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FOOD CHAIN CONTAMINATION WITH HEAVY METALS THROUGH WASTEWATER IRRIGATION: A REVIEW

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Abstract: Globally, agriculture sector consumes more water than any other sector of life. In order to cope with the problem of water shortage for irrigation, farmers use wastewater for irrigation in almost all countries of the world. Mining, domestic sewage and industries are the major sources of wastewater. The farmers use wastewater for irrigation because it contains nutrients for the growth of plants and have positive impacts on plants productivity. Along with nutrients wastewater also contains chemicals and heavy metals. Food plants uptake heavy metals from wastewater irrigated soil and accumulated in their edible parts. Vegetables irrigated with wastewater mostly contaminated with heavy metals and pose many health problems because of the accumulation of high amount of heavy metals. In many countries of the world the values of Total Target Hazard Quotient(TTHQ) is higher than one which means that consumption of these contaminated vegetable pose health risks for the human.

Keywords: wastewater irrigation; food crop; heavy metal contamination; health risk

Introduction

Heavy metals (HM) are released to environment from both natural and anthropogenic sources. Major anthropogenic sources like industries, agriculture, mining, transport and domestic sewage discharge HMs to the environment and lead to geo-accumulation, bioaccumulation and biomagnifications (Sharma et al., 2006; Gazso, 2001). Rapid urbanization and industrialization along with improper environmental planning and management are responsible for the discharge of wastewater and shortage of irrigation water. Agriculture sector needs more water than any other sector and nearly the whole world is facing fresh water shortage. In order to cope with the problem of water shortage in irrigation sector, wastewater has been used as a non-conventional resource from the past few decades (Chary et al., 2007). In suburban areas, the use of industrial or municipal wastewater for irrigation purposes is a common practice in many parts of the world (Singh et al., 2004). Farmers as well as municipalities always appreciate the use of wastewater for irrigation purpose because it is an alternative of fresh water for farmers and a way of disposal for municipalities. Water bodies are continuously and gradually polluted with HM (Lokeshwari et al., 2006).

Long-term wastewater irrigation is not only causing accumulation of HMs in soil but also contaminating food crops with HMs (Boularbah et al., 2006; Mapanda et al., 2005). According to Khan et al. (2008a) in metropolitan areas of Beijing, China, both the industrial and domestic sewage are treated biologically and then used for irrigation purpose. Even after biological treatment, the wastewater contains beneficial nutrients, organic and inorganic pollutants like HMs (Chen et al., 2005). Irrigation with wastewater from industries and urban areas is an important source of HMs for the agriculture soils (Cui et al., 2005). HMs reached to soil through irrigation, adsorbed and retained to organic and inorganic soil alloids (Bride, 1986). The plants uptake the HMs from soil out of which some are good for their life functions like metabolic process and enzymatic reactions (Adrian, 1986). HMs are the components of enzymes, helping in protein synthesis and iron balance of the cell (Kosolapov et al., 2004). Both the deficiency and excess of HMs can cause serious disorders in ecological system. Excessive uptake of HMs by plants is neither good for plants nor for human beings who are the plants consumers, cause phytotoxicity in plants and health problems in human (Haq et al., 2003).

As mentioned earlier, soil receives HMs such as Cd, Zn, Cr, Ni, Pb and Mn from wastewater irrigation. Due to continuous and long term use of wastewater for irrigation the capacity of soil to hold the HMs decreases and finally the soil release the HMs to groundwater and/or the soil solution available for plant uptake. Excessive accumulation of HMs in agricultural

soils through wastewater irrigation may not only result in soil contamination, but also leads to elevated HMs uptake by crops and thus affect food quality and safety (Muchuweti et al., 2006). Furthermore, vegetables cultivated in wastewater-irrigated soils are responsible to take up HMs in large enough quantities to cause human health problems (Khan et al., 2008b). Under specific condition the HMs accumulate in the soil to the levels, which are toxic and can lead ecological consequences (Wang et al., 2005).

HMs enter to human body through different ways but the food chain contamination is one of the important pathways which contributes 90% of HMs as compare to other routes like inhalation and dermal contact (Loutfy et al., 2006). Figure 1 shows the rout of transmission of HMs from sources to human.

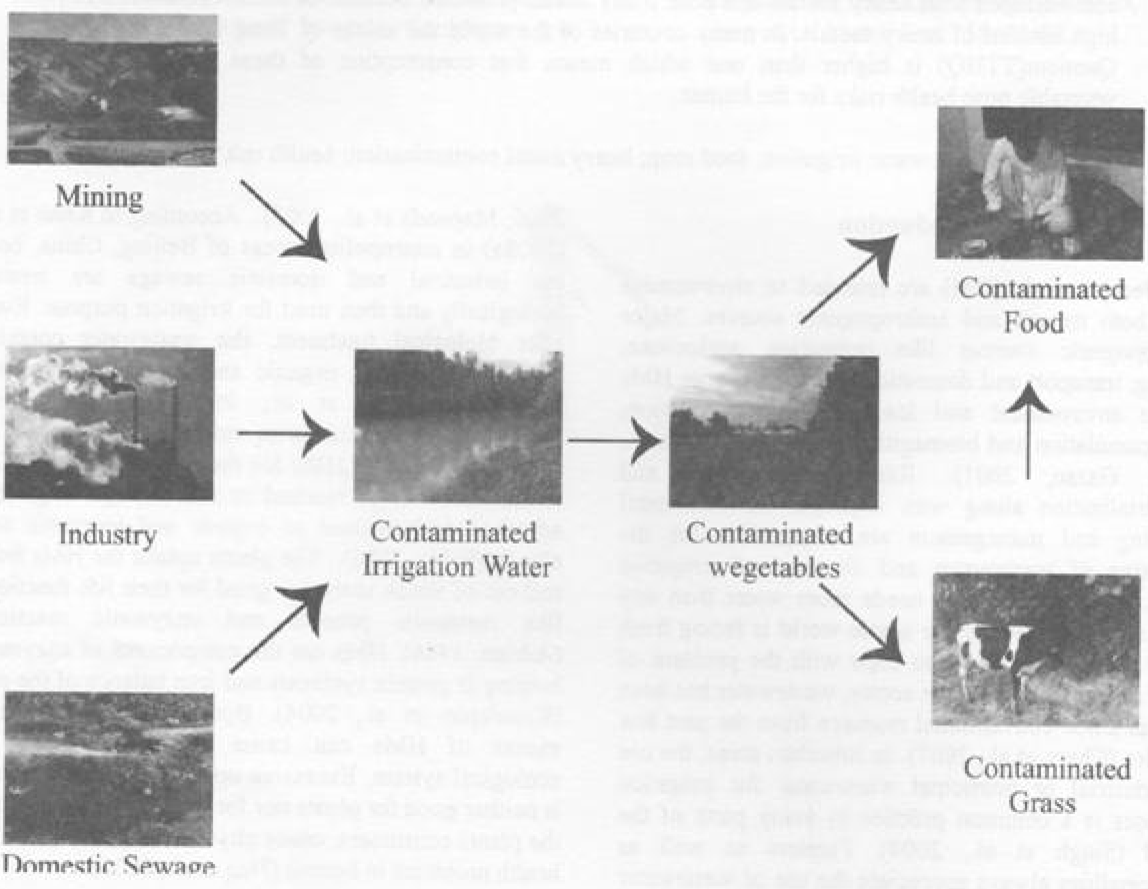

Fig. 1. Food chain contaminated with heavy metals through wastewater irrigation.

The lifetime exposure to HMs is a pressing environmental health risks which were not properly investigated in the past (Suk et al., 2002). The accumulation of HMs in the human bodies can cause serious health problems. Chronic exposure to certain HMs reduces lung function (Rastogi et al., 1991; Tager et al., 2005), responsible for asthma, emphysema and lung cancer (Kuo et al., 2006). HMs bind to protein and inhibit enzymes like enzymes of mitochondria (Rossi et al., 1993; Goering, 1993). Metals in the human body interfere with many voltage and ligand-gated ionic channels which cause many neurotoxic effects (Garza et al., 2006). Metals specially Mg, Ni and As can cause tachycardia, increased blood pressure and anaemia which is due to inhibitory effect on haematopoiesis (Huang and Ghio, 2006). In the past, numerous research works were conducted by different researchers to highlight the wastewater irrigation and its adverse impact on environment and human health (Khan et al., 2008ab; Chary et al., 2007). However, the main objective of this study was to summarize the research work about the wastewater irrigation, food crop contamination with HMs and health problems.

Free Availability of Fertilizers

Commercial fertilizers are expensive and majority of the farmers in developing countries are poor, can not afford the cost of these fertilizers. Industrial and domestic sewage irrigation recovers the deficiency of some of the nutrients (Parveen et al., 2006). The use of sewage for irrigation is inexpensive, easy and logical practice (Dursun et al., 2005), increases crop yields and reduces cost of production because crops irrigated with wastewater need less inorganic nutrients in the form of fertilizers (Ahmad et al., 2006). Sewage can be a good replacement of commercial fertilizers for crop production because it contains plants nutrients and organic matter (Dursun et al., 2005). Wastewater irrigation provides nutrients to plants in the required amount or even more than the required amount.

Wastewater irrigation is considered a good source of organic matter and plant nutrients but among all the necessary things for plants the most important are N and P (Shah and Raizullah, 2003). The availability of N increases cations capacity of soil, which as a result increase capacity of soil to retain nutrients (Epstien et al., 1976). Furthermore, sewage is also a good source of micronutrients such as Fe, Zn, Mn, Cu (Chen and Stevenson, 1986). The nutrients are inorganic raw materials necessary for the growth and development of plants and are required in certain quantities (Parveen et al., 2006). The nutrients increase plant productivity (Bansal, 1992). Some nutrients like N is important in carbohydrates utilization, P is important in energy transformation and K in enzymes activation, protein synthesis and osmotic regulation (Samuel, 1985). Mohammad et al, (2004) reported that the uptake of N is higher in wastewater irrigated plants than the plants that get nutrients from commercial fertilizers like diammonium phosphate (DAP). In the fertilizers treatments the uptake was recorded as 79.2 mg/plant while in plant treatment with 80 t/ha use of wastewater was 577.8 mg/plant.

Wastewater irrigation increase plants biomass and productivity due to improved soil fertility, increase soil aeration, permeability, water retention, water infiltration, better aggregation and fewer surfaces crusting (Tisdale, 1993). A positive correlation exists among micronutrients content and soil physio-chemical properties (Singh and Mongina 1993; Goswami and Darmaker, 2002). In the developing world the countries like Pakistan and some developed countries are also using a mixture of municipal and industrial wastewater for crop production (Nazif et al., 2006).

Positive Impacts of Wastewater Irrigation on Plants

The use of wastewater for irrigation is a common practice nowadays. These practices are responsible for the improvement of physical, chemical and biological properties (Parkpian et al., 2003) of soil and finally improve the fertility index of soil and ultimately increase the production per unit area. As mentioned earlier, the wastewater contains both macro and micro plants nutrients so its application significantly increase the germination rate of seeds and, increase the growth of seedling and improve the yield of crops. According to Qasim et al, (2000) the 75% and 100% sewage mixture is good for maize plants. The application of the wastewater increase N uptake by plants. The application of 160 t/ha of wastewater increased the N uptake by lettuce plants from 1.93% (control treatment) to 3.7% and K showed increase uptake only in treatment with 20 t/ha (Muhammad and Athamneh., 2004), similarly the application of wastewater increases the value of the fresh and dry weight of lettuce. Burun et al, (2006) reported that with increasing rate of wastewater application to soil (3-25 t/d) the barley grain yield and nutrients contents of barley were

increased. Dursun et al, (2005) in a experiment on seedling of pepper observed the maximum values of plant growth parameters like germination rate, germination period, hypocotyls length, cotyledon width, shoot and root length, shoot and root fresh weight, shoot and root dry weight, stem diameter, leaf per seedling at treatment with 75% of wastewater. Similarly number of productive tiller, grain/ spike, weight of 1000 grain, grain yield, straw yield, plant height, spike length, leaf area (cm2) of wheat plants with the treatment of 40 t/ha and 80 t/ha of wastewater showed maximum values (Jamil et al.,2006).

The applications of wastewater has significantly increased growth parameters of bean seedlings like root and shoot length, root and shoot fresh weight, root and shoot dry weight (Zeid and Abou El Ghate 2007). Spinach growers get maximum yield with the application of wastewater having a large amount of organic matter (Ahmad et al., 2006). The application of wastewater enhances leafy vegetables yield in short run and according to Ahmad et al, (2006) 1% increase in the use of wastewater is responsible for 23% increase in spinach yield. Wastewater containing HMs, which are essential for the activities of living things but as the concentration increases up to a certain limit create toxicity in plants (Gulfaraz et al., 2003). The metals like Fe, Mn and Co are essential metals and are required for many enzymes for the normal functions of body (Gulfaraz et al., 2003).

Sources of HM in Irrigation Water

Mining

Mining and processing are the important factors for environmental contamination with HMs (Navarro et al 2008; Gabler and Schneider 2000; Marszalek and Wasik 2000), and resulted the disturbance in aquatic and terrestrial ecosystem (Malinovsky, et al., 2002). Physical disturbance of surrounding landscape, effluent from acid mine transported into near by rivers, emitted dust and spilled mine tailing are the factors for the contamination of environment from the mine area (Zhuang et al., 2009). Mining activity is considered as one of the factor of contamination of water with HMs (Prasad and Bose, 2001) and surrounding agriculture soil accumulate excessive amount of HMs (Pruvot et al., 2006). The adverse impact of mining activities depends on many factors like mine type and size of the operation. Mining operation first changes the topography of land and then become a factor for the change of hydrogeologic conditions (Bell et al., 2000). Generally the impacts of the mining on soil, plants and on human decreases with increasing distance from the mine (Zhuang et al., 2009). Kachenro et al. (2006) reported that the concentrations of HMs in the soil were higher in the area near the metals smelter like Boolaroo and Port Kembla.

HMs pollution of mine area causes health problems in the local inhabitants (Kachenko and Singh, 2006) such as high blood Pb in the children (Pruvot et al., 2006; Bosso and Enzweiler, 2008). Certain regions or villages around Dabaoshan in China mine have been termed endemic cancer regions because esophageal cancers, liver cancer, and other cancers were reported frequently in humans and poultry, with a mortality rate approaching to 56% in humans because of high contamination of soil, sediments and plants with HMs in the surrounding areas (Zhuang et al., 2009). In other countries like Iron the Cu-mine (Sungun mine) contaminated Aras River, which is the largest river of the country. This river is responsible for the supply of water to tens of cities and villages, irrigation to a large piece of land, fish husbandry and to industrial areas. The concentrations of HMs like Cd, Cr, Cu, Fe, Mn, Mo, Pb and Zn were (not detectable for Cd), (0.39- 0.41 mg/l). (0.51- 1.03 mg/l, (0.62- 1.5 mg/l), (0.38- 0.63 mg/l), (0.22- 1.21mg/l) (ND- 0.01mg/l), (1.2-1.5mg/l) respectively, in the surface water in the vicinity of Sungun River (Bidhendi et al., 2007).

Domestic sewage

Table – 1 shows the concentration of HMs in the domestic sewage in many countries of the world. Growing urbanization along with other environmental problems created huge urban runoff in the last decades. The discharge of sewage and runoff to the water bodies and soil is a major threat for environment worldwide (Shinya and Tsuruho, 2003). Urban runoff is a source of pollution to river and coastal oceans and consists of pollutants which appear as risk not only for plants and animals but also for human (Nabizadeh et al., (2005). The threat of this risk is increasing with increasing sources of pollution and accumulation of pollutants over a longer period of time (Molly, 2002). Chemicals from homes and offices, automobiles, industrial discharges, erosion from construction sites are the main sources of contamination of the existing drainage. Repeated application of this water for irrigation can build up the concentration of HMs to a level which is toxic for plants and human (Kakar et al., 2006).

Table 1. Concentration of HMs (mg/l) in domestic sewage used for irrigation.

S. No	Area	Zn	As	Cd	Pb	Cu	Cr	Ni	Fe	Mn	Co	References
1.	Tehran city, Iron	0.638		0.04	0.097	0.035						Nabizadeh et al, (2005)
2.	Quetta, Pakistan	(0.08-0.21)			(0.05-0.12)	(0.03-0.07		(0.09-0.18)	(0.55-1)	(0.14-0.23)		Kakar et al, (2006)
3.	Rawalpindi, Pakistan	(0.5-0.83)		(0.021-0.031)	(0.24-0.84)	(0.37-0.62)	(0.39-0.45)					Chattah et al,(2003)
4.	Abotabad, Pakistan	(0.43-0.62)		(0.012-0.034)	(0.25-0.36)	(0.21-0.49)	(0.38-0.44)					Chattah et al,(2003)
5.	Attok Pakistan	(0.46-2)		(0.024-0.46)	(0.59-0.73)	(0.62-0.84)	(0.27-0.41)					Chattah et al,(2003)
6.	Pandu, Peshawar, Pakistan	0.06		0.26	0.75	0.99		0.11				Perveen et al, (2006).
7.	Well water Zob- Ahan steel industrial complex, Iran	(0.08-0.21)			(0.06-0.13	(0.025-0.125)	(0.125-0.25)	(0.055-0.175)	(0.07-19.8)		(0.14-0.20)	Rahmani and Rezaei, (2007)
8	Surface water Zob- Ahan steel industrial complex, Iran	2		0.1	1	1	0.5	2	3		1	Rahmani and Rezaei, (2007)
9.	Alaro River Ibadan, Nigeria				0.14	0.0923	0.021	0.03		0.456		Fakayode, (2005)
10.	Drainage ditches Florida, USA	121	18.67	70.50	5.53	63.7	2.05	3.05			1.1	Minglui et al, (2004)
11.	Wastewater Jaipur City, India	0.68 - 60.84	Non traceable	Non traceable	Non traceable	0.05-1.0	Non traceable	0/01-0.07	0.1-0.4	0.1-0.4		Singh and Chandel (2006)
12.	Karnaphuli River estuary, Bangladesh	1.112	Ug/ml	0.09	0.675	0.891	0.512	0.891	28.1	0.983		Das et al., (2002)
13.	Luxor, upper Egypt	0.03				traces			0.036	0.012		Hussein et al, (2004)
14.	Gangetic plain, India	785		154.5		317.7	35.3	47.17		186		Singh and Agrawal, (2007)
15.	Westren Delhi, India	0.061		0.00153	0.033	0.029		0.049	1.464	0.064		Rattan et al, (2005)
16.	Tehran city, Iron	0.638		0.04	0.097	0.035						Nabizadeh et al, (2005)
17.	Quetta, Pakistan	(0.08-0.21)			(0.05-0.12)	(0.03-0.07		(0.09-0.18)	(0.55-1)	(0.14-0.23)		Kakar et al, (2006)
18.	Rawalpindi, Pakistan	(0.5-0.83)		(0.021-0.031)	(0.24-0.84)	(0.37-0.62)	(0.39-0.45)					Chattah et al,(2003)
19.	Abbottabad, Pakistan	(0.43-0.62)		(0.012-0.034)	(0.25-0.36)	(0.21-0.49)	(0.38-0.44)					Chattah et al,(2003)
20.	Attok Pakistan	(0.46-2)		(0.024-0.46)	(0.59-0.73)	(0.62-0.84)	(0.27-0.41)					Chattah et al,(2003)
21.	Pandu, Peshawar, Pakistan	0.06		0.26	0.75	0.99		0.11				Perveen et al, (2006).
22.	Well water Zob- Ahan steel industrial complex, Iran	(0.08-0.21)			(0.06-0.13	(0.025-0.125)	(0.125-0.25)	(0.055-0.175)	(0.07-19.8)		(0.14-0.20)	Rahmani and Rezaei, (2007)

Blanks represent not detected

S. No	Area	Zn	As	Cd	Pb	Cu	Cr	Ni	Fe	Mn	Co	References
23.	Surface water Zob- Ahan steel industrial complex, Iran	2		0.1	1	1	0.5	2	3		1	Rahmani and Rezaei, (2007)
24.	Alaro River Ibadan, Nigeria				0.14	0.0923	0.021	0.03		0.456		Fakayode, (2005)
25.	Drainage ditches Florida, USA	121	18.67	70.50	5.53	63.7	2.05	3.05			1.1	Minglui et al, (2004)
26.	Wastewater Jaipur City, India	0.68 - 60.84	Non traceable	Non traceable	Non traceable	0.05-1.0	Non traceable	0/01- 0.07	0.1-0.4	0.1-0.4		Singh and Chandel (2006)
27.	Karnaphuli River estuary, Bangladesh	1.112	Ug/ml	0.09	0.675	0.891	0.512	0.891	28.1	0.983		Das et al., (2002)
28.	Luxor, upper Egypt	0.03				traces			0.036	0.012		Hussein et al, (2004)
29.	Gangetic plain, India	785		154.5		317.7	35.3	47.17		186		Singh and Agrawal, (2007)
30.	Westren Delhi, India	0.061		0.00153	0.033	0.029		0.049	1.464	0.064		Rattan et al, (2005)

Blanks represent not detected

Industries

Table – 2 shows the concentration of HMs in the effluent of many industries. Industrial revolution, which is a source of providing basic facilities to human on one hand but generating many problems for man and its environment on the other hand. The effluent of industries consists of HMs the discharge of which to water bodies not only contaminated water bodies but also the soil. HMs contamination not only degrading the quality of our natural resources but also adversely impacting agriculture production. The industrial sector discharge effluent to water bodies like rivers, canals and drainage system (Haq et al., 2005). The municipality considers these local water bodies as a natural and easily available sink for untreated wastewater from industries (Ali, 1997). The discharge of untreated industrial effluent in the surface drains contaminate surface water bodies and then contaminate soil and plants (Haq et al., 2005). The process of contamination of ground water and soil with HMs by industries has increased nowadays Industrial wastewater is also a threat towards the groundwater quality (Bashir et al., 2001).

Water pollution is a problem for the environment but especially for the people who live in developing countries (Rehman et al., 2008). Rattan et al. (2005), reported that the HMs like Zn, Fe, Ni, Mn, and Cu in the sewage effluent of Keshipur effluent irrigation scheme had much higher concentration as compared to local groundwater. Similarly Rehman et al. (2008) conducted a study to analyze the concentration of HMs in the drained water of three main industrial estates of Pakistan (Peshawar, Gujranwala and Hattar Haripur). The wastewater of these industries was highly contaminated with HMs, especially Pb and As. These effluents have been used for irrigation since last fifty years.

Food chain contamination with HM

Soil contamination with HM

Table – 3 summarizes the HMs concentration in the soil irrigated with wastewater. Wastewater contains not only HMs but also organic matter necessary for plants and soil ecosystem. Soil organic matter consists of two fractions i.e the humus fraction (humic acid, fulvic acid, humin) and the particulate fraction (Maldonado et al., 2008). Moreover, the application of wastewater significantly increases the HMs in soil (Samaras and Kallianou., 2000). Soil organic matter increases with long term wastewater irrigation because of the carbon present in wastewater (Jamil et al., 2006; Hooda and Alloway., 1993). The decomposition of organic matter in the soil is also responsible for the release of N content in plant available form after several years of wastewater application (Hemandez et al., 2002) and also increases the amount of soil P (Debosz et al., 2002), Mohammad and Athamneh, (2004) observed an increase of 7.66 mg/kg to 77.13mg/kg of N with the addition of 160 t/ha of wastewater. Soil pH is responsible for the availability of HMs, involved in the control of soil reaction with HMs and precipitation and dissolution of mineral in the soil (Chaudri et al., 2001). The application of wastewater to irrigated soil decreases soil pH (Jamil et al., 2006; Mohammad and Athamneh, 2004; Chang et al., 1990; Karthikeyan et al., 2005; McLaren et al, 2004; Maldonado et al., 2008). The decrease in soil pH, which is actually the generation of acidity, was due to the mineralization of wastewater (Welch and Lund., 1989). The application of wastewater is also responsible for the decrease of electric conductivity (EC) of soil. The application of 160 t/ha of wastewater decrease soil EC from 0.508 ds/m to 0.49ds/m (Mohammad and Athamneh., 2004). High salinity can affect the mobility of HMs (Maldonado et al., 2008).

The mobility and bioavailability of HMs in the soil depends upon the physical and chemical properties of soil. The process like adsorption, precipitation reactions are the factors controlling the mobility of HMs in the soil (Li et al., 2003). Accumulation of HMs in soil treated with high doses of wastewater has been reported by Aguilar et al (2001). Similarly El-Demerdashe et al. (1995) reported that long term addition of wastewater to soil accumulated HMs to a level which is toxic to some plants. Similar findings were observed in study conducted by (Jarausch et al., 2000). The wastewater application to soil increase the level of HMs in the soil which is positively correlated with soil organic matter and negatively correlated with soil pH (Jarausch et al., 2000). HMs soon after the entrance to the soil are adsorbed by the solid fraction (Surita et al., 2007). The presence, potential toxicity and mobility of HMs in the soil depends upon the saturation of specific sites of adsorbent, the crystalinity of absorbent, the morphology of absorbent, changes in of soil pH (Puls et al., 1992) The presence of HMs in soil is not only responsible for the toxicity of plants and animals but also for stopping the essential

biochemical processes which further change the balance of ecosystem. Accumulation of HMs in the soil decrease N fixation process and decomposition of organic matter which is further responsible for the change of natural nutrient cycles (Baath, 1989). The presence of microorganisms is very important for many process like assimilation, nitrogen fixation and degradation of organic matter for the use of plants (Brookes, 1995), which can be adversely affected by HMs in soil (Stuczynskiel et al., 2003; Nwuche and Ugodi, 2008; Khan et al., 2008).

HMs in plants

Table – 4 summarizes the HMs concentration in the plants irrigated with wastewater.

The uptake of HMs by plants from the soil depends on the soil properties like temperature, amount of nutrients, organic matter and soil pH (Akan et al., 2009). The accumulation of HMs in plants body is positively correlated with the soil organic matter (Chen et al., 1990) and negatively correlated with soil alkalinity (Akan et al., 2009). The uptake of HMs by plants is also positively correlated with wastewater irrigation (Sharma et al., 2007). According to Akan et al. (2009) the uptake of HMs by plants was higher in dry season than rainy season because of wastewater irrigation. The accumulation of HMs in plants not only depends on the availability of these in soil but also depends on plant species as well (Punz and Seighardt, 1993). Vetches can accumulate HMs like Co, Cu and Fe many times than their level in the soil (Kumar et al., (2009). The order of accumulation of Zn and Cd in vegetables was Green pepper >spinach > dill > mint> celery > eggplant > cress, Radish leaves >Cress>Radish roots>Dill>Spinach>Eggplant respectively (Bigdeli and Seilsepour, 2008).

The concentrations of HMs within the same plant are different in different plant organs.

The concentration of HMs in different organs of plants are in the order leaf>stem>root>tuber>seed (Santamaria. et al, 1999). Vegetables accumulate high amount of HMs in roots and leaves (Ademoroti, 1996). Leaves contain higher content of HMs (Akan et al., 2009). According to Sanita et al, (1999) the rate of accumulation of Cd in aerial parts of plants are higher than underground parts.

Kumar et al. (2009) found high mobility rate of HMs from soil to roots but little from roots to other plant organs. Rate of mobility of different HMs are different. Rates of mobility of Cd, Pb, Fe, Zn, Co, Ni and Cu are 1.61, 1.54, 1.21, 1.19, 1.17, 0.99 and 0.90 respectively(Kumar et al., (2009). The transfer potential of HMs among different plants systems i.e soil-root, root – stem and stem-leaves are different. The rate of transport of HMs in different plant systems are in order of stem-leaves >soil-root > root-stem (Kumar et al., (2009).

Human health risks associated with heavy metals

Some HMs like Cu, Zn and Co are essential for metabolic activities of animals and plants at some concentration but others like Cd and Pb is toxic to plants, animals and humans even at low concentration. The excessive accumulation of HMs in soil and plants pose serious health risks to human (Granero and Domingo, 2002).

The product of average concentration of HMs in the food item and the consumption rate of that food item is the daily intake of the HMs by human (Santos et al., 2004; Yu et al., 2006). The average consumption rate of vegetable is 200 g/person.d in Huludan city (Rattan et al.,2005) The dietary intakes of Hg, Pb, Cd, Zn and Cu in Huludan city, China for adult are 2.135×10^{-3} mg/d, 8.15×10^{-2} mg/d, 4.19×10^{-2} mg/d, 12.26 mg/d, 2.73 mg/d respectively, while for children are 9.71×10^{-4} mg/d, 4.33×10^{-2} mg/d, 2.02×10^{-2} mg/d, 7.25 mg/d, and 1.437 mg/d. The daily intake of HMs through vegetables in Baiyin, China is 0.05-0.16 mg/d, 0.99-2.2 mg/d 3, 2.15-5.1 mg/d, 6.29-13.16 mg/d,0.10-0.22 mg/d for Cd, Pb, Cu, Zn and As respectively (Yu et al., 2006). The daily intake of for Pb, Cd, Cu and Zn through vegetables is 30 µg/ g, 4.67 µg/ g, 0.45 µg/ g and 1.58 µg/ g for Pb, Cd, Cu and Zn in Alexandria city, Egypt (Mohamed et al., 2006). The consumption rate of vegetables in the area around the Dabaoshan mine, China is 274g/d and the intake of Cu, Zn, Pb and Cd through these vegetables is 327 µg/ g , 2357 µg/ g , 47 µg/ g and 59 µg/ g respectively(Zhuang et al., 2009). The daily consumption of rice and vegetables in Fujian Province, southeast China is 0.5kg and 0.5kg respectively, while the concentration of As in rice and vegetables is 0.20mg/kg and 0.17mg/kg respectively so the total intake of As through rice and vegetables is .10mg and 0.09mg respectively (Huang et al., 2006). The combine intake is 0.19(Huang et al., 2006), which is higher than the permissible limit i.e 0.14mg As (Tripathi et al., 1997).

Table 2. Concentration of HMs (mg/l) in the industrial effluent.

S. No	Area	Zn	As	Cd	Pb	Cu	Cr	Ni	Fe	Mn	Co	References
1.	Korangi area Karachi	(0.005-5.5)		(0.004-2.4)	(0.05-2.25)	(0.005-1.91)	(0.004-5.62)	(0.02-5.35)	(0.04-5.58)	(0.01-1.97)		(Saif et al., 2005).
2.	Marble industries	0.06		0.056	3.20		0.46	0.03	0.03			Khan et al, (2002)
3.	Match industries	0.06		0.056	3.20		0.46	0.03	0.03			Khan et al, (2002)
4.	Steel industries	0.05		0.07	1.49		0.03	2.02	0.02			Khan et al, (2002)
5.	Pharmaceutical industries	0.01		0.03	0.7		0.03	2.05	0.08			Khan et al, (2002)
6.	Steel industries											Gulfaraz et al, (2003)
7.	Textile mill(Islamabad, Pakistan)	4.69	0.8	1.7	0.76	4.4	1.15	3.5	5.46	1.94	2.57	Gulfaraz et al, (2003)
8.	Textile mill (Rawalpindi , Pakistan)	5.1	0.6	2.7	1.56	7.1	1.95	2.6	5.06	1.24	2.17	Gulfaraz et al, (2003)
9.	Refinery (Islamabad, Pakistan)	1.57	0.19	409	5.13	3.77	1.15	2.2	3.7	0.53	0.15	Gulfaraz et al, (2003)
10.	Refinery (Rawalpindi , Pakistan)	2.51	0.69	3.4	6.11	2.79	0.159	3.201	2.12	1.11	0.19	Gulfaraz et al, (2003)
11.	Hydrogenated oil (Islamabad, Pakistan)	.19		0.157	0.011	1.09	0.12	6.2	3.64	0.156	0.21	Gulfaraz et al, (2003)
12.	Hydrogenated oil (Rawalpindi , Pakistan)	0.496		2.15	0.18	2.18	0.1	5	4.6	0.17	0.11	Gulfaraz et al, (2003)
13.	Biomass power plant	6.73		0.028	0.108		0.14	0.041	0.05	0.36	0.311	Nagajyoti et al, (2008)

Blanks represent not detected

Table 3. Concentrations of HMs (mg/kg) in soil irrigated with different wastewater.

S. No	Area	Zn	As	Cd	Pb	Hg	Cu	Cr	Ni	Fe	Mn	Co	References
1	D. I. Khan , Pakistan	16			40		15			15.5	21		Jamil et al., (2006)
3	Chihuahua, Mexico			4.48	155.83		51.36		10.74				Maldonado et al, (2008)
4	Dalsung copper-tungsten mine, Southeast Korea.	419		4.4	1,028		1,953						Jung, (2008)
5	Imo State, southeast Nigeria (Dry season)			6.2	71.9	0.02		4.7	6.5				Onweremadu et al, (2007)
6	Imo State, southeast Nigeria (Rainy season)			2.9	51.9	0/01		2.2	1.9				Onweremadu et al, (2007)
7	Central Jordan	146.94		4.98	62.17	1.81		83.93					Banat et al, (2005)
8	Guiyang area of Chenzhou, Hunan Province, China	508.6	44.6	7.53	348.3		356						Guo-li et al, (2008)
9	Turkey	12.1		5.9	80		20		22		171	48	Turkdogan et al (2002)
10	Yellow River, China	224.86	446.64	7.43	223.22		132.82	47.07					Yu et al, (2006)
11	Yangzhong, China	98.1	10.2	0.3	35.7	0.2	33.9	77.2	38.5				Huang et al, (2007)
12	Northwest Spain	85.4		0.15	24.8	0.45	15.7	24.1	8.4				Lopez-Mosquera et al, (2000)
13	Granada, Spain	5.5–76	3.5–20		15–36		13–25.6	29–66	7–20			7–23	Diez et al, (2009)
14	Southern Italy	150			100		120	150	120			20	Adamo et al, (2002)
15	Coimbatore, Tamil Nadu, India	397		0.07	175.5		157	114	171.4				Malarkodi et al, (2007)
16	Belgrade, Serbia	268.4		8.90	350		122.29	70.23	123.7		641	25.59	Grzetic et al, (2008)
17	Nilohi, Delhi, India	7.31		0.20	1.19		4.91		1.19	20.1	3.29		Rattan et al, (2005)
18	Mundka, Delhi, India	3.68		0.11	2.60		4.39		0.58	50.2	7.46		Rattan et al, (2005)

Blanks represent not detected

Table 4. Concentrations of HMs (mg/kg) in Plants.

S. No	Area	Zn	As	Cd	Pb	Cu	Cr	Ni	Fe	Mn	References
1	Wheat (Triticum indicum)	2.452	1.942	1.918	3.496	5.403		5.403			Gulfaraz et al, (2003)
2	Barley (Hordium vulgare)	8.4				7.5			7	1.3	Burun et al, (2006)
3	Effluent irrigated vegetables	78.8		7.4	64	103.2	22.5	88	638.8	973.3	Haq et al (2005)
4	Tube well irrigated vegetables	32.4		1.8	12.4	19.5	4.2	14.8	172.5	111.8	Haq et al (2005)
5	Vegetables irrigated with dairy-industry sludge	25.3		0.1	0.37	5	1.74	2.45			Lopez-Mosquera et al, (2000)
6	Wheat (Triticum indicum)	49.6				51.6		10.1	122	53	Rattan et al., (2005)
7	Spinach (spinecia oleracea)	77.1				20.6		18.4	711	39.3	Rattan et al., (2005)
8	Maize (Zea mays)	78.8				14.9		16.5	531	26	Rattan et al., (2005)
9	Wheat (Triticum indicum)	65.3				9.39		20	404	15.3	Rattan et al., (2005)
10	Cauliflower (Brassica oleracea)	46.7				10.8		14.4	328	31.8	Rattan et al., (2005)
11	Cucumber (Cucurbeta indica)	79.4				19.3		21.5	932	19.9	Rattan et al., (2005)
12	Parsley (Petroselinumcrispum)	85.78		11.54	7.44						Eslami et al, (2007)
13	Leek (Allium cepa)	72.12		8.34	10.21						Eslami et al, (2007)
14	Radish (Raphanus sativs)	107.5		7.64	19.15						Eslami et al, (2007)
15	Wheat (Triticum indicum)			0.93	3.06		3.1	8.9			Chatha et al, (2002)
16	Wheat (Triticum indicum)	65.3				9.39		20	404	15.3	Rattan et al, (2005)
17	Spinach (spinecia oleracea)	77.1				20.6		13.2	711	39.3	Rattan et al, (2005)
18	Maize (Zea mays)	78.8				14.9		18.3	531	26	Rattan et al, (2005)

Blanks represent not detected

The ratio of determined dose of pollutant to its reference dose is target hazard quotient (THQ) (Zhuang et al., 2009), if its value is less than 1 then will not produce apparent adverse impacts. Zheng et al., (2007) calculated target hazard quotients (THQs) for individual HM for individual vegetables specie with $THQ = C \times (E_F\ E_D\ F_{IR}) / (W_{AB}\ T_A\ RfD) \times 10^{-3}$ where E_F is the exposure frequency (365 days/year), E_D is the exposure duration (70years). F_{IR} is the food ingestion rate (g/person/day). C is the metal concentration in food (µg/g). WAB is the average body weight and TA is the averaging exposure time (365 days/year number of exposure years). The reference doses used for Pb, Cd, Zn and Cu as 4 µg/kg/d, 1 µg/kg/ d, 300 µg/kg/d, 40 µg/kg/d respectively. Rattan et al, (2005) assessed the risk to human health (Hazard Quotient, HQ) for the intake of HMs like Zn, Cu and Ni through vegetable with the formula HQgv = (add/RfD), where HQgv is hazard quotient to human from the consumption of green leafy vegetables, add is the average daily dose (mg metal/kg body weight/day) and RfD the reference dose. The reference doses used for Zn, Ni and Cu as 0.30 mg/kg bw/day, 0.02 mg/kg bw/day and 0.5 mg/kg bw/day respectively.

Zhuang et al, (2009) calculated THQ with $THQ = (EFr \times ED \times FI \times Mc) / (RfD \times Bw \times AT) \times 10^{-3}$ where EFr is exposure frequency, ED is exposure duration, FI is food ingestion (g /person/d); MC is metal concentration in food (µg /g) RfDo is the oral reference dose (mg/ kg/ d); BW is the average body weight. AT is averaging time for noncarcinogens (365 days /year−1× number of exposure years, assuming 70 years in this study).the oral refrence dozes for Cu, Zn, Pb and Cd used is 03mg/kg/d (Zhuang et al., 2009).

The values for HQgv for Cu are 0.004 to 0.021, 0.008 to 0.015 and 0.004 to 0.014 for gobhi, spinach and Indian rape respectively in western Delhi, India. The values for HQgv for Zn are 0.040 to 0.068, 0.035 to 0.152 and 0.027 to 0.053 for gobhi, spinach and Indian rape respectively western Delhi, India. The values for HQgv for Ni are 0.027 to 0.442, 0.046 to 0.502 and 0.016 to 0.429 for gobhi, spinach and Indian rape respectively western Delhi, India. Total diet THQs of each metal (TDHQ) for Hg, Pb, Cd, Zn and Cu were 0.053, 0.364, 0.749, 0.731 and 1.220 respectively for adult in Huludan city, China, while for children was 0.042, 0.331, 0.618,0.739 and 1.099 (Zheng et al., 2007). Total THQ (TTHQ) of HMs for individual vegetables is the sum of the THQ of each metal Zheng et al., 2007). TTHQ of HMs (Hg, Pb, Cd, Zn and Cu) for vegetables in Huludao city, China is 0.963 and 0.531 for adult and children respectively (Zheng et al., 2007).

The presence of one pollutant can increase or decrease the adverse impacts of other pollutant (Harrison and Chirgawi., 1989). Only to assume that that they only produce additive impacts THQs can be summed up to produce hazard index (HI) for the combination of different HMs. HI is 3.119 and 2.828 for the adult and children in Huludao city, China through diet (Zheng et al., 2007). The relative contribution of vegetable in HI 22.2% and 18.7% for adult and children respectively Huludao city, China (Zheng et al., 2007).

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