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The analyses of heavy metal concentrations in soil, waste water and *Raphanus sativus (L.)* at three different growth stages

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Abstract

The recent experiment was conducted for the comparison of the heavy metal concentrations in soil, sewage water and in *Raphanus sativus (L.)* at three different growth stages, irrigated with municipal wastewater of Rawalpindi city. Field surveys were carried out. Three experimental sites, Shamsabad road, Nala lai and Liaqat Bagh road were selected in Rawalpindi during this survey. Water, soil and vegetable (*Raphanus sativus L.)* samples were collected from all these sites. The collected samples were analyzed following the standard procedures for heavy metals like, Copper (Cu), Chromium (Cr), Lead (Pb), Cadmium (Cd), Nickel (Ni), Zinc (Zn), Cobalt (Co), Arsenic (As), Manganese (Mn), Iron (Fe), Magnesium (Mg) and Molybdenum (Mo). The survey data showed significant variations between heavy metals concentrations in water, soil and vegetable (*Raphanus sativus L.)* samples at three different growth stages.

Keywords: Municipal, variation, experimental, significant, heavy metals.

INTRODUCTION

Untreated or partially treated wastewater can introduce a huge amount of inorganic and organic contaminants into agricultural soils (Wang and Tao, 1998). The common sources of heavy metals found in environment are solid waste disposal, automobiles exhaust, waste water irrigation, sludge application and industrial activities (Shi et al., 2005).During last few decades, soil has become more contaminated by increasing the concentrations heavy metals like Cu, Zn, Ni, Cd and Pb (Chibuike and Obiora, 2014) from different sources such as fertilizers, pesticides, municipal waste, traffic emission and industrial effluents (Morgan *et al.,* 2013). Plants grown near these sites accumulate metals in their organs (Jarup, 2003). Vegetables accumulate heavy metals in their edible and non-edible parts. Leafy parts of vegetables accumulate higher amounts of heavy metals than their fruits (Sawidis *et al.,* 2001). The ability to accumulate these metals depends on several factors as its assimilation capability, levels of sewage sludge amendments applied (Muchuweti *et al.,* 2006) and plant metal uptake or transfer factor of metals from soil to plants.

Mapanda *et al.,* (2005) determined that the concentrations of heavy metals in vegetables per unit dry matter generally follow the order: leaves > fresh fruits > seeds.Pakistan is an agricultural country with high population growth. It is reported that naturally Pakistani soils have low fertility to maintain crop production

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economically (Rashid, 1993; Jamal *et al.,* 2002). In Pakistan, the annual production of fruits and vegetables is about 1285.6 thousand tons. Annual vegetables production from it consist of 5675.8 thousand tons (Nazli and Meilki, 2008). Ingestion of vegetables irrigated with waste water and grown in soils contaminated with heavy metals poses a possible risk to human health and wildlife (Mussarat *et al.,* 2007). Increasing the heavy metal contents in the soil also increases the uptake of heavy metals by plants depending upon the soil type, plant growth stages and plant species (Farooq *et al.,* 2008). It is estimated that about 10% of the world total population dependent to the waste water irrigated food crops and vegetables (Corcoran *et al.,* 2010). Property of heavy metals to soluble in water make them harmful and cause damaging effects to all living organisms including plants, animals and humans even at low concentration (Uzu *et al.,* 2011).

Continuous use of wastewater on crop lands over long periods of time may exert adverse impacts on the quality of soil and also on plants grown on such soils (Sinha *et al.,* 2006). Vegetables accumulate heavy metals in their edible and non-edible parts. Plants are directly affected by dangerous heavy metals which are accumulated in agricultural soil due to uncontrolled practices for the use of waste water for irrigation purpose (Muhammad *et al.,* 2013). Although some of the heavy metals, such as Zinc (Zn), Manganese (Mn), Nickel (Ni) and Copper (Cu) act as micro-nutrients at lower concentrations but they become toxic to both the plants and their human consumers at higher concentrations. Plants which are growing in heavy metal contaminated soil causing adulteration in food chain that may be lethal to human beings and animals (Jolly *et al.,* 2013; Shahid *et al.,* 2015).

Health risks due to heavy metal contamination of soil and vegetables have been widely reported (Satarug *et al.,* 2003). Human nervous, immune, circulatory, skeletal, endocrine and enzymatic system can be damage due to excessive intake of Pb in human body (Guo *et al.,* 2012). Men, women and children can be the victims of different toxicological problem by eating carrot grown in Cd contaminated soil (Roy and McDonald, 2015). Heavy metal pollution not only destroy the worth of food, water, soil but also hazardous to human and animals health (Zeng *et al.,* 2011).

Crops and vegetables which are grown in soils contaminated with heavy metals have greater tendency to accumulate more heavy metals than those grown in uncontaminated soil (Marshall *et al.,* 2007).

By increasing the world population, pollution have become a global problem and we need to control it by more information and evaluation of soil pollution (Mahmoud and El-Kader, 2015; Riding *et al.,* 2015; Wang *et al.,* 2015). Sewage water as transporting agent, take out heavy metals along with it into the soil which are distributed, deposited and accumulated in different localities (Mahmoud *et al.,* 2012).

When Heavy metals consumed in excess and for a prolonged period of time, these can cause various diseases. Plant growth and development is adversely affected by any change in abiotic stresses which negatively affects the physiological and biochemical yield performance of crop. When plants suffer from these stresses it causes reduction in crop yield (Farooq *et al.,* 2008). These may disturb the normal functions of central nervous system, lungs, liver, heart, kidney and brain, cause hypertension, abdominal pain, skin eruptions, intestinal ulcer and different types of cancer (Friedel *et al.,* 2000).(Itoh *et al.,* 2014) reported that high intake of Cd by dietary need can cause postmenopausal breast cancer.

In developing countries formers are directed to adopt low cost practices to produce plentiful amount of food for the inhabitants (Iqbal *et al.,* 2016) to fulfill the need of feedings but contaminated food material have great health risk to human beings (Jan *et al.,* 2010; Khan et al., 2010; Mahmood and Malik, 2014). Prolonged irrigation with wastewater could lead to the accumulation of heavy metals in soils beyond crop tolerance levels (Rusan *et al.,* 2007). Uptake of trace metals from soil differs from plant to plant and from site to site.

Thus, there is need of careful studies in order to fully analyze and understand the long term environmental impacts of the use of sewage water for crop irrigation (Nabulo *et al.,* 2008). Now many countries facing the problem of water shortage but the waste water used as irrigation agent in that countries that brings many harmful heavy metals which directly enter the food chain via primary producers and cause big damage to soil, plants and dependents of them (Al. Ansari *et al.,* 2013; Duan *et al.,* 2015).

Soil provide feedings to earth lives (Brevik *et al.,* 2015; Baig *et al.,* 2010; Decock *et al.,* 2015; Berendse *et al.,* 2015) so it is very essential to investigate how societies degrade the soil quality and fertility. This study was carried out to assess how much metals are accumulated in soils which are irrigated with water containing heavy metals as no special techniques are used but additional agricultural practices are used.

MATERIALS AND METHOD

Collection of samples

The samples of *Raphanus sativus (L.)* were randomly collected from the fields, irrigated with municipal wastewater of Rawalpindi city at seedling, vegetative and maturity stages. Leafy vegetables were preferred for sampling because previous researches indicate that they accumulate heavy metals at a greater capacity than other vegetables.

Study area

Three sites were selected to study the sewage water effects on vegetables:

i). Shamsabad road
ii). Nala lai
iii). Liaqat Bagh road.

The industrial and sewage waste were deposited over there.

Washing of samples

The collected vegetable (*Raphanus sativus L.)* samples were washed with distilled water to remove dust particles.

Weighing

Fresh weight of samples of the studied plant was taken in grams (g) using Electric balance.

Drying of samples

Leaves of vegetable (*Raphanus sativus L.)* were air-dried and then placed in an oven at 100°C for 72 hrs and then dry weight was taken.

Grinding of samples

Dried samples of leaves of vegetables were ground into a fine powder using pestle and mortar and stored, until was used for acid digestion.

Preparation of samples/wet digestion

Samples (0.2 g) of leaves of each vegetable were weighed on electric balance and treated with 10 ml of concentrated HNO3. The flasks containing the samples were kept for a night at room temperature. After that, 2 ml H2O2 were added to the sample and then placed on hot plate. More H2O2 was occasionally added to the sample, while the digestion continued until a colorless solution was obtained. After cooling, the solution was filtered with ashless Whatmann No.42 filter paper and it was then transferred quantitatively to a 50 ml volumetric flask and adding up to the mark with the distilled water. Soil digestion was also carried out in the same way as mention earlier. Sewage water was filtered and then subjected to analysis.

Preparation of standards and analysis of samples

Working standard solutions of Lead (Pb), Cu, Chromium (Cr), Zn, Cadmium (Cd), Iron (Fe), Arsenic (As), Cobalt (Co), Aluminum (Al), Mercury (Hg), Mn, Ni, Magnesium (Mg) and Molybdenum (Mo) were prepared from the stock standard solutions containing 1000 ppm of element and measurement of elements was done using atomic absorption spectrophotometer (AAS). Calibration curves were prepared for each element individually applying linear correlation by least square method. A blank reading was also taken and necessary correction was made during the calculation of concentration of various elements.

Statistical analysis

Three samples of leaves of each vegetable were analyzed individually. One way SPSS analysis of variance (ANOVA) was used to determine significant difference between groups.

RESULTS AND DISCUSSION

The survey data showed variation in heavy metals concentrations in water from the different sources. All the sewage water samples by which the vegetables were irrigated, recorded the safe levels of heavy metals accumulation. The field experimental data showed that due to sewage application, Zn content was much higher in leaves of R. sativus. Cadmium accumulation was also much higher. Like all the heavy metals, Nickel also showed similar trend for its accumulation in the vegetables. Sewage waste water showed higher concentration of heavy metals as compared to vegetables, but lower than that of soil samples.

The other elements including Nitrogen, Phosphorus and Calcium are not toxic to human unless they are present in high concentrations. The present study provides baseline data on the concentrations of Pb, Cu, Cr, Zn, Cd, Fe, As, Co, Al, Hg, Mn, Ni, Mg, and Mo in R. sativus (L.) (Figure 1). The concentration of Mn was observed to be the lowest at the seedling (initial) stage of growth and the highest during the vegetative (middle) stage. Fe concentration in soil was higher at final stage and low at the initial stage. Cd concentration in soil was the highest at the final stage but low at the initial stage. Co concentration in soil was maximum at final stage and vegetative stage.

Minimum concentration was examined at initial stage. Zn concentration in soil was in order as final>middle>initial. Ni concentration in soil was higher at final stage and minimum at initial stage. Mg concentration in soil was higher at final stage and minimum at initial stage. Cu concentration in soil was maximum at final stage but minimum at initial stage and intermediate at middle stage. Cr concentration in soil was maximum at the final stage but minimum at initial stage and intermediate at middle stage. Pb concentration in soil was in the following order: middle>final>initial. As concentration in soil was in the following order: final>middle>initial. Hg concentration in soil was

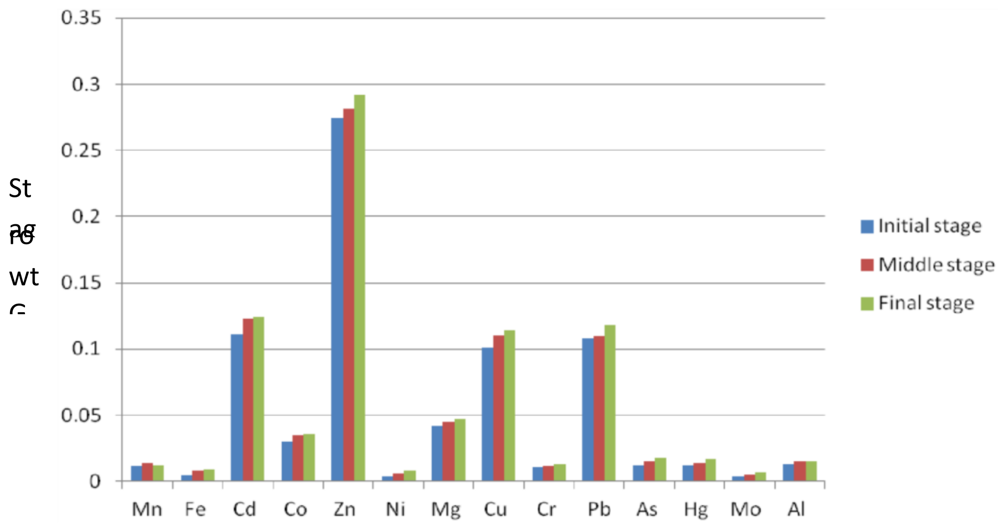

Figure 1 . Concentration of heavy metals in soil at 3 growth stages of *Raphanussativus* (mg kg^{-1}).

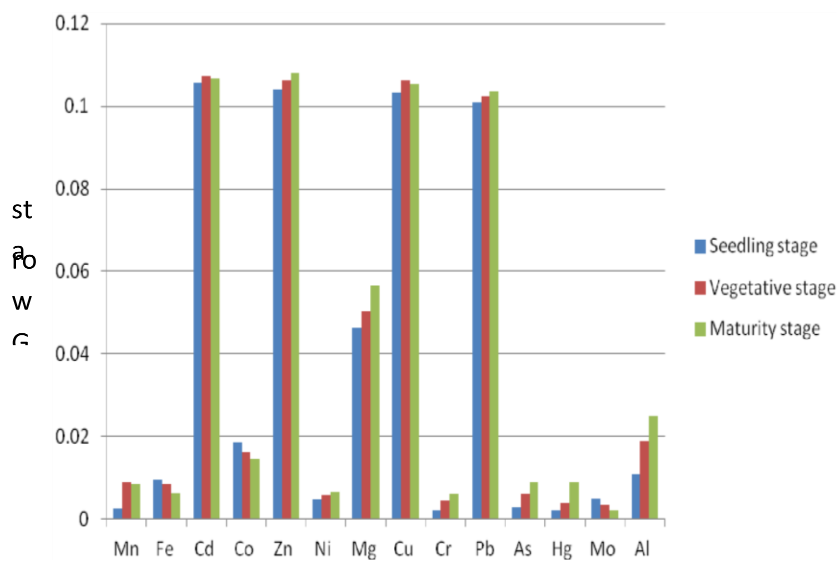

Figure 2. Concentration of heavy metals in root at 3 growth stages of *Raphanussativus* (mg kg^{-1}).

maximum at final stage but minimum at initial stage. Mo concentration in soil was higher at final stage and lower at initial stage. Al concentration was higher at final stage and minimum concentration was examined at initial stage.

Butt *et al.,* (2005) collected the vegetable samples of squash, potato, spinach, turnip, tomato and coriander and determined the accumulation of cadmium, lead and copper concentration in these vegetables irrigated with canal water and wastewater.

They reported that vegetables irrigated with sewage/industrial effluents had more heavy metals and micronutrients accumulation as compared to canal water irrigated vegetables. As in our study, the metals are accumulated as irrigated by sewage water.

Concentration of Mn reached maximum at vegetative stage and minimum concentration was observed at the initial stage. Iron (Fe) concentration in *R. sativus (L.)* was maximum at seedling stage, but minimum at final stage. Cd concentration in *R. sativus* was maximum at maturity stage, but minimum at seedling stage. Co concentration in *R. sativus (L.)* leaves was maximum at seedling stage and minimum at final stage. Zn concentration in *R. sativus* leaves was in order as final>middle>initial. Ni concentration in *R. sativus (L.)* was maximum at maturity

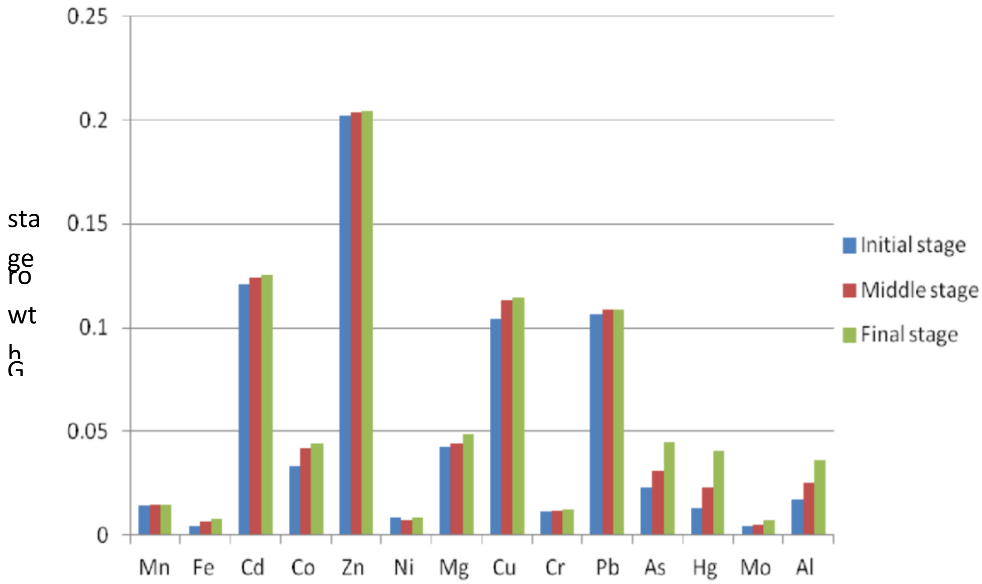

Figure 3 . Heavy metals profile of sewage water at 3 growth stages of *Raphanussativus* (mg L^{-1})

stage but minimum at seedling stage and intermediate at middle stage. Mg concentration in *R. sativus* leaves was in order as middle>final>initial. Cu concentration in *R. sativus (L.)* was maximum at vegetative stage, but minimum at initial stage. Cr concentration in *R. sativus* leaves was minimum at initial stage, but maximum at maturity stage. Pb concentration in R. sativus leaves was in order as maturity>vegetative>seedling. Since concentration in *R. sativus* leaves was in the order as maturity>vegetative>seedling. Hg concentration in *R. sativus* was higher at maturity stage, but lower at seedling stage. Mo concentration in *R. sativus* leaves was in order as seedling>vegetative>maturity. Al concentration was higher at maturity stage and lower concentration was examined at the seedling stage (Figure 2).

Concentrations of metals vary greatly at three different stages of the studied vegetables. Same results were reported by Latif (2009). This researcher reported that soils irrigated with wastewater had higher concentrations of metals as compared to canal or underground water/other sources. However, the concentration of metals varied with soil texture, depth and concentration of metals in polluted water. The lower concentration of Mn was examined at the initial stage and almost equal at the middle and final stages. Fe concentration of *R. sativus* in sewage water was lower at the initial stage, but higher at final stage. Cd concentration of *R. sativus* in sewage water was higher at the final stage, but lower at the initial stage. Co concentration in sewage water was higher at the final stage than in middle stage. Lower concentration was examined at the initial stage.

Zn concentration in sewage water was in the order as final>middle>initial. Ni concentration in sewage water was lower at middle stage and nearly equal at initial and final stages. Mg concentration in sewage water was in the order as final>middle>initial. Cu concentration in sewage water was higher at the final stage, but lower at the initial stage and intermediate at the middle stage. Cr concentration in sewage water was nearly equal at all three stages. Pb concentration in sewage water was higher at the middle stage and lower at the initial stage. As concentration in sewage water was in the order as final>middle>initial. Hg concentration in sewage water was lower at the initial stage and higher at the final stage (Figure 3).

Mo concentration in sewage water was in the order as final>middle>initial. Al concentration was higher at the final stage than the middle and lower concentration was examined at the initial stage. Similar results were reported by Mussarat *et al.,* (2007), who conducted a study to determine the concentration of heavy metals in sewage water and canal water used for irrigation purposes on agricultural lands of Peshawar. The concentration of Fe, Zn, Mn and Cu was within permissible limits of EPA Pakistan standards (EPA, 1993). Appropriate treatment of wastewater before application to fields was highly recommended whether it is from canal water or from sewage.

CONCLUSION

From this study, it is concluded that all the analyzed samples of sewage water, soil and vegetables showed significant variations in heavy metals accumulation. All the sewage water samples with which vegetables were irrigated showed the safe limits of heavy metals accumulation. The field experimental data showed that due to sewage application, Zn content was much higher in the leaves of *R. sativus L.* Cd accumulation in vegetables irrigated with sewage water was also much higher. Like all the heavy metals, Ni also showed similar trend for its accumulation in the vegetables. In water, there was higher concentration of heavy metals as compared to vegetables, but lower than that of soil samples examined.

REFERENCES

Al-Ansari N, Aldardor W, Siergieieve D, Knutsson S .(2013). Effect of Treated Waste Water Irrigation on Vegetables. Journal of Environmental Hydration. 22:12

Baig, J. A., Kazi, T. G., Shah, A. Q., Arain, M. B., Afridi, H. I., Khan, S. and Soomro, A. S. (2010). Evaluating the accumulation of arsenic in maize (Zea mays L.) plants from its growing media by cloud point extraction. Food and Chemical Toxicology, 48(11): 3051-3057.

Berendse, F., van Ruijven, J., Jongejans, E., and Keesstra, S. (2015) Loss of plant species diversity reduces soil erosion resistance.Ecosystems, 18: 881–888.

Butt MS, Sharif K, Bajwa BE, Aziz A (2005). Hazardous effects of sewage water on the environment: Focus on heavy metals and chemical composition of soil and vegetables. Managment of Environmental Quality. 16:338-346.

Brevik, E. C., Cerdà, A., Mataix-Solera, J., Pereg, L., Quinton, J. N., Six, J. and Van Oost, K. (2015). The interdisciplinary nature of SOIL. Soil, 1(1): 117.

Chibuike, G. U. and S. C. Obiora. "Heavy metal polluted soils: effect on plants and bioremediation methods.(2014). " Applied and Environmental Soil Science 2014 pp., 12.

Corcoran, E. (Ed.). (2010). Sick water?: the central role of wastewater management in sustainable development: a rapid response assessment. UNEP/Earthprint.

Decock, C., Lee, J., Necpalova, M., Pereira, E. I. P., Tendall, D. M., and Six, J. (2015). Mitigating N2O emissions from soil: from patching leaks to transformative action, Soil, 1: 687–694.

Duan, B., Liu, F., Zhang, W., Zheng, H., Zhang, Q., Li, X. and Bu, Y. (2015). Evaluation and Source Apportionment of Heavy Metals (HMs) in Sewage Sludge of Municipal Wastewater Treatment Plants (WWTPs) in Shanxi, China. International journal of environmental research and public health,12(12):15807-15818.

EPA (1993). National environmental quality standards. The gazette of Pakistan, Notification SRO No.742 (1)/43, Pakistan Environ. Urban. Aff. Div,Islamabad.

Farooq, M., F. Anwar and U. Rashid. 2008. Appraisal of heavy metal contents in different vegetables grown in the vicinity of an industrial area. Pakistan journal of Botany. 40(5): 2099-2106.

Friedel, J. K., Langer, C. Siebe, K. Stahr. 2000. Effects of long term wastewater irrigation on soil organic matter soil microbial biomass and its activities in central Mexico.Biology and Fertility of Soil. 31: 414-421.

Guo, G., Wu, F., Xie, F., & Zhang, R. (2012). Spatial distribution and pollution assessment of heavy metals in urban soils from southwest China. Journal of Environmental Sciences, 24(3): 410-418.

Huheey JE, Keiter EA, Keiter RL (2000). Inorganic Chemistry, 4th ed., Pearson Education Inc., USA, p. 889.

Iqbal, H. H., Taseer, R., Anwar, S., Mumtaz, M., Qadir, A., & Shahid, N. (2016). Human health risk assessment: heavy metal contamination of vegetables in Bahawalpur, Pakistan.bulletin of environmental studies, 1(1): 10-17.

Itoh, H., Iwasaki, M., Sawada, N., Takachi, R., Kasuga, Y., Yokoyama, S., Onuma, H., Nishimura, H., Kusama, R. and Yokoyama, K. (2014). Dietary cadmium intake and breast cancer risk in Japanese women: A case–control study. International journal of hygiene and environmental health 217(1): 70-77.

Jamal, A., Ayub, N., Usman, M., & Khan, A. G. (2002). Arbuscular mycorrhizal fungi enhance zinc and nickel uptake from contaminated soil by soybean and lentil. International Journal of Phytoremediation, 4(3), 205-221.

Jan, F.A., Ishaq, M., Ihsanullah, I. and Asim, S. (2010). Multivariate statistical analysis of heavy metals pollution in industrial area and its comparison with relatively less polluted area: A case study from the City of Peshawar and district Dir Lower. Journal of hazardous materials, 176(1): 609-616.

Jarup, C. 2003. Hazards of heavy metals contaminations. British Medicine Bulletin, 68: 167-182.

Jolly, Y. N., Islam, A., and Akbar, S.: Transfer of metals from soilto vegetables and possible health risk assessment, Springer Plus,2, 1–8, 2013.

Khan, S., Rehman, S., Khan, A.Z., Khan, M.A. and Shah, M.T. (2010). Soil and vegetables enrichment with heavy metals from geological sources in Gilgit, northern Pakistan. Ecotoxicology and Environmental Safety, 73(7): 1820-1827.

Latif MI (2009). Quantitaive assessment of heavy metals in soils and vegetables irrigated with sewag in rawalpindi area. (95- arid-19).

Mahmoud, E., & Abd El-Kader, N. (2015). Heavy metal immobilization in contaminated soils using phosphogypsum and rice straw compost. Land Degradation & Development, 26(8): 819-824.

Mahmoud, A., & Hoadley, A. F. (2012). An evaluation of a hybrid ion exchange electrodialysis process in the recovery of heavy metals from simulated dilute industrial wastewater. Water research, 46(10): 3364-3376.

Mahmood, A., Malik, R.N. (2014). Human health risk assessment of heavy metals via consumption of contaminated vegetables collected from different irrigation sources in Lahore, Pakistan. Arabian Journal of Chemistry, 7(1): 91-99.

Mapanda,F., E.N. Mangwayana, J. Nyamangara and K.E. Gillera. 2005. The effect of long-term irrigation using wastewater on heavy metal contents of soils under vegetables in Harare, Zimbabwe. Agriculture, Ecosystems & Environment.107: 151-165.

Marshall FM, Holden J, Ghose C, Chisala B, Kapungwe E, Volk J, Agrawal M, Agrawal R, Sharma RK, Singh RP (2007). Contaminated Irrigation Water and Food Safety for the Urban and Periurban Poor: Appropriate Measures for Monitoring and Control from Field Research in India and Zambia.Incpetion Report DFID Enkar R8160, SPRU, University of Sussex. www.pollutionandfood.net 2007.

Morgan, R.: Soil, heavy metals, and human health, in: Soils and human health, edited by: Brevik, E. C. and Burgess, L. C., Boca Raton, FL, USA, CRC Press, 59–82, 2013.

Muchuweti, M., Birkett, J.W., Chinyanga, E., Zvauya, R., Scrimshaw, M.D. and Lester, J.N. (2006). Heavy metal content of vegetables irrigated with mixtures of wastewater and sewage sludge in Zimbabwe: implications for human health. Agriculture, Ecosystems & Environment, 112(1), pp.41-48.

Muhammad H, Ayub M, Iqbal Z, Anwar Malik M. (2013). Heavy Metals Toxicity in Psidium guajava Irrigated by Polluted Water of Hudiara Drain in District Lahore, Punjab, Pakistan. Biologia (Pakistan) 59(2):239-244.

Mussarat M, Bhatti A, Khan F (2007).Concentration of metals in sewage and canal Water used for irrigation in peshawar, Sarhad

Journal of Agriculture. 23: 2.

Nabulo G, Origa HO, Nasinyama GW, Cole D (2008). Assessment of Zn, Cu, Pb, and Ni contamination in wetland soils and plants in the lake basin. International Journal of Environmental Science and Technology. 5 (1):65-74.

Nazli, H., & Meilke, K. (2008). Implications of high food prices for poverty in Pakistan. Agricultural Economics, 39(s1), 477-484.

Rashid,A., Rahmatullah and M. Salim. 1988. Soil condition and crop factors inducing zinc deficiency in plants. In; Proc. National Seminar on Micronutrients in Soil and Crops in Pakistan, held in Peshawar Dec.13-15-1987. Peshawar; NWFP Agricultural University; 94-117.

Riding, M. J., Martin, F. L., Jones, K. C., and Semple, K. T. (2015). Carbon nanomaterials in clean and contaminated soils: environmental implications and applications, SOIL, 1: 1–21.

Roy, M., & McDonald, L. M. (2015). Metal Uptake in Plants and Health Risk Assessments in Metal-Contaminated Smelter Soils. Land Degradation & Development, 26(8): 785-792.

Rusan, M. J., S. Hinnawi .2007. Long term effect of waste water irrigation of forage crops on soil and plant quality parameters. Dasalination; 215:143-152.

Satarug, S., Baker, J.R., Urbenjapol, S., Haswell-Elkins, M., Reilly, P.E., Williams, D.J. and Moore, M.R. (2003). A global perspective on cadmium pollution and toxicity in non-occupationally exposed population. Toxicology letters, 137(1), pp.65-83.

Sawidis, T., M.K. Chettri, A. Papaionnou, G. Zachariasis and J. Stratis. 2001. A study of metal distribution from lignite fuels using trees as biological monitors. Ecotoxicology and Environmental Safety. 48: 27-35.

Shahid, N., Anwar, S., Qadir, A., Ali., H., Suchentrunk, F. and Arshad,H.M.(2013). Accumulation of some selected heavy metals in Lepus nigricollis from Pakistan.Journal of Basic and Applied Scientific Research, 3(11): 339-346.

Sinha, S., S. Mallick, R. K. Misra, S. Singh, A. Basant, A. K. Gupta. 2007a. Uptake and translocation of metals in Spinacia oleracea L. grown on tannery sludge-amended and contaminated soils: Effect on lipid peroxidation, morpho-anatomical changes and antioxidants. Chemosphere., 67 (1): 176–187.

Sinha S, Gupta AK, Bhatt K, Pandey K, Rai UN, Singh KP (2006).Distribution of metals in the edible plants grown at Jajmau, Kanpur (India) receiving treated tannery wastewater: Relation with Physicochemical properties of the soil. Environmental Monitoring and Assessment. 115: 1– 22.

Shi, Z., S. Tao, B. Pan, W .Fan, Q.He, S.P.Zuo, W.R.Shen and P.K.Wong. 2005. Contaminations of rivers in Tianjin, China by Polycyclic aromatic hydrocarbons. Environmental pollution. 134:97-111.

Uzu, G., Sauvain, J.-J., Baeza-Squiban, A., Riediker, M., Sánchez Sandoval Hohl, M., Val, S., Tack, K., Denys, S., Pradere, P. andDumat, C.(2011). In vitro assessment of the pulmonary toxicity and gastric availability of lead-rich particles from a lead recycling plant. Environmental Science & Technology, 45(18): 7888-7895.

Wang XJ, Tao S (1998). Spatial structures and relations of heavy metal content in wastewater irrigated agricultural soil of Beijing's Eastern farming regions. Bulletin of Environmental Contamination and toxicology. 61, 261–268.

Wang, H.-Q., Zhao, Q., Zeng, D.-H., Hu, Y.-L., and Yu, Z.-Y. (2015). Remediation of a magnesium-contaminated soil by chemical amendments and leaching, Land Degrad. Dev., 26, 613–619, 2015.

Zeng, F., Ali, S., Zhang, H., Ouyang, Y., Qiu, B., Wu, F. and Zhang, G. (2011). The influence of pH and organic matter content in paddy soil on heavy metal availability and their uptake by rice plants. Environmental pollution, 159(1): 84-91.