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# Different heavy metal concentrations in plants and soil irrigated with industrial / sewage waste water

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**Abstract:** Application of waste water for irrigation purposes has increased over the past years. This waste water contains high amount of trace elements and heavy metals. Objectives of this study were to evaluate the concentration of iron (Fe), lead (Pb) and manganese (Mn) in soil irrigated with waste water at different depths and also in the leaves and flowers of vegetables grown in that soil. Samples were collected from vegetable farms located along drain where vegetables were grown by untreated sewage water. Plant samples were washed and cut into pieces, air dried in fluidized bed dryer. After digestion, concentration of heavy metals was detected by atomic absorption spectrophotometer (AAS). The results revealed that heavy metals concentration in soil irrigated with waste water was higher the toxicity level at depth of 0-15cm than the lower layer 16-30cm while the leaves and fruits of vegetables also showed higher concentration of heavy metals. The maximum concentration of lead, iron and manganese was recorded in soil samples taken from Nawabanwala, Malkanwala and Sheikhanwala respectively.

**Keywords:** Drain, Soil, Lead, Vegetables, Spectrophotometer

## 1. Introduction

Chemical elements having specific gravity of at least five times the specific gravity of water are termed as heavy metal. Heavy metals are important in soil ecology so they are gaining attention as environmental pollutants. Whenever heavy metals are gathered up into the soil, they may transfer to the food chain and cause dangerous health effects [1].

Some of the heavy metals are essential for life in small quantities. Problems arise when their quantity increases from certain limit called threshold limit. But some of the heavy metals are even dangerous in small amounts and they achieve more toxic levels as amount of water increases in soil ([2, 3, 4]. Metals with their specific character of being piled up in the body proteins, are constant threat as they can persist in body for long time [5]. Through the soil, heavy metals are taken up by plants. Roots and foliar surface are two main paths by which elements are taken up or gathered up by plants [6]. It is obvious from reports that there is a varying capacity of different plants to gather up heavy metals, so health risks are associated when food crops are consumed [7]. Waste water and industrial water disposal is a problem in all over the world. Its ultimate fate is either agricultural land or rivers. As far as agricultural use is concerned, it is not only a rich source of nutrients and organic matter but it also includes heavy metals like Fe, Mn, Zn, Pb, Cr Cd, Ni, or Co [8, 9]

Faisalabad is an industrial city. In Faisalabad city, there are 512 large industrial units, 328 textile and engineering and 92 chemical and processing units. Theses Industrial units are discharging large volumes of untreated waste water that is being used by farmers to water their crops [10, 11].

Effluent of these industries contains elevated levels of heavy metals that are above the permissible levels given by WHO (Ayers and Westcott, 1988). A research was conducted during 1998 and 2007, from which it is obvious that EC, SAR and RSC of effluents collected from different sites within municipal limits of Faisalabad city were high and they were not suitable for irrigation.

Lead (Pb) has gained attention in present era as it is a strong environmental pollutant. Its increasing quantity is being observed in crops near urban and industrial localities.

Its high quantity is found in upper layer of soil that is potential threats for plants [12]. As compared to other heavy metals, lead has the ability to persist in soil for a long time and it can severely affect the crops as well as human beings. It is obvious from previous research that it has the ability to accumulate in root parts and very little amount is actualy moved to shoot pars [13]. Other functions of plant are also effected by lead accumulation in plants, few of them are discussed here i.e. negative effect on seed germination ([14]), interruption in mitosis [15, 16], stimulation of leaf chlorosis [17], toxic effects on nucleoli (Liu et al., 1994), restricting shoot and root growth [15, 18], decrease in photosynthesis [19, 20] and stimulation and inhibition of enzyme activities [21].

Manganese is an important micronutrient that is important throughout the growth cycle. 30 mg $kg^{-1}$ dry weight of manganese is necessarily required by plant tissues for optimal growth and this quantity is a need of each plant species [22]. It works as cofactor in more than 30 enzymes so for the proper working of these enzymes, manganese is an essential element [23]. However, excess manganese can cause toxic effects as well and this toxic effect is enhanced by acidic soil [24]. Manganese toxicity can cause foliar chlorosis, necrotic spotting, hindrance in chlorophyll synthesis, reduction in photosynthesis, inhibition in shoot growth and root injury [25]. It has been observed that manganese work as a transition element and has the ability to induce oxidative stress. It has been proved by many reports in which plant species under manganese toxicity showed oxidative stress. Fe function in tissues can be affected by excess manganese as it stimulates active $Fe^{+2}$ to inactive $Fe^{+3}$ forms [26]. Manganese can cause neurological diseases in human beings.

Iron is also an important micronutrient. It is stored in iron storage protein (ferritin) and can be used in photosynthetic process [27].

Keeping in view the above facts, a study was designed to analyze the heavy metals in selected area of Faisalabad to determine the environmental risks and the impact on soil and vegetables and to quantify the sources of pollution in Faisalabad to determine the distribution of heavy metals in selected areas of Faisalabad. The distribution of heavy metals in different soil layers and concentration of metals in soils and different parts of plants (leaves and fruit) was also determined.

## 2. Materials and Methods

### *2.1. Study area and Sampling Site*

There is large number of effluents water channels around the Faisalabad city. Most of these channels are covered but at some places they are opened. To determine the metal contamination in the effluent being used to irrigate the soil and vegetables grown there. Different number of farmer's fields with different vegetables grown was selected for this study. Main target of this study was to estimate the concentration of lead (Pb), iron (Fe) and manganese (Mn) in wastewater, soil and plants. These fields were irrigated with the city effluent. The selected fields were located adjacent to the (1) Nawaban Wala, (2) Sheikhan Wala, (3) Sitara Colony, (4) Malkhan Wala, (5) Peoples Colony, (6) Rabani Colony, (7) Shalimar Park, (8) D-type Colony, (9) Nemoana, and (10) Ahmad Nagar Faisalabad.

### *2.2. Sewage Water Analysis*

Samples of sewage water were collected randomly from collection sites. The pH and EC of samples was determined by pH meter and EC meter. Then filter the samples with Whatman 42 filter paper and store the samples in storage bottles. The concentrations of selected heavy metals were measured by using Atomic Absorption spectrophotometer (AAS) [28]. Standards using distilled water were prepared as matrix for each element.

### *2.3. Soil Sampling and Analysis*

After considering average field conditions i.e. extreme high and low value, for example, slope, appearance of crop and a grid line was established at regular intervals (15-30 cm) and each intersection 1 m diameter area was sampled by taking 8-10 course. The depth of sampling was chosen according to land use. For shallow rooted crops 0-6 cm and for long rooted crops 6-12 cm, was suitable. Contamination was prevented at all stages. As crushing is easier at right moisture level, the soil was passed through 2- 3 mm sieve and air dried. The samples were stored and used in soil analysis according to requirements.

### *2.4. DTPA Preparation*

1.97g of DTPA, 1.1g of anhydrous $CaCl_2$ and 14.92 g of TEA were dissolved in approx. 800 ml of distilled water. After sufficient time for DTPA to dissolve on magnetic stirrer hot plate, volume was made. Adjusted the pH 7.3 with 1:1 HCl or 1:1 $NH_4OH$ while stirring [29] soil samples 25 g soil sample was taken and 50 ml of DTPA solution added to it. Then it was shaken continuously for 2 hours on horizontal shaker and was filtered. A blank solution (containing all reagents except soil) was run with samples as blank. Read each element concentration on concentration mode by Atomic Absorption Spectrophotometer.

### *2.5. Plant Sampling and Analysis*

Sampling was carried out from selected vegetable farms located along drain were vegetables were grown by untreated sewage water.

For Plant sampling, leaves and fruits (edible portion) were taken randomly from different vegetable crops. No young leaves and old leaves were taken. Leaves of moderate size and age were collected. Same method was applied for edible part of vegetables sampling. Plant samples were washed and cut into pieces, air dried in fluidized bed dryer (FBD) at 80°C for 4 hrs. The dried material was then powdered in a hammer mill. The samples of plants were homogenized before air-drying and stored in clean, sample bottles which were used in plant analysis according to requirements.

### *2.6. Dry Ashing for Plant Analysis*

1g of dried and grinded sample of plant (leaves and fruit) was weighed in crucibles and then the crucibles were placed in furnace for 2-3 hours at 550 $C^0$. After letting the crucibles to cool down they were taken out from the furnace. Then 5 ml of 2 M HCl was added to each crucible to dissolve the ash. The crucibles were placed on hot plate at low temperature to dissolve ash completely. If ash remained un-dissolve add more HCl and heat on hot plate until complete mixing. Then these plant samples were diluted up to 50 ml with distilled water. After dilution each solution was filtered using Watman-42 filter paper and stored in sampling bottles. [28]. A blank solution (containing all reagents except plant sample) was also digested with samples as blank. Read on concentration mode by Atomic Absorption spectrophotometer.

### *2.7. Calculations Required*

The heavy metal concentration in leaves and fruits of plants were measured with atomic absorption spectrophotometer and then further applying following formula,

Heavy metal (ppm) = AAS reading x dilution factor

## 3. Results

The electric conductivity (EC) and pH of wastewater being used to irrigate the vegetables and soil in presented in Figure 1. The results shows that the pH in wastewater was slightly acidic in nature and in most of the samples the pH is lower than 6.5 while on other hand the electric conductivity was in limit for few samples otherwise it was also exceeding the limit.

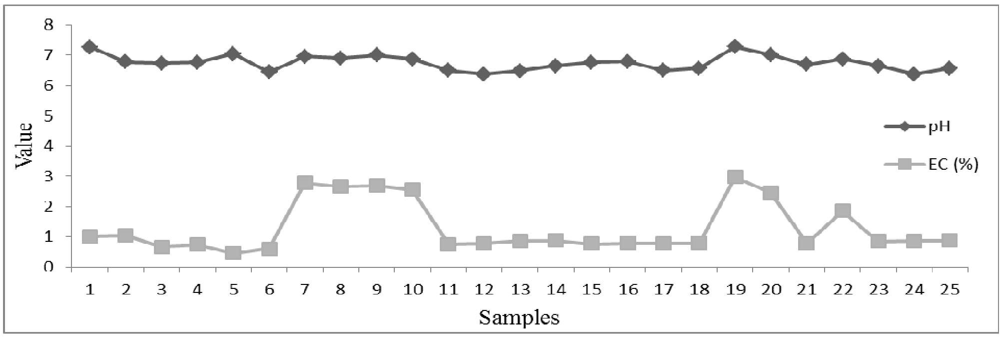
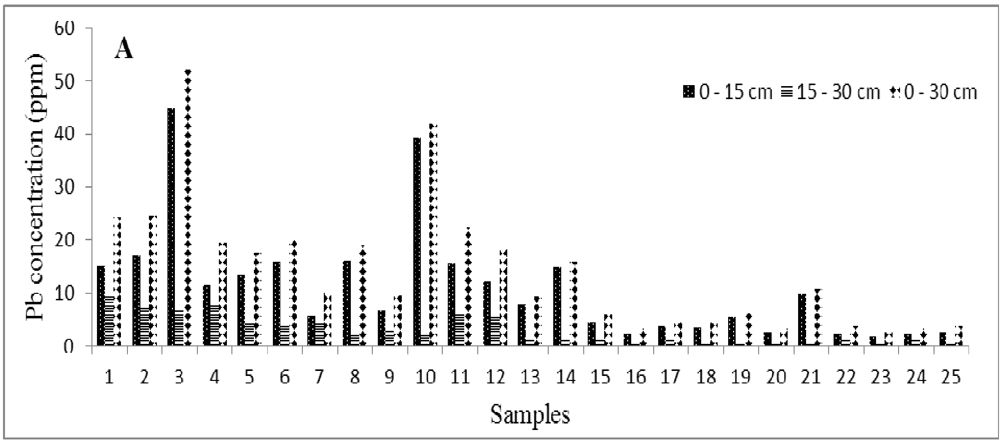



***Figure 1.*** *Electric conductivity (EC) and pH of sewage waste water being used for irrigation of selected soil and plants.*

Figure 2(A) showed that the maximum concentration of Pb was 52.04 ppm in sewage sample number 3 which was taken from the Site near to Nawabanwala colony while the 2nd highest value was 42.08 ppm in sample number 10 that was taken from D-type colony. As both these area has textile industries which are source of heavy metal contamination. Industrial effluents contain suspended solids, biodegradable organic matter, toxic organic compounds (e.g. phenols), and heavy metals [30]. Figure 2(B) showed that the maximum concentration of iron (Fe) was 35.29 ppm in sample number 7 which was taken from the site near to Malkanwala colony while the second highest value was 33.51 ppm in sample number 9 that was taken from D-type colony.

Figure 2(C) showed that the maximum concentration of manganese was 48.57 ppm in sample number 3 which was taken from the site near to Nawabanwala colony. And the second highest value was 36.15 ppm in sample number 6 that was taken from Sheikhanwala colony.



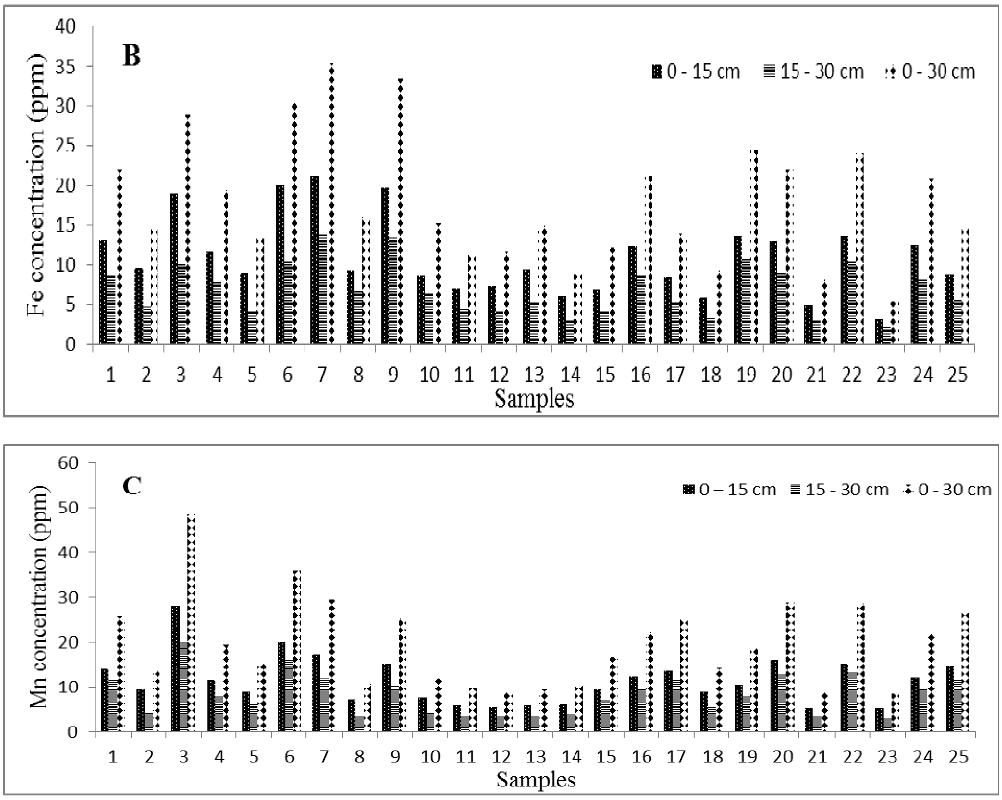
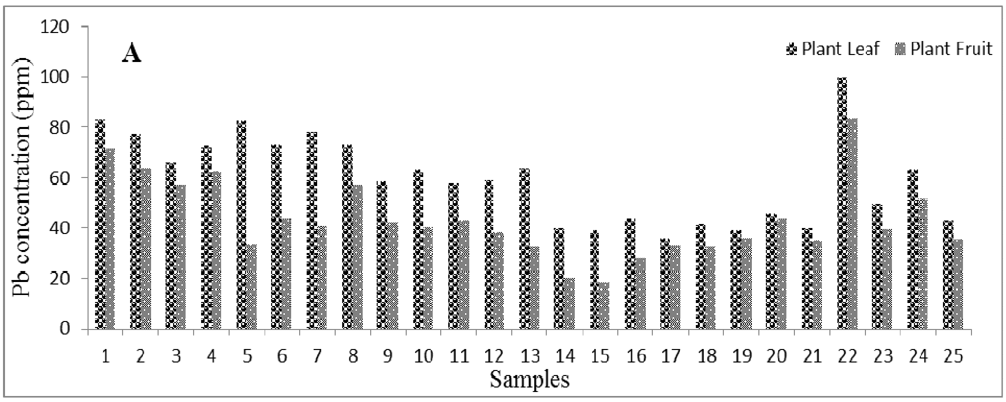



***Figure 2.*** *the concentration of Pb (A), Fe (B) and Mn (C) at different depth levels of soil 0-15, 15-30 and 0-30 cm being irrigated with waste water,*

The Figure 3(A) showed the uptake of Pb in vegetable samples. The data indicated that the highest Pb uptake (99.8 ppm) in vegetable leaves was obtained in sample number 22 which was taken from Rabani Colony while the lowest Pb uptake (39.3 ppm) in vegetable leaves was obtained in sample number 19 which was taken from Sitara Colony Faisalabad. The concentration of Pb in remaining soil samples was between this highest and lowest value while Figure 3(A) also describe the concentration of lead in vegetable fruit samples. Maximum lead concentration (83.7 ppm) in vegetable fruit samples were obtained in samples 22 which was taken from Rabani Colony and minimum Pb concentration (18.5 ppm) was obtained in sample 15 followed by sample No. 14. These samples were taken from Shalimar Colony and Peoples Colony respectively.

The concentration of Fe in vegetable leaves and fruit samples is given in Figure 3(B). In case of vegetable leaf samples, the maximum concentration of Fe was 572.5 ppm in sample 12 while the second highest concentration was 571.6 and both of these samples were obtained from people's colony. In case of fruit samples the highest Fe concentration was 287.5 ppm in sample 19 which was taken from Sitara Colony while the second highest value was 255.7 ppm that was taken from people's colony. Within time these areas has been changed to industrial areas so the vegetables gain industrial water to grow up.



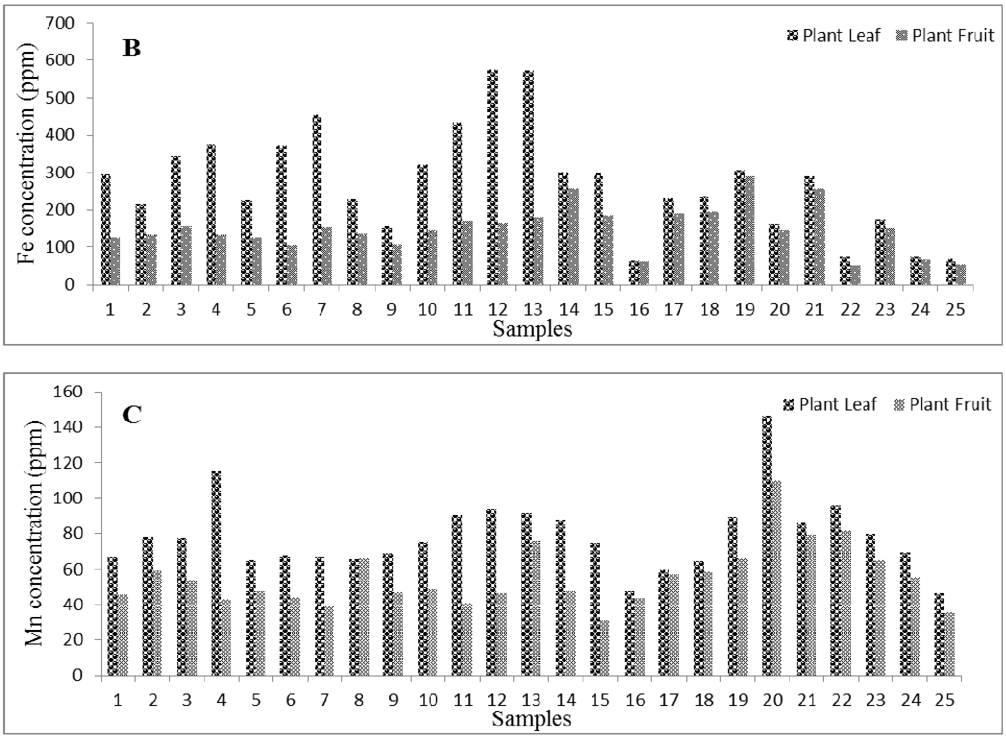



***Figure 3.*** *The concentration of Pb (A), Fe (B) and Mn (C) in leaves and fruits of different plants grown on soils being irrigated with waste water,*

The concentration of Mn in vegetable leaf and fruit samples is shown in Figure 3(C). The highest Mn concentration in vegetable leaves (146.5 ppm) was recorded in sample 20 which was taken from Rabani Colony and the lowest concentration of Mn (46.5 ppm) was recorded in sample 25 which was taken from Nemoana, Faisalabad while the maximum Mn uptake in vegetable fruit (109.8 ppm) was obtained in sample 20 which was taken from Rabani Colony and the minimum Mn concentration (35.7 ppm) was obtained in sample 25 which was taken from Nemoana. The concentration of Mn in the remaining samples was between the recorded highest and lowest value.

# 4. Discussion

The use of municipal and industrial waste water for irrigation purposes has increased over the past few decades, because of its easy accessibility, discarding troubles and shortage of fresh water. Area irrigated with waste water worldwide is about 20 million hectares and it contributes 40% food production [24]. In Pakistan, 32,500 hectares [5] Utilize waste water add considerably large amount of heavy metals in soil and plants grown. The use of wastewater for irrigation has led to variations in physicochemical characteristics of soil and uptake of heavy metal by food crops, mainly vegetables and our present results for pH and electric conductivity [31, 32]. Our results for pH and EC of wastewater are in agreement with the results of Habiba et al., [33] and Iqbal et al ., [34].

According to Farid et al., [35] the safer limit for Pb is 5 ppm in plants while the lowest value in the above samples is more than 5 ppm. So these concentrations obtained from samples are very high and it is not safe to use these vegetables as a food source. Lead is a serious body cumulative it enters in body through water and air and cannot be detached from vegetables and fruits by washing [8]. Pb introduction in food chain can affect the human health and the accumulation in vegetables has increasing attention [35]. The dietary limit of iron (Fe) in food is 10.01-60.06 ppm/day [36]. The major sink reported of Fe accumulation is leaves which used to form chlorophyll. When the pH of soil decreased to 5.0 and concentration of Fe increased to 300 mg kg-1 triggers Fe toxicity in plants [3]. However, previous studies reported the high concentration of Fe in vegetables and its effects on synthesis of chlorophyll in plants relevant to its abundance in earth crust. And the results of present study are in agreement with the study of [31]. A study was conducted by Prabu [37] to assess heavy metal contamination of vegetables that were irrigated with polluted water and according to his results metal transfer factors from soil to vegetables were significant for Zn, Mn, Cu, Fe and Cd and accumulation of Cr and Ni was comparatively less. This result is in agreement of this study as conditions in both the experiments were same and both are conducted to evaluate the effects of industrial water contamination.

According to The National Research Council, safe and sufficient daily intake levels of manganese ranges from 0.3 to 1 ppm/day and beyond 5 ppm is toxic [38] while the permissible level of Mn is 0.2 mg kg-1 and the results of our study are higher than of this limit. The elements responsible for high portion of Mn in vegetables were supposed to by the application of fertilizers and agricultural pesticides and of soil type [39].

# 5. Conclusion

The present study revealed that heavy metals concentration in the soil irrigated with waste water was above the toxicity levels. The maximum concentration of lead, iron and manganese was recorded in soil samples taken from Nawabanwala, Malkanwala and Sheikhanwala. The concentration of heavy metals in upper layer of soil (0 -15 cm) is higher than the lower layer (15-30 cm). The reason behind is that the upper layer was receiving sewage water permanently while the penetration of sewage water below 30 cm was less. That's why the heavy metals accumulated more in the upper layer while the edible portion (fruit) of the plants accumulate the more heavy metal concentration as compare to leaves while the pH and EC plays and important role in uptake of heavy metal in plants.

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