RESEARCH ARTICLE

HEALTH RISK ASSESSMENT AND HEAVY METAL CONTAMINATION LEVELS IN GREEN CHILLI DUE TO UNTREATED WASTEWATER IRRIGATION IN CHAK JHUMRA, FAISALABAD

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ABSTRACT

To address the global issue of water scarcity, untreated wastewater irrigation has become a common practice in the developing countries to meet the emerging demand of irrigation water. It is a common practice in Pakistan as well to apply municipal wastewater for irrigation purposes, which is carrying high concentrations of heavy metals originating from industrial sources. The research was conducted in Chak Jhumra, Faisalabad, Pakistan to check the effect on health due to untreated wastewater. The purpose of this research work was to find out the concentrations of hazardous elements present in the wastewater and conduct health risk assessment of utilizing the contaminated vegetables, being grown on untreated effluent. The main parameters to be investigated for groundwater, wastewater, soil and vegetables were EC, TSS, SAR and Heavy metals like (Ni, Zn, Pb, and Cu). Concentrations of the targeted heavy metals were determined in these media and health risk assessment was conducted. It was finally concluded that the soil properties were greatly influenced by the supply of this wastewater. Zinc was found above safe limit, Cu was found within safe limit, Ni and Pb were above critical limits in all sites. Groundwater was found suitable and its values were within safe limits. Health risk assessment has also exhibited significant impact of the concentrations of heavy metals in the vegetables being utilized by the common man.

KEYWORDS

Heavy metals (Ni, Zn, Cu, Pb), subsurface contamination, untreated industrial effluent, green chilli, health risk assessment.

1. INTRODUCTION

There is water scarcity in Pakistan because of depleting ground and the surface water resources, and other water management issues prevailing in the country. There is need to search for other non-conventional water resources for irrigation purposes e.g. wastewater has become important due to water scarcity. Immense research on this issue has been done and latest statistical data shows that the Indus System and its streams are providing an average 142 MAF of water per year. Out of which nearly 96 MAF is being used for irrigation purposes, 36 MAF flows to oceans and about 10 MAF is exploited by the system losses which involve seepage, evaporation and spill during floods. Now research shows that, 40.5 MAF groundwater is being pumped per year and 60-80% is saline. Total water availability has decreased from 1,299 cubic meters (m³) per capita in 1996-97 to 1,100 m³ per capita in 2006. It is expected that water availability will be reduced about 700 m³ per capita in 2025 against the international standard of 1500 m³ per capita.

32,500 Hectare land is directly irrigated with wastewater in Pakistan and no guidelines exist for vegetation being irrigated with wastewater (Ensink

et al., 2004). Wastewater use for irrigation has both advantages and disadvantages. Wastewater provides significant benefits as it contains nutrient contents that can be used for crop production. However, the use of wastewater also imposes negative impacts as it contains toxic wastes that can uptake by plants and therefore, harmful for human health. Along with toxic concentration of heavy metals and soluble salts, wastewater also contains nutrients and organic matter (Kirkham, 2006). Heavy metals are very toxic inorganic elements because they have large perseverance, non-biodegradable nature and lengthy biological half-lives. They have the skill to accumulate in different tissues of plants and animal body parts (Basta et al., 2001). It is estimated by the World Bank that 17 to 20% of water pollution comes from textile mills under the finishing and dyeing process. There are seventy-two health hazardous and poisonous chemicals have been known in water from dyeing processes, and thirty of this cannot be removed (Khan et al., 2017).

In Faisalabad, third largest city of Pakistan, there is little isolation of domestic and industrial wastes sites. Groundwater is being polluted by many sources and its salinity level of its also increasing day by day. There are many industries discharging their waste directly into public sewers

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without prior treatment which is harmful for human health. It is reported that leaching of wastes into groundwater is causing diseases. However, there is a waste stabilization pond treatment plant, which is treating some 20mg/day of flow, but its operational efficiency is not identified as there is no regular monitoring system for this (Mashiatullah et al., 2005; Chen et al., 2000). World urban population is increasing day by day due to improved living condition. This is one of the reasons of water scarcity, farmers are using wastewater for producing food crops. Toxic metals can enter human body by consumption of contaminated vegetables, by untreated wastewater irrigation in fields, by number of automobiles which are emitting their smoke in open air and it is causing deposition of heavy metals in leafy vegetables. Vegetables which are growing by using wastewater has high concentration of heavy metals than those vegetables which are growing by using ground water.

Sewage land use has increased over the last few years and efforts have been made to substantiate the application of this material to lands used in food production. Wastewater is usually polluted with an extensive variety of trace elements. Many of them are toxic and not essential for animals and plants (Brožek et al., 2010). It is observed that commonly wastewater is released with little or even without any treatment in natural water bodies e.g. fresh water, which can become extremely polluted. Farmers do not have any other choice to use water except wastewater even in urban or peri urban areas. They even intentionally use unmixed wastewater as it provides a lot of nutrients and cheaper than other water sources (Asaolu, 1995). When crops and vegetables are irrigated with this wastewater, crops and vegetables uptake those toxic heavy metals which through food chain enters the human body and causes serious health problems.

According to several studies and reports, heavy metals such as Pb and Cd have serious effects on the human life including effects on young children and pregnant women. Measurement of their concentrations, uptake, accumulations and evaluating their effects on the plant growth, including concentration of some nutrients in the green chili may help to minimize their harmful effects to the human body. Consequently, this study was proposed to investigate the uptake of some heavy metals by green chili. The research objectives were to evaluate groundwater quality of the fields irrigated by untreated wastewater and to conduct health risk assessment to determine the impact of heavy metals on human health through vegetables.

2. MATERIALS AND METHODS

2.1 Study Area

The research was conducted in Chak Jhumra city as shown in Fig. 1, which lies between latitude 31.5673°N, 73.1828° E at an altitude of 179 m. Chak Jhumra is situated at about 18 km from Faisalabad. According to Census 2017, its population is 332,461 Urban 48,724 Rural, 283,737. Its area is 523 km²

Figure 1: Map of study area at Chak Jhumra

2.2 Research Methodology

2.2.1 Site Description and Research Plan

The study was conducted at four sites, named as, M-3 industrial area (SITE A), Yadgar Town (SITE B), Faizan-e-Madina (SITE C) and Chiniot Road

(SITE D) where vegetables were grown with treated and untreated wastewater. Twenty (20) wastewater samples, twenty-four (24) groundwater samples, twelve (12) soil samples and twelve (12) vegetables samples were taken from different four sites of Chak Jhumra as mentioned earlier from four sites. All above data was analysed statistically to determine effect of wastewater on soil, vegetables, and groundwater.

2.2.2 Sampling Plan for Wastewater/Groundwater/Soil/vegetables

Twenty (20) samples of wastewater were collected from drain during different time intervals. Each sample was collected in quantity of One (01) liter and collected in air tight bottles. All samples for wastewater were analyzed for pH, Temperature, EC, TSS and Heavy metals. Twenty-four (24) samples of groundwater were collected from surrounding area. Sample from different depth of soil, vegetables, and wastewater collection sites were taken. Analysis for temperature, EC, TSS and Heavy metals for all samples were done according to the standard procedures as described in (APHA, 2005). Twelve (12) soil samples were taken from wastewater collection sites. Each soil sample had quantity of ½ kg and stored in polythene bags. All samples were air dried ground and sieved and were taken at different depth intervals.

From study area, ten (10) vegetable samples were taken from different sites. Each sample was dried and grinded into fine powder.

2.3 Experimental & Analytical Methodology

Each wastewater sample had the quantity of 1 liter and kept in plastic bottles with airtight caps. To preserve the sample, these were kept in refrigerator at 4°C throughout the period of analysis. All samples were analysed for pH, Temperature, EC, TSS, SAR, RSC and heavy metals using standard method as described in (APHA, 2005). Sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) were analysed by method described by (APHA, 2005). Sodium is one of the most studied elements because of its toxic effects both to soil texture and crops. Calcium and Magnesium in water are determined via a titrimetric method: the indicator chelates with the Calcium and Magnesium ions to form a red colored complex. Residual sodium carbonate was analysed by following the method described by (APHA, 2005). Green Chilli analysis for heavy metals (Zn, Cu, Pb and Ni) was carried out through atomic absorption spectrophotometer (AOAC, 1990). All the samples were taken and preserved were dried and then grinded so that it can easily be investigated. There were total 12 samples collected and analysis was performed same way. Data was analyzed by using the methods described by (Khan et al., 2009). Soil to plant transfer quotient was calculated in order to observe the exposure of metals to human beings. Daily intake of metal was calculated, and it compared with the standard intake of metals to determine health risks. Health Risk Index was calculated to find the exposure of humans to health hazards. Health risk assessment model applied to assess the health risk exposed. To find out HRI, transfer factor should be known. Higher transfer quotient of heavy metals indicates stronger accumulation of respective metals by that vegetables.

Transfer factor (TF): $TF = C_{\text{Plant}} / C_{\text{Soil}}$

Where C plant is concentration of heavy metals in plants and C soil is concentration of heavy metals in soil. As vegetables are contaminated by heavy metals so their daily intake need to be estimated for comparison as given by (USEPA, 2006). It was calculated by given equation.

$DIM = C_{\text{metal}} \cdot C_{\text{factor}} \cdot D_{\text{food intake}} / B_{\text{average weight}}$

$C_{\text{metal}} \cdot C_{\text{factor}} \cdot D_{\text{food intake}} / B_{\text{average weight}}$ represent the heavy metal concentration in plants (mg/kg), conversion factor, daily intake of vegetables and average body weight respectively. Conversion factor was (0.085). Average adult weight was taken from selected area. Average food intake considered according to situation.

Health risk index (HRI): $HRI = DIM / RfD$

If value of HRI is less than 1 it will be safe for consumption. Reference dose for Cu, Pb, Ni, Zn was 0.04, 0.004, 0.02, and 0.30 (mg/kg bw/day)

respectively (US-EPA, 2006). If value is greater than 1, the exposed population is said to be safe. Risk of intake of metal-contaminated vegetables to human health was characterized by Hazard Quotient (HQ). This is ratio of determined dose to reference dose. If ratio is greater than 1, then population will experience health risk. The following equation is used

$$HQ = W * M / B * RfD$$

Where W is dry weight of contaminated vegetable, M is concentration of metal in vegetable, B is body weight of person, RfD is reference dose. If HQ is >1 , there is potential health risk and related interventions and protective measures should be taken. The collected and compiled data was statistically analysed. Concentration of metals was presented in terms of mean with their standard deviation. Microsoft Excel was used to evaluate the results graphically.

3. RESULTS AND DISCUSSION

3.1 Health Risk Analysis

It was required to find out the health risk due to consumption of vegetables being cultivated on untreated wastewater, green chilli, by following the methodology as described earlier. The detailed findings of the health risk assessment are explained in the following sections.

3.1.1 Soil to Plant Transfer Quotient (TF)

The soil to plant transfer quotient was calculated for all the four sites and has been shown in Table 1 (Cui et al., 2005).

Table 1: Soil to Plant Transfer Quotient				
Green Chili	Cu	Ni	Pb	Zn
Site A	0.576	0.239	0.102	0.636
Site B	0.804	0.184	0.049	0.215
Site C	0.998	0.110	0.008	0.642
Site D	0.657	0.226	0.136	0.796

Table 2: Daily Intake of metals (kg/person/day)				
Green Chili	Cu	Ni	Pb	Zn
Site A	0.01	0.01	0.00	0.02
Site B	0.00	0.01	0.00	0.07
Site C	0.00	0.02	0.00	0.02
Site D	0.00	0.01	0.01	0.02

Table 2 indicated daily intake values of all the metals under study at the selected four (04) sites. Daily intake of vegetable show that intake of Zn is high in all vegetables.

Table 3: Health Risk Index for all the four sites				
Green Chili	Cu	Ni	Pb	Zn
Site A	0.25	0.5	0.00	0.06
Site B	0.00	0.5	0.00	0.23
Site C	0.00	1.00	0.00	0.06
Site D	0.00	0.5	2.5	0.06

Table 3 has shown the results of health risk index calculations for the four sites.

3.2 Health Risk Assessment (HQ)

The average daily intake for adults and children considered to be 0.345 and 0.232 kg/person/day. Average adults and children body weight was considered 73 and 33 kg.

Table 4: Health Risk Assessment (HQ)				
Green Chili	Cu	Ni	Pb	Zn
Site A	0.9	1.6	1.3	0.5
Site B	0.9	1.4	0.6	0.6
Site C	1.3	1.3	0.1	0.6
Site D	0.9	2.7	2.3	0.6

Table 4 indicated the findings of all the HQ calculations for the four study sites.

3.2.1 Health Risk through Contaminated Vegetable in Site A

Table 5 showed that heavy metals in green chili was in order of $Zn > Cu > Ni > Pb$. Transfer factor for green chili was in range 0.102-0.636. The trend for DIM was maximum for Zn. HRI was greater than 1 in Pb so it exposed potential health risk and in safe limit for Zn, Cu and Nickle. The average heavy metals concentration for site A is shown in Fig. 2.

Table 5: Heavy Metal Concentration in Green Chili Site A.						
Metals	Average Concentration (mg/kg)	Transfer Factor	HRI	HQ	DIM	Permissible Maximum Limit (FAO. 2000)
Cu	7.28	0.576	0.25	0.9	0.01	40
Ni	6.74	0.239	0.5	1.6	0.01	67
Pb	1.09	0.102	1.41	1.3	0.01	0.3
Zn	34.30	0.636	0.06	0.5	0.02	20

Figure 2: Average concentration of heavy metals in Green Chili at Site A

3.2.2 Health Risk Through Contaminated Vegetable in Site B

Table 6 showed that heavy metals in green chili was in order of $Zn > Cu > Pb > Ni$. Transfer factor for green chili was in range 0.215-0.049. The trend for DIM was maximum for Zn. The results of Cu, Pb, and Zn, Ni are within safe limit because their values are lower than 1. The average heavy metals concentration for site B is shown in Figure 3.

Table 6: Heavy Metal Concentration in Vegetable Green Chili at Site B.						
Metals	Average Concentration (mg/kg)	Transfer Factor	HRI	HQ	DIM	Permissible Maximum Limit (FAO. 2000)
Cu	7.49	0.804	0.13	0.9	0.01	40
Ni	0.52	0.184	0.59	1.4	0.01	67
Pb	5.90	0.049	0.01	0.6	0.00	0.3
Zn	38.13	0.215	0.23	0.6	0.07	20

Figure 3: Average concentration in green chili site B

3.2.3 Health Risk Through Contaminated Vegetable in Site C

Table 7 showed that heavy metals in green chili was in order of $Zn > Ni > Cu > Pb$. Transfer factor for green chili was in range 0.998-0.008. The trend for DIM was maximum for Zn and Nickle. lead was found out of danger. Cu and Nickle values for HQ and HRI are greater than 1 for Ni and Lead are almost close to safe limit. The average heavy metals concentration for site C is shown in Figure 4.

Table 7: Heavy Metal Concentration in Vegetable Green Chili Site C.

Metals	Average Concentration (mg/kg)	Transfer Factor	HRI	HQ	DIM	Permissible Maximum Limit (FAO. 2000)
Cu	8.1	0.998	0.025	1.3	0.01	40
Ni	10.12	0.110	1.00	1.3	0.02	67
Pb	2.03	0.008	2.5	0.1	0.01	0.3
Zn	32.13	0.642	0.06	0.6	0.02	20

Figure 4: Average concentration in green chili Site C

3.2.4 Health Risk Through Contaminated Vegetable in Site D

Table 8 showed that heavy metals in green chili was in order of Zn>Cu>Ni>Pb. Transfer factor for green chili was in range 0.796-0.136. The trend for DIM was maximum for nickel and copper was found out of danger. Cu and Zinc values for HQ and HRI are lower than 1 these are almost close to safe limit. The average heavy metals concentration for site D is shown in Figure 5.

Table 8: Heavy metal concentration in vegetable green chili site D.

Metals	Average Concentration (mg/kg)	Transfer Factor	HRI	HQ	DIM	Permissible Maximum Limit (FAO. 2000)
Cu	7.25	0.657	0.00	0.9	0.00	40
Ni	8.13	0.226	1.5	2.7	0.03	67
Pb	1.05	0.136	2.5	2.3	0.01	0.3
Zn	31.15	0.796	0.06	0.6	0.02	20

Figure 5: Average concentration in green chili site D

3.2.5 Health Risk Assessment and Contamination evaluation at Site A (M-3 Industrial Site)

Analysis for wastewater to find heavy metal concentration in selected region was done and it was determined that all values lie within safe limits. Copper concentration in wastewater was 0.04 mg/L as compared to its permissible limit which is 0.1 mg/L. Copper concentration in soil was found 5.0 mg/kg at 30 cm depth while its permissible limit is 0.50 mg/kg. Zinc concentration in soil was 4.30 mg/kg at the depth of 30 cm while it's should be 1.5 mg/kg. Lead concentration in soil was 0.13 mg/kg as its permissible limit is 1.00 mg/kg. For green chili, heavy metals results were highly significant. Green chili analysis explained that three heavy metals were in excess which are copper and zinc. Copper concentration in green chili was 7.28 mg/kg as the compared allowable limit was 10.00 mg/kg which is within safe limit. Zinc concentration in green chili was 34.30 mg/kg while its allowable limit is 5.00 mg/kg. In groundwater, these are found within safe limit.

3.2.6 Health Risk Assessment and Contamination evaluation at Site B (Yadgar Town)

In groundwater, heavy metals concentration found within safe limit. For wastewater analysis, all values of heavy metals were found within safe limit. Copper concentration in wastewater was 0.14 mg/L as compared to permissible limit of 0.1 mg/L. Copper concentration in soil was 4.41 mg/kg at 30 cm depth while its allowable limit is 0.50 mg/kg so it's harmful. Zinc concentration in soil was 2.5 mg/kg at the depth of 30 cm while it should be 1.5 mg/kg. Nickel concentration in soil at 30 cm depth was 0.05 mg/kg as compared to permissible limit of 1.0 mg/kg. Green chili analysis of heavy metals explained that two heavy metals were in excess i.e. copper and zinc. Copper concentration in Green chili was 7.49 mg/kg while its allowable limit is 10.00 mg/kg. Zinc concentration in Green chili was 38.13 mg/kg as it is 10.0 mg/kg in safe limit.

3.2.7 Health Risk Assessment and Contamination evaluation at Site C (Faizan e Madina)

All heavy metals were found within safe limit for groundwater. Copper concentration in wastewater was 0.18 mg/L as compared to permissible limit of 0.1 mg/L. The concentration of Copper metal was 0.07 mg/L and its permissible limit is 2 mg/L in groundwater. Copper concentration in soil was found 3.35 mg/kg in ground level while its allowable limit is 0.50 mg/kg. Lead concentration in soil was found 0.17 mg/kg as compared to permissible limit of 1.00 mg/kg. Zinc concentration in soil was 3.5 mg/kg at 30 cm depth but its allowable limit is 1.5 mg/kg. Two heavy metals in excess i.e. copper and zinc for Green chili analysis. Zinc concentration in Green chili found 32.13 mg/kg while its allowable limit is 5.00 mg/kg.

3.2.8 Health Risk Assessment and Contamination evaluation at Site D (Chiniot Road)

Wastewater analysis for heavy metals explained all values lies in acceptable limits except copper. Concentration of copper in wastewater was 0.5 mg/L as compared to its permissible limit which is 0.1 mg/L. The analysis of soil samples for heavy metals showed highly significant results in its values. The concentration of Copper in soil was 3.74 mg/kg at 30 cm depth while its allowable limit is 0.50 mg/kg. Lead concentration in soil was 0.2 mg/kg at 30cm while its permissible limit is 1.00 mg/kg. Zinc concentration in soil was 4.5 mg/kg at 30 cm depth but its allowable limit was 1.5 mg/kg. Green chili analysis explained there were two heavy metals in surplus which are copper and zinc. Zinc concentration in Green chili was 31.15mg/kg while its allowable limit is 5.00 mg/kg.

4. CONCLUSION

The present study was performed to assess heavy metal levels of commonly consumed vegetables and their associated health risks at Chak Jhumra, Faisalabad. All parameters of groundwater were affected by wastewater except pH which was in the permissible limits in all sites. pH of soil in all sites was also in the permissible limits. Four heavy metals i.e. copper, lead, zinc and nickel were studied for green chili. Nickel has hazard quotient higher than 1 at all the sites. For Lead (Pb) the hazard quotient is higher than 1 at Site A and D. While hazard quotient for Copper is exceeding 1 for Site C. Maximum concentration of heavy metals in soil was noticed at the depth of 30 cm. In case of wastewater, almost all parameters under study were exceeding permissible limits. Site A (M-3 Industrial area) was found less affected by wastewater irrigation as compared to other sites and almost all parameters under study at this site were within permissible limits. Based on the findings of this study it is recommended that further research work should be carried out to study the levels of heavy metals in vegetables in and around Site C and D in order study potential hazard to the cultivated crops and improve measures to reduce their levels in vegetables and ultimately prevent these avoidable health problems.

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