in\ study\ area}{Potential\ toxic\ element\ conc.\ in\ reference\ area}$$

The CF have four categories according to the degree of contamination in the sediments Table 2. The background values of Ni, Cu and Pb are 31.9, 27.3, and 29.7 mg kg^{-1}, respectively.

Pollution Load Index (PLI)

Pollution load index (PLI) has been used for the total assessment of metal contamination for a site or area. The following equation was used for the PLI calculations (Esshaimi et al. 2012);

$$PLI = \sqrt[n]{CF1 \times CF2 \times CF3 \times \ldots \times CFn}$$

CF to CFn shows the contamination factor and n is the number of metals.

Geochemical index (Igeo)

Geochemical index (I_{geo}) was first used by Muller (1969) to determine the metal contaminations in sediments by comparing the samples values with background values of metals. I_{geo} is calculated by follows equation;

$$Igeo = log_2\left(\frac{C_n}{1.5B_n}\right)$$

Where Cn is the value in the samples for the metal n, Bn indicate the background value for the metal n (Turekian and Wedepohl 1961), and the factor 1.5 is used because of possible variations of the background data due to lithological variations.

Ecological risk index (ERI)

The potential ecological risk of heavy metals in soil can be accessed by a potential ecological risk index (Sulaiman et al. 2019).

$$ERI = Tr \times CF$$

Where Tr showing the toxic response factor and CF is concentration factor.

Metal transfer factor (MTF)

Metal transfer factor (MTF) is used to calculate the metal concentration in the plant tissue (Rangnekar et al. 2013). Following equation is used for the calculation;

$$MTF = \frac{Metal\ concentration\ in\ plant}{Metal\ concentration\ in\ soil}$$

The concentration was taken in mg kg^{-1} and determination based on dry weight of plant and soil. The value of TF greater than 1 indicate the metals accumulation in the vegetables, if value is 1 it shows the vegetables have no metal's influence and value less than 1 indicates the vegetable exclude the metals from uptake. Plants having high TF values can used in the process of phytoremediation.

Results

Pre-analysis of canal and sewage water

The pH, EC, SAR and RSC of sewage and canal water being used for the irrigation represented in the Table 3. The pH of sewage water samples remains below 8.00, while canal water samples mostly have pH above >8.00, EC of the sewage and canal water samples remain in the limits and few were exceeding the permissible limits. The SAR values for the sewage water varied from 2.40-20.33 and for the canal water it ranged from 1.26 to 3.05 (mmol $L^{-1})^{1/2}$. The RSC of sewage water ranges from 1.47 to 16.21 and in the canal irrigated sites the values varies from -0.238 to 2.074 (me L^{-1}).

Soil Analysis

Table 4 represent the pH, EC and SAR of soils irrigated with sewage and canal water. The pH of sewage and canal irrigated soil samples collected from the fourteen different sites around the Sargodha city varies from 7.58 to 7.93 and 7.3 to 8.84, respectively. The values for EC ranged from 2.25 to 10.13 and 1.30 to 3.30 dS m^{-1}, while SAR values ranged from 5.35 to 27.24 and 1.88 to 10.20 (mmol $L^{-1})^{1/2}$, respectively for sewage and canal irrigated soils.

Metals concentration in Irrigation water

Table 5 show the concentration of Ni, Cu and Pb in the sewage and canal water used for irrigating the vegetables and soils. In sewage water, the highest value for Ni, Cu and Pb were 0.057, 0.023 and 0.026 mg L^{-1}, respectively. For the canal water, maximum values found for the Ni, Cu and Pb were 0.02, 0.19 and 0.063 mg L^{-1}, respectively.

Metals concentration in Soil receiving sewage and canal water

The maximum concentration of Ni, Cu and Pb in the soil samples receiving sewage irrigation was found 0.68, 34.38 and 16.22 mg kg^{-1}, respectively while in canal water irrigated soils, the highest values were 0.84, 21.42 and 10.73 mg kg^{-1} for the same metals, respectively (Table 6).

Metals concentration factor (CF) in Soil receiving sewage and canal water

The data described in the Table 7, Fig. 2 represents the CF of Ni, Cu and Pb in the contaminated soils collected form the sewage and canal irrigated sites. As indicated all sites had the have low level of contamination as the values for metals remains below 1 and samples collected from site 3 and 7 sewage irrigated sites show moderate level of contamination.

Pollution load index (PLI) in soils receiving sewage and canal irrigation water

The values for the PLI remain within the permissible limits. The samples collected from the sewage and canal irrigated sites for the Ni and Cu while 3 sewage irrigated sites showed Pb PLI greater than 1 (Table 8; Fig. 3), indicating soil pollution, while all the remaining sites had PLI values <1, indicating no or tolerable pollution status (Tomlinson et al. 1980).

Geo-accumulation Index (Igeo) in soils receiving sewage and canal irrigation

The estimated values of Igeo from the samples collected from the sewage and canal irrigated are less than 0 (Table 9; Fig. 4), categorized as un-polluted area for the given metals according to the criterial given by the Aguilar et al. (2019). The values of the I_{geo} 0 ≤ indicates no pollution, and the values $0 \leq I_{geo} \leq 1$ show non polluted to moderately polluted, $1 \leq I_{geo} \leq 2$ shows moderate soil pollution, values form $2 \leq I_{geo} \leq 3$ indicate moderate to strongly pollution, $3 \leq I_{geo} \leq 4$ is considered as strongly polluted, if values are $4 \leq I_{geo} \leq 5$, then it is termed as strongly to extremely polluted, and the I_{geo} values ≥ 5 is categories as extremely polluted Aguilar *et al.* (2019).

Ecological Risk (ER) in soils receiving sewage and canal irrigation

The values for the ecological risks for all the Ni, Cu and Pb found less than 150 from the sewage and canal irrigated sites indicated the low ecological risk areas (Table 10; Fig. 5). Wu et al. (2010) made four categories of potential ecological risk values less than 150 categories as low risk area values from 150 to 300 have moderate ecological risk 300 to 600 classified as considerable risk and if the vales were higher than 600 considered as very high ecological risk.

Ni, Cu and Pb concentration in the vegetable receiving sewage and canal irrigated.

The concentration of Ni, Cu and Pb in the four different vegetable samples collected from the fourteen sewage and fourteen from canal irrigated sites. The maximum concentration of concerning metals in the samples receiving sewage irrigation were 4.78, 28.33 and 2.25 mg kg^{-1}. While in canal water irrigated areas, the highest values recorded were 4.58, 24.90 and 3.84 mg kg^{-1} and 14 for the Ni, Cu and Pb respectively (Table 11; Fig. 6). The vegetables samples showed higher Pb concentration than WHO permissible which was 10, 10-25, 2 mg kg^{-1} for the Ni, Cu and Pb, respectively.

Metal Transfer Factor (MTF) in vegetables receiving sewage and canal irrigation

The results in Table 12 represents the MTF for Ni, Cu and Pb in the sewage and canal irrigated sites. The Ni showed the highest transfer factor (27.27) for the tomato crop. Overall, MTF of Ni was recorded highest for all the vegetable samples collected from the sites than that of Cu and Pb. All the samples collected from sewage irrigated sites had higher MTF compared to canal irrigated sites.

Discussion

About 40% the of total vegetables production is produced using sewage water (SW). (González et al. 1998; Sayo et al. (2020). This practice has been increasing due the freshwater scarcity, which is more common in the arid and semi-arid regions of the world. The use of sewage water negatively affects the quality of the soil i.e., EC, pH, SAR etc. supply excessive metals in soil and crops grown on that soil (Sana et al. 2013). The pH, EC and SAR of the soil and sewage water samples collected from the study are close to the findings of the study by Iqbal et al. (2013) and Mussarat et al. (2007). We have recorded the pH, EC, SAR, and RSC in the ranges of 7.30-8.55, 2.36-8.93 dS m^{-1}, 2.40-20.33 and 1.47-21.42 me L^{-1}, respectively in sewage water. The reasons behind the high variability in the properties of water are due to the excessive addition of industrial and municipal effluents, which are ultimately used as irrigational water, ultimately (Cheng et al. 2020). Another reason of higher contamination in sewage water is the presence of numerous kind of heavy metals and nutrients like nitrates and phosphates supplied in through the use of fuels and agro-chemicals (Pankratz 2017; Qadir et al. 2020; Yabalak 2021). In canal water, these parameters were recorded 7.76-9.04, 0.50-0.96, 1.26-3.05 and 0.23-3.74, respectively. As discussed above, the reasons were the same nutrients i.e., metals and different nutrients excess, but the source could be different i.e., agricultural run-off (Hassan et al. 2018), natural rocks weathering and erosion (Zhang et al. 2018), and atmospheric deposition also contributes significantly into heavy metals pollution and their supply to ground as well as surface water (Wright et al. 2018). The soil properties i.e., pH, EC and SAR were also varied in canal and sewage irrigated soils. The EC, pH and SAR were recorded 2.25-10.13 dSm^{-1}, 7.58-7.93, and 5.34-27.24 me L^{-1}, respectively in sewage water irrigated areas, while 7.30-8.84, 1.30-3.76 and 1.86-10.20 for the same parameters in canal irrigated areas. The reasons behind variability in pH, EC and SAR values were due to the irrigation with sewage water which is rich in metals and nutrients like phosphate and nitrates and deposited in soil as discussed above. The variability in the pH, EC and SAR values in canal irrigated areas were due to ground and surface water contained contaminants and excessive fertilizer and pesticides application (Zwolak et al. 2019).

Metal concentration in vegetable edible parts

The permissible limits of Ni, Cu and Pb are 0.20, 0.20 and 5.00 mg L^{-1} for wastewater and 35.0, 36.0 and 85.0 mg kg^{-1} for agricultural soils, respectively (WHO/FAO 2013). The highest values of the heavy metals from the sewage and canal water samples were found lower than the permissible limits. In the soil samples collected from sewage and canal irrigated areas, not any single sample showed higher values above the permissible limits. So, the soil found safe for growing vegetables. But metal concentrations in vegetables from 3 areas were found exceeding the permissible limits of Pb were exceeding the limits as reported by Mensah et al. (2009) i.e., the safer limits for Ni, Cu and Pb in the vegetables are 67.90, 73.30 and 0.30 mg kg^{-1}. Moreover, vegetables samples collected from the collective 12 (7 sewage and 5 canal irrigated sites) were having the higher concentrations of Pb. The higher concentrations of Pb in the edible parts of the vegetables is due to automobile emission as Pb is present in the gasoline and used as fuel (Suzuki et al. 2009; Atayese et al. 2009), car batteries (Özkan 2012). Vegetables (Cauliflower) collected from 2 sites having Pb higher than the permissible. It also due to the brick-kiln emissions as coal is used in the kilns which is considered of poor quality fuel and has higher Pb contents (Ravankhah et al. 2017). The vegetables grown near the bricks kiln are mostly contaminated with metals (Sikder et al. 2016).

Concentration and translocation factors

The CF and TF values (Table 6 and 11) indicated that CFs of Ni, Cu and Pb were in the range of 0-0.009, 0.051-0.625 and 0.174-1.298 in sewage water irrigated areas, respectively. In canal irrigated areas, CF for Ni. Cu and Pb were within the range of 0.001-0.0111, 0.12-0.389 and 0.383-0.858, respectively. The CF for Pb in sewage water irrigated areas were found to be higher (1.298), showing moderate metal risk otherwise all other areas and metals were within the safe limits (Table 6). The variation in TFs was found 2.87-27.60, 0.21-4.55 and 0-0.05 for Ni, Cu and Pb in sewage water irrigated areas, while 0.17-27.27, 0.14-2.57 and 0.002-0.066 for the same metals in canal irrigated areas (Table 11). The variations in the CF and TFs might be due to the plant physiological condition, in which the absorption depends on the concentration of this ion in the soil and the plant physiological demand (Alamo-Nole and Su 2017; da Silva et al. 2016). Ni, Cu and Pb TFs in stems were high which may indicate that the plants' ability to transfer ions from the roots to the leaves is eventually inhibited. Additionally, Ni and Pb form stable complexes with amino acids, which might indicate reduced transportation of this ion from the roots. Pb distribution in the soil does not directly influence the concentration in the leaves, but it can increase its concentration in the roots (da Silva et al. 2016). In addition, the transport of metal ions can be controlled by chelation processes which provide the absorption, distribution, and detoxification of excess ions (Takarina and Pin 2017).

Pollution load, geo-accumulation, and ecological risks indexes

The pollution load, geo-accumulation and ecological risk indexes for the Ni, Cu and Pb are presented in Table 7, 8 and 9. In either the sewage or canal irrigated area, all the metals (Ni, Cu and Pb) did not contaminated (Igeo < 0) any of the sites studied. The maximum result of the PLI calculation for both studied areas showed the 0.095, 0.79 and 1.13 for Ni, Cu and Pb. The PLI of Pb (1.13) was slightly contaminated in sewage irrigated areas (Table 7). The results about ERI of both sites showed <150 values i.e., low risks (Table 9). The higher values pf Pb contamination is attributed to the traffic and brick kiln emissions near the study areas and subsequent precipitations and sewage water irrigation (Egbueri 2020; Lin et al. 2020).

Conclusions

The results of the present study revealed that the use of canal and sewage water has different effects on soil and plant health. From the heavy metals i.e., Ni, Cu and Pb, pollution was prominent in the sewage irrigated areas compared to canal irrigated areas. CF, PLI, Igeo, MTF and ERI calculation indicated the moderate pollution levels in the sewage irrigated areas due to Pb pollution. the metal concentration in edible vegetable parts were exceeding the permissible limits for all metals. At the end of the study, it was concluded that vegetables production using sewage irrigation could lead to ecological and human health risks through bioaccumulation of metals in food chain.

Declarations

Statement and Declarations

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Competing interests

There is are competing interests between the authors.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Ahsan Shehzad. The first draft of the manuscript was written by Zia Ur Rahman Farooqi and Sanaullah Tariq. All other authors checked and commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Data availability

All the data is presented in the paper.

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Tables

Table 1: Sample collection sites for sewage and canal irrigated areas

Sites	Sewage irrigated sites		Sites	Canal irrigated sites		Vegetable	Scientific name
	Longitude	Latitude		Longitude	Latitude		
1	32.053164	72.720253	1	32.039659	72.611369	Cauliflower	*Brassica oleracea*
2	32.021016	72.696611	2	32.056885	72.641238	Cauliflower	*Brassica oleracea*
3	32.072411	72.644111	3	32.039613	72.639977	Cauliflower	*Brassica oleracea*
4	32.062518	72.634782	4	32.033296	72.603833	Cauliflower	*Brassica oleracea*
5	32.053968	72.721256	5	32.046890	72.617531	Spinach	*Spinacia oleracea*
6	32.048227	72.704315	6	32.040562	72.625071	Spinach	*Spinacia oleracea*
7	32.075538	72.647207	7	32.032265	72.603911	Spinach	*Spinacia oleracea*
8	32.062455	72.634971	8	32.051460	72.646673	Spinach	*Spinacia oleracea*
9	32.020163	72.696635	9	32.043313	72.612848	Apple gourd	*Citrullus lanatus*
10	32.062492	72.634766	10	32.036403	72.605712	Apple gourd	*Citrullus lanatus*
11	32.050855	72.719803	11	32.043333	72.613189	Tomato	*Solanum lycopersicum*
12	32.021747	72.696912	12	32.066507	72.575701	Tomato	*Solanum lycopersicum*
13	32.066498	72.638520	13	32.029887	72.603488	Tomato	*Solanum lycopersicum*
14	32.061977	72.634338	14	32.039750	72.612549	Tomato	*Solanum lycopersicum*

Table 2: Categories of degree of contamination of the sediments.

CF	Degree of contamination
$CF_i < 1$	Low
$1 \leq CF_i < 3$	Moderate
$3 \leq CF_i < 6$	Considerable
$CF_i \geq 6$	Very high

Table 3: EC, pH, SAR, and RSC of sewage water (SW) and canal water (CW).

Sites	pH-SW	pH-CW	EC SW	EC CW	SAR SW	SAR CW	RSC SW	RSC CW
1	7.49	8.10	8.93	0.57	12.96	1.26	16.21	1.19
2	7.70	8.45	6.53	0.61	9.94	1.33	7.523	-0.23
3	7.30	8.06	2.41	0.64	2.40	2.22	1.474	0.312
4	7.82	8.19	3.20	0.84	2.83	2.18	2.464	0.87
5	7.83	8.19	6.60	0.50	11.36	1.66	10.23	0.25
6	7.42	8.74	6.94	0.70	12.86	3.03	11.24	1.25
7	7.68	7.89	3.39	0.83	3.59	2.45	2.347	0.05
8	7.98	7.78	2.89	0.83	6.23	2.27	7.566	3.74
9	8.34	7.76	3.50	0.67	11.12	3.05	12.41	1.22
10	7.39	8.62	7.32	0.77	20.33	2.67	21.42	0.24
11	7.85	8.14	3.69	0.63	4.49	1.69	3.072	1.7
12	8.55	8.03	3.73	0.96	8.48	2.9	5.217	0.34
13	7.46	8.45	2.36	0.53	3.98	1.9	3.752	0.42
14	7.58	9.04	2.61	0.94	3.12	2.46	2.714	2.07
Min	7.30	7.76	2.36	0.5	2.4	1.26	1.474	-0.23
Max	8.55	9.04	8.93	0.96	20.33	3.05	21.42	3.74
Mean	7.74	8.24	4.57	0.71	8.12	2.21	7.68	0.95
SD	0.36	0.37	2.18	0.14	5.24	0.59	5.97	1.04

Table 4: EC, pH, SAR, and RSC of sewage water (SW) and canal water (CW) irrigated soils.

Sites	pH SW	pH CW	EC SW	EC CW	SAR SW	SAR CW
1	7.70	8.19	4.46	2.05	14.98	2.22
2	7.73	8.36	3.61	2.73	9.838	2.70
3	7.68	8.84	3.53	3.30	6.683	5.90
4	7.92	7.82	3.25	2.41	5.834	3.94
5	7.86	8.19	6.73	1.83	27.24	3.00
6	7.73	8.74	4.96	1.30	19.43	2.02
7	7.78	7.89	2.25	2.33	6.790	6.33
8	7.89	7.78	5.51	3.03	9.299	7.63
9	7.89	8.84	4.76	2.50	16.08	4.42
10	7.93	7.83	2.62	3.02	5.348	6.83
11	7.79	7.49	10.13	2.07	24.58	1.867
12	7.88	7.7	4.34	3.76	13.22	10.20
13	7.58	7.3	3.45	2.33	8.80	3.62
14	7.92	7.82	4.26	1.74	13.53	2.97
Min	7.58	7.30	2.25	1.30	5.34	1.86
Max	7.93	8.84	10.13	3.76	27.24	10.20
Mean	7.80	8.05	4.56	2.45	12.97	4.54
SD	0.10	0.48	1.98	0.66	6.916	2.48

Table 5: Ni, Cu and Pb concentration in sewage and canal water.

Sites	Ni SW	Ni CW	Cu SW	Cu CW	Pb SW	Pb CW
1	0.042	0.03	0.006	0.018	BDL	BDL
2	0.014	0.03	0.018	0.021	BDL	0.055
3	0.019	0.06	0.009	0.140	BDL	0.046
4	0.045	0.05	0.003	0.159	BDL	0.063
5	0.043	0.004	0.003	0.018	BDL	BDL
6	BDL	0.005	0.009	0.034	BDL	0.059
7	0.024	0.008	BDL	0.061	BDL	0.049
8	0.057	0.007	BDL	0.06	BDL	0.013
9	0.017	0.016	BDL	0.052	0.010	0.010
10	BDL	0.02	0.023	0.165	BDL	0.012
11	0.025	0.03	0.006	0.081	BDL	BDL
12	0.036	0.04	0.003	0.095	BDL	0.028
13	0.013	0.04	BDL	0.031	0.026	0.023
14	0.057	0.07	BDL	0.191	0.002	0.032
Min	0	0.004	0	0.018	0	0
Max	0.057	0.07	0.023	0.191	0.026	0.063
Mean	0.028	0.029	0.005	0.080	0.002	0.027
SD	0.018	0.020	0.007	0.060	0.007	0.023

BDL=below detection limit

Table 6: Ni, Cu and Pb concentration in sewage and canal water irrigated sites.

Sites	Ni SW	Ni CW	Cu SW	Cu CW	Pb SW	Pb CW
1	0.47	0.11	20.25	12.38	12.33	7.47
2	0.20	0.12	10.31	6.60	3.33	8.74
3	0.52	0.19	34.38	14.48	13.36	7.25
4	0.66	0.22	23.49	21.42	10.14	10.73
5	0.44	0.22	9.24	7.96	4.41	4.79
6	0.65	0.26	6.71	9.31	6.25	5.61
7	0.48	0.41	31.87	13.76	16.22	6.68
8	0.56	0.47	12.89	10.28	9.99	9.16
9	0.13	0.27	2.79	12.20	2.18	6.89
10	0.22	0.31	16.42	14.27	9.37	9.16
11	0.18	0.40	4.43	10.80	6.12	8.07
12	0.10	0.46	2.80	12.64	2.37	9.44
13	0.51	0.73	21.42	8.97	12.55	7.82
14	0.68	0.84	3.79	18.69	2.47	6.38
Min	0.1	0.11	2.79	6.6	2.18	4.79
Max	0.68	0.84	34.38	21.42	16.22	10.73
Mean	0.414	0.357	14.344	12.411	7.935	7.727
SD	0.206	0.215	10.599	4.042	4.670	1.622

Table 7: Level of contamination (CF) in the soil receiving sewage and canal irrigation waters.

Sites	CF Ni SW	CF Ni CW	CF Cu SW	CF Cu CW	Pb SW	Pb CW
Min.	0	0.001	0.051	0.12	0.174	0.383
Max.	0.009	0.011	0.625	0.389	1.298	0.858
Mean	0.005	0.004	0.268	0.225	0.634	0.618
SD	0.003	0.002	0.199	0.073	0.373	0.129

Table 8: pollution load index (PLI) in soils receiving sewage and canal irrigation

Sites	PLI Ni SW	PLI Ni CW	PLI Cu SW	PLI Cu CW	PLI Pb SW	PLI Pb CW
Min.	0.037	0.032	0.225	0.346	0.418	0.619
Max.	0.095	0.105	0.791	0.624	1.139	0.926
Mean	0.0716	0.066	0.481	0.469	0.7602	0.782
SD	0.0203	0.019	0.199	0.075	0.2474	0.083

Table 9: Geo-accumulation Index (I_{geo}) in soils receiving sewage and canal irrigation

Sites	I_{geo} Ni SW	I_{geo} Ni CW	I_{geo} Cu SW	I_{geo} Cu CW	I_{geo} Pb SW	I_{geo} Pb CW
Min.	-10.13	-9.998	-1.772	-1.398	-3.104	-1.969
Max.	-7.37	-7.065	-0.681	-0.887	-0.209	-0.805
Mean	-8.32	-8.531	-1.188	-1.144	-1.533	-1.309
SD	0.939	0.866	0.388	0.138	1.017	0.316

Table 10: Ecological Risk Index (ERI) in soils receiving sewage and canal irrigation

Sites	I_{geo} Ni SW	I_{geo} Ni CW	I_{geo} Cu SW	I_{geo} Cu CW	I_{geo} Pb SW	I_{geo} Pb CW
Min.	0.008	0.008	0.254	0.600	0.872	1.916
Max.	0.054	0.067	3.125	1.947	6.488	4.292
Mean	0.033	0.028	1.342	1.128	3.174	3.091
SD	0.016	0.017	0.997	0.367	1.868	0.649

Table 11: Ni, Cu and Pb concentration in the vegetable receiving sewage and canal irrigated.

Sites	Ni SW	Ni CW	Cu SW	Cu CW	Pb SW	Pb CW
Min.	0.08	0.009	4.63	2.73	0.012	0.022
Max.	4.58	0.067	28.33	24.9	0.518	0.461
Mean	1.136	0.028	13.685	11.350	0.278	0.216
SD	1.435	0.017	6.908	6.882	0.167	0.133

BDL=below detection limits.

Table 11: Metal Transfer Factor (MTF) in vegetables receiving sewage and canal irrigation

Sites	MTF Ni SW	MTF Ni CW	MTF Cu SW	MTF Cu CW	MTF Pb SW	MTF Pb CW
Min.	2.879	0.174	0.211	0.143	0	0.002
Max.	27.6	27.273	4.555	2.573	0.055	0.066
Mean	11.239	5.340	1.855	1.056	0.017	0.030
SD	9.228	8.144	1.688	0.742	0.020	0.021

Figures

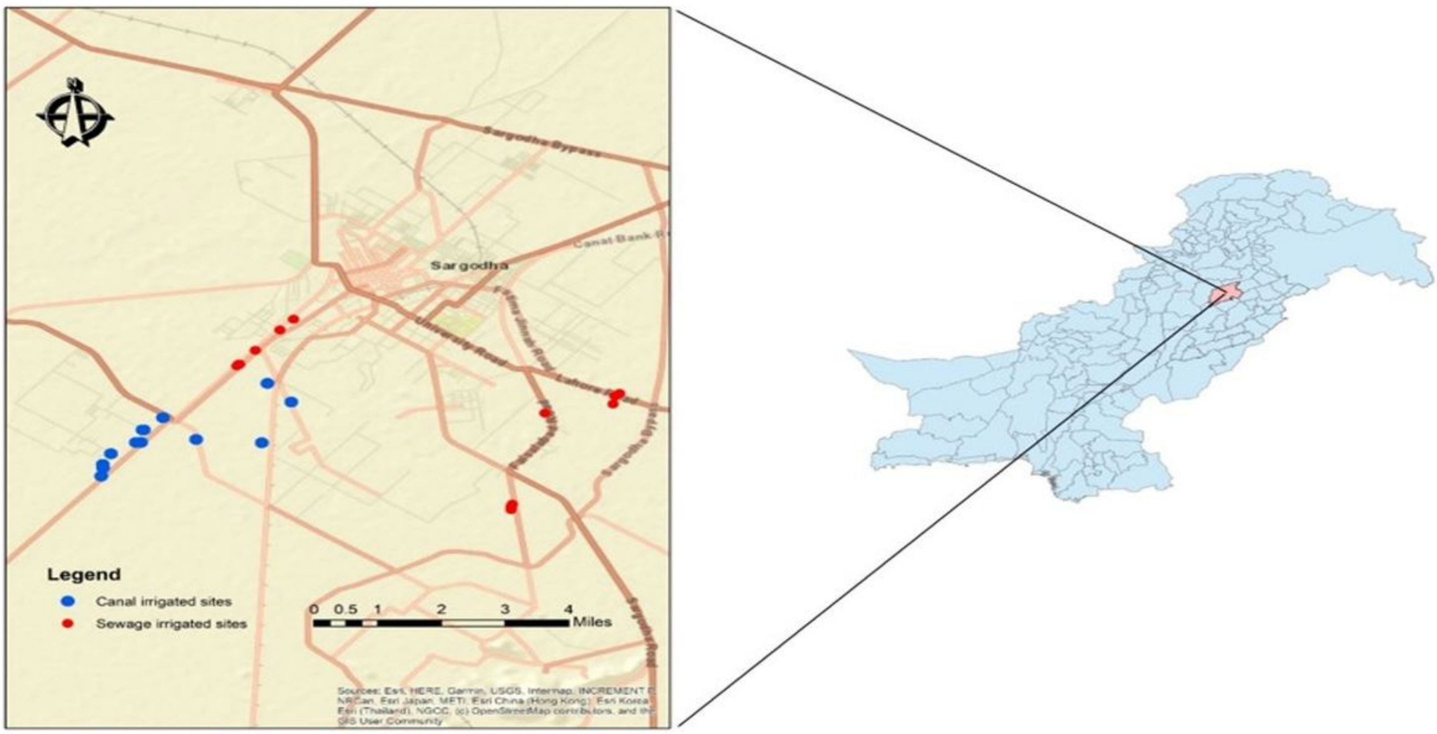

Figure 1

Graphical representation of the study area

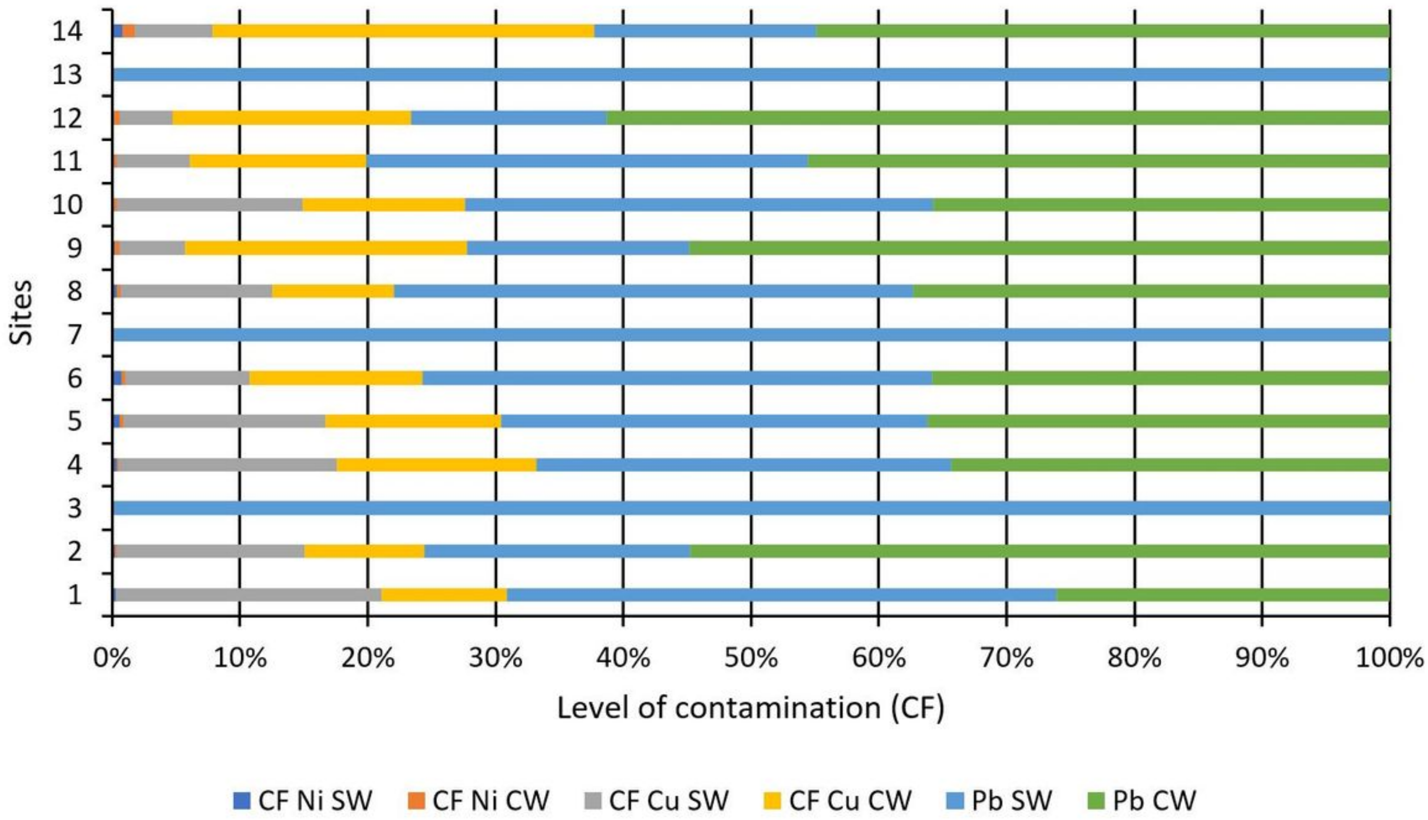

Figure 2

Level of contamination (CF) in the soil receiving sewage and canal irrigation waters

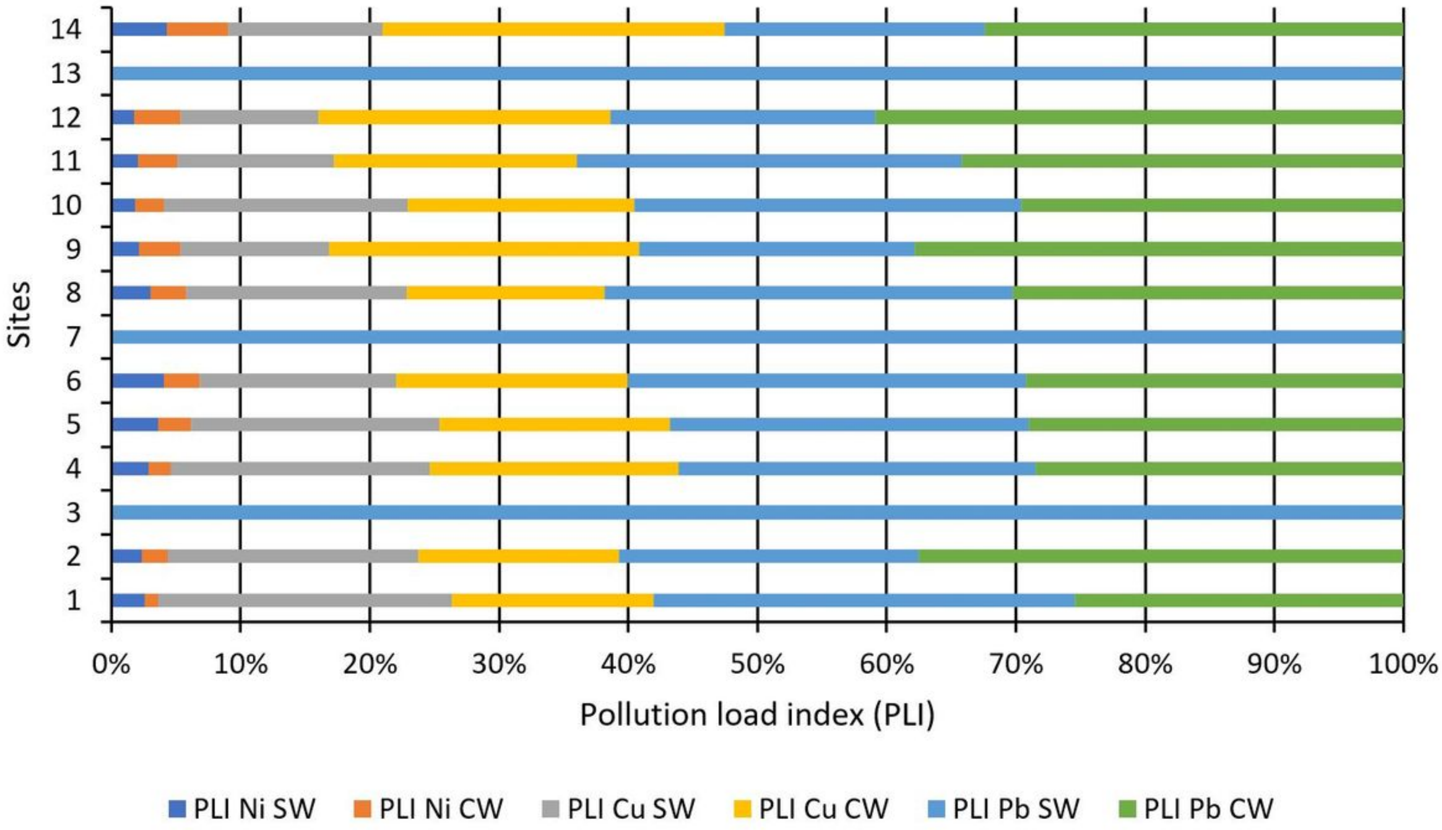

Figure 3

Pollution load index (PLI) in soils receiving sewage and canal irrigation

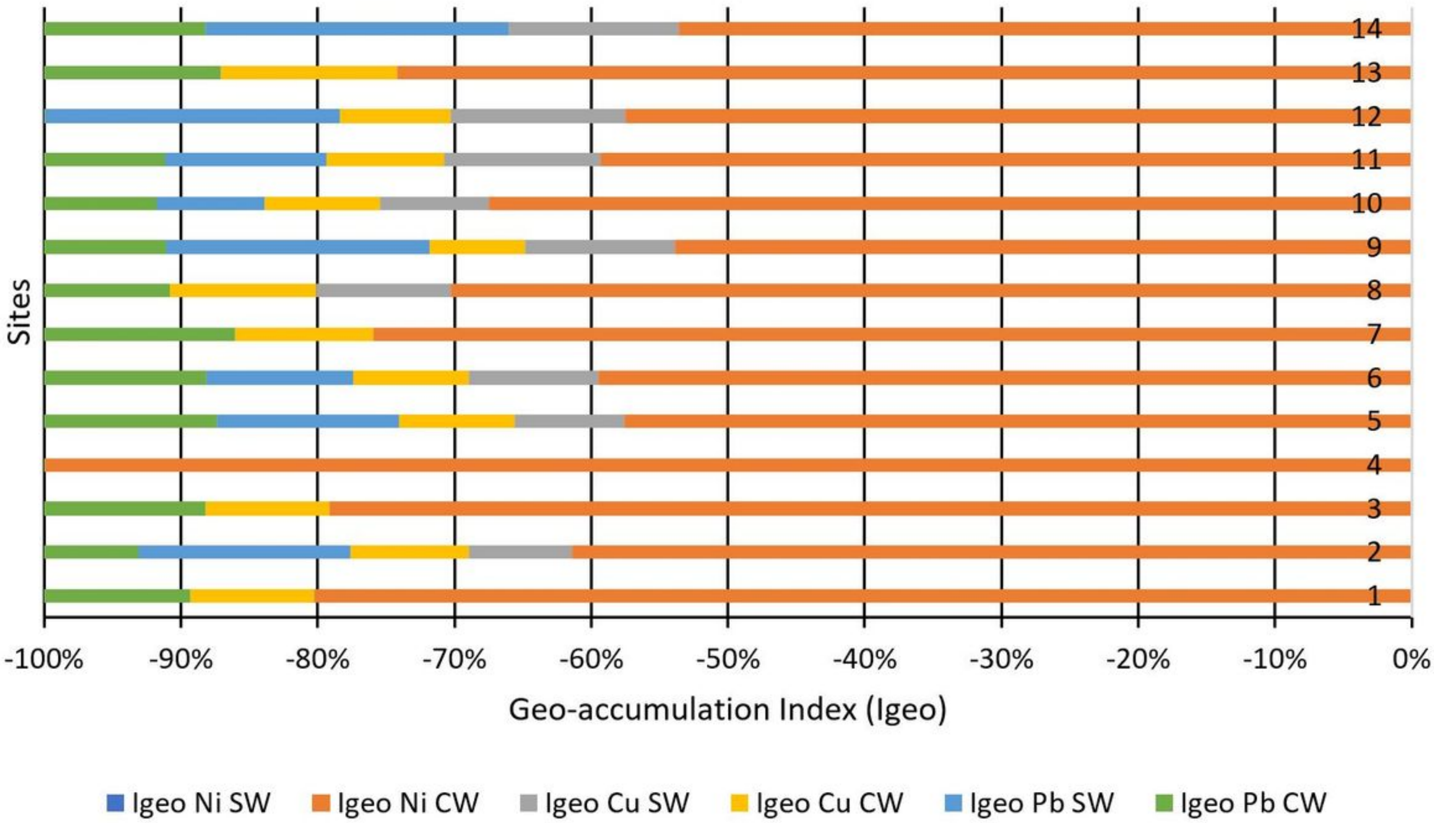

Figure 4

Geo-accumulation Index (I_{geo}) in soils receiving sewage and canal irrigation

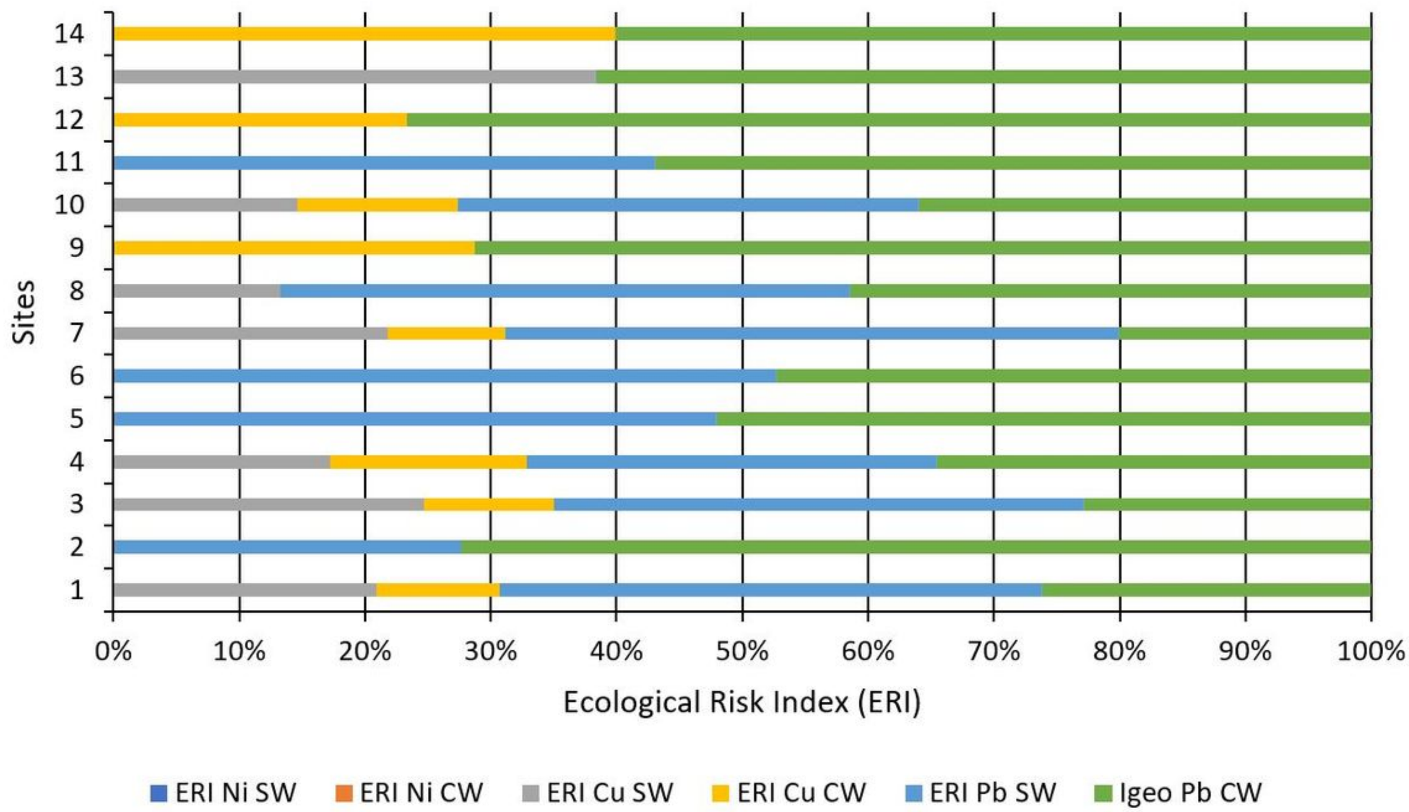

Figure 5

Ecological Risk Index (ERI) in soils receiving sewage and canal irrigation

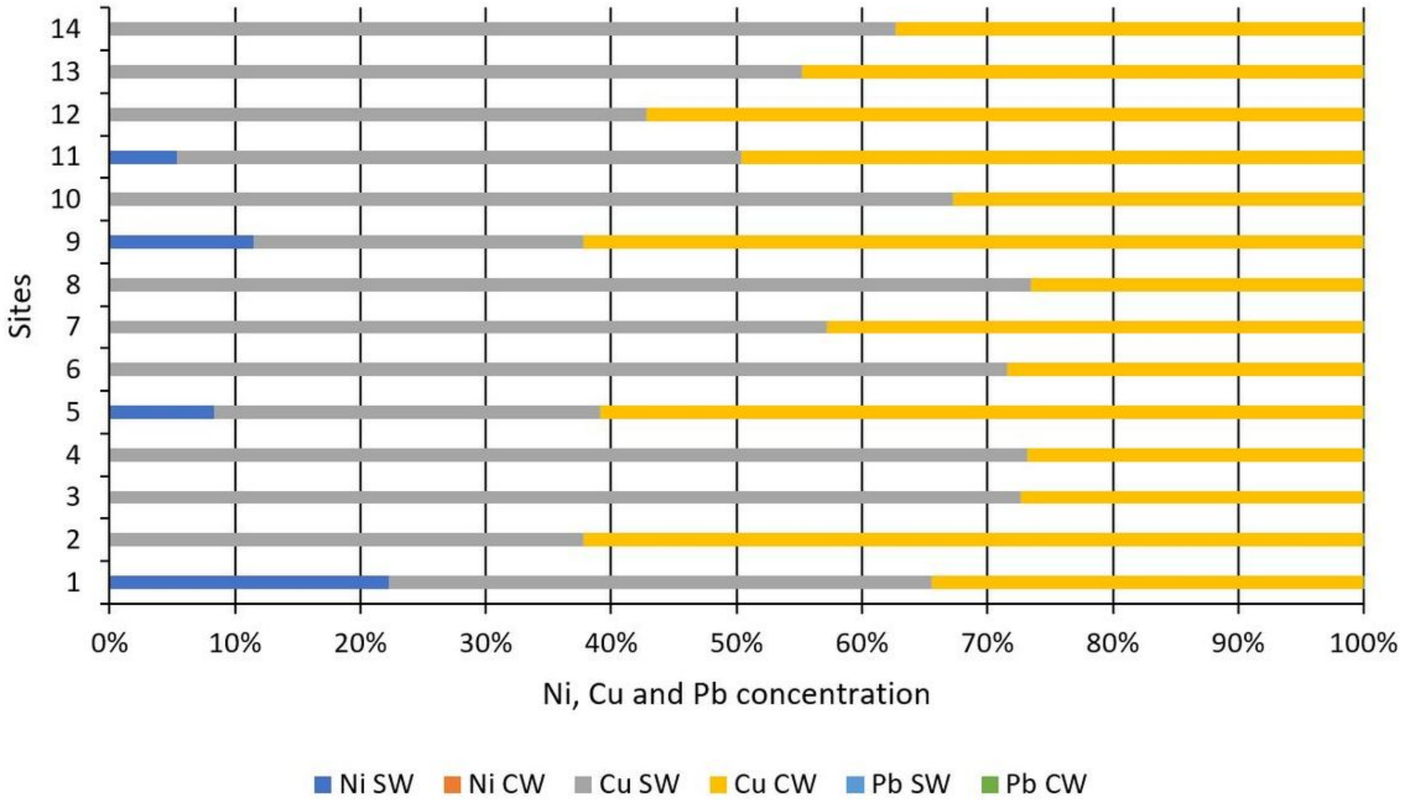

Figure 6

Ni, Cu and Pb concentration in the vegetable receiving sewage and canal irrigated