Study on Accumulation of Heavy Metals in Vegetables Receiving Sewage Water

[1]SAJIDA PERVEEN, [2]IHSAN IHSANULLAH*, [1]ZIAUDDIN SHAH,
[1]WAJAHAT NAZIF, [1]SYED SADAQAT SHAH AND [3]HAMEEDULLAH SHAH
[1]*Department of Soil and Environmental Sciences, KPK Agricultural University, Peshawar, Pakistan.*
[2]*Nuclear Institute for Food and Agriculture (NIFA), Tarnab, Peshawar, Pakistan.*
[3]*Department of Agriculture Chemistry, KPK Agricultural University, Peshawar, Pakistan.*

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Summary: A study was conducted to evaluate heavy metals content of sewage water and its impact on soil and vegetables. Thirty samples each of water, soil, and vegetable leaves and twenty-one samples of edible vegetable portions were collected from different sites, in between Peshawar city and Pakistan. Parameters like pH, and electrical conductivity (EC) were also determined. The pH of sewage water was slightly alkaline; electrical conductivity was with in the safe limit. Heavy metals Cu, Mn, Pb, and Cd, were detected but were found below the toxic level in soil. Levels of Fe, Ni, Cr, and Cd, were observed above the safe level in edible portion of plant while Cu, and Fe, concentrations exceeded in leaves. Zinc was found to be deficient in both water, and soil samples. All the tested heavy metals except Mn, and Cr were found more in fruits than in leaf and root of vegetables while Mn and Cr were found more in root. As some heavy metals were found in excessive amount in sewage water as well as in vegetables irrigated with this water. So it is recommended that vegetables directly consumed in raw form should not be grown with sewage water.

Introduction

Although certain natural processes may cause some of the water pollution, however, human activity is the largest cause of our seas, rivers, and lakes getting polluted. We need to use water from groundwater sources, rivers, and lakes every day both in our industries as well as our homes. The contaminated water gets back into the rivers, lakes and oceans. The used water from agricultural and industrial practices and household use create waste water also referred to as sewage. If this is allowed to flow back in to water systems without being treated, it causes pollution, which results in harming both humans as well as animal life. Water also gets polluted when there is a runoff of rain water from industrial, agricultural, and urban areas, which flow directly through storm water drains into water systems without any treatment. The disposal of sewage is a major problem in developing countries where there is not adequate sanitation in large areas, thus carrying disease causing bacteria and viruses into sources of water.

Toxicity studies of heavy metals confirm that these metals can directly damage human beings by impairing mental and neurological function, influencing neurotransmitter production and utilization, and altering numerous metabolic body processes. Systems in which toxic elements can induce impairment include the blood and cardiovascular, detoxification pathways (colon, liver, kidneys, skin), endocrine (hormonal), energy production pathways, enzymatic, gastrointestinal, immune, nervous (central and peripheral), reproductive, and urinary [1].

The problem associated with the disposal of sewage water and municipal wastes are crucial aspects of water pollution, which could be considered in the context of wider current environmental issues [2]. Application of waste water for irrigation purposes has increased over the past years. This waste water contains high amounts of trace elements and heavy metals. Waste waters are contaminated with trace elements like lead (Pb), cadmium (Cd), nickel (Ni), mercury (Hg), uranium (U), copper (Cu), zinc (Zn), boron (B), cobalt (Co), chromium (Cr), arsenic (As), molybdenum (Mo), manganese (Mn), *etc.* Many of these are non-essential and are toxic to plants, animals and human beings. Waste water is suitable for irrigation if the content of toxic elements is reduced considerably [3].

The use of polluted water in the immediate surrounding of big cities in our country is a common practice for growing of vegetables. Although the waste is considered to be a rich source of organic material and plants nutrients, yet it also contains sufficient amounts of soluble salts and heavy metals like iron, copper, manganese, zinc, lead *etc.* When this water is applied for irrigation purpose for the growing of crops for long period, these heavy metals may accumulate in soil and that may be toxic to the plants and also cause deterioration of soil [4]. Sewage is produced in alarming amount in the country but still no proper means has been adopted for its safe disposal. Sewage/sanitary systems are limited to the parts of few major cities and the remaining urban population depends for effluent water disposal on septic tank over flow into stream drain. Domestic sewage from human settlements particularly in major

*To whom all correspondence should be addressed.

cities is an important source of biological aquatic pollution.

The rate of uptake of such toxic metals by plants is governed by their concentration in the soil solution. So the crops grown on such soils may accumulate heavy metal in excessive amounts in various food parts [5], which ultimately may results in clinical problem in animals and human beings throughout the world.

Peshawar has become one of the dense populated and polluted cities of the country for last few decades. The problem of disposal of municipal, industrial and sewage effluents along with scarcity of irrigation water is very severe. These effluents are used for irrigation purpose in surrounding areas of the city, which may cause accumulation of toxic heavy metals in soil and contaminate the vegetables and other edible crops grown on it. Keeping in view the above facts, a study was designed to assess the heavy metal status of these effluents and correlate it to the accumulation of these heavy metals in soil and vegetables grown on it.

Results and Discussion

The present study is mainly based on the monitoring of environmental pollution in regard to water and soil with time in the Peshawar basin, situated in the north western portion of Pakistan adjacent to the Afghanistan border (Fig.1). Peshawar basin is occupied by the major cities of North West Frontier Province (NWFP) *i.e.*, Peshawar, Charsadda, Nowshehra and Mardan and like other big cities of Pakistan the environment is being polluted ruthlessly and carelessly here too. The high rate of industrialization resulting into drastic and unplanned urbanization with heavy load of transportation together with a retarded rate of awareness /education in mainly poor masses have contributed to creating pollution of all sorts including those of air, water and soil. Peshawar is one of the major metropolis of the country and provincial capital of the Khyber Pakhtunkhwa. According to 1999 census, Peshawar district had a population of 1650941 excluding Afghan refugees with a growth rate of 4.1 [6]. Maximum permissible levels (MCL) of tested metals for the drinking water [7] are given in Table-1 while national environmental quality standards (NEQS) for municipal and liquid industrial effluents [8] are outlined in Table-2 for comparison. Chemical characteristics of irrigation water and soil were evaluated as per following details:

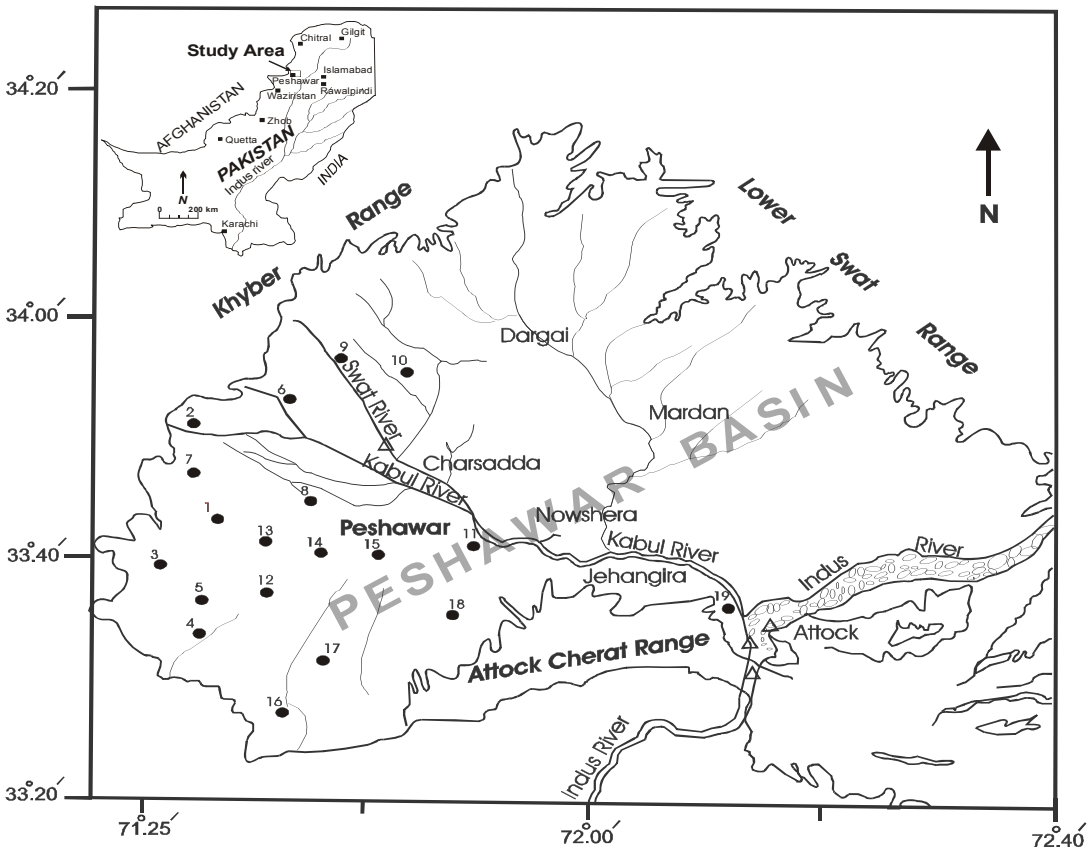

Fig. 1: Location map of the Peshawar basin.

Table-1: The maximum permissible levels (MCL) of selected metals for the drinking water.

Characteristics	MCL of US-EPA	MCL of WHO	MCL of Pak-EPA
		(µg/L)	
Copper	300	300	300
Nickel	50	50	50
Lead	1000	1000	1000
Cadmium	50	50	-
Chromium	20	-	-

Table-2: National environmental quality standards for municipal and liquid industrial effluents (mg/L).

S. No.	Parameter	Existing Standards	Revised Standards into		
			Land waters	Sewage Treatment	Sea
1	pH	6-10	6-9	6-9	6-9
2	Copper	1.0	1.0	1.0	1.0
3	Manganese	1.5	1.5	1.5	1.5
4	Zinc	5.0	5.0	5.0	5.0
5	Iron	2.0	8.0	8.0	8.0
6	Nickel	1.0	1.0	1.0	1.0
7	Lead	0.5	0.5	0.5	0.5
8	Cadmium	0.1	0.1	0.1	0.1
9	Chromium	1.0	1.0	1.0	1.0

pH Measurements

The pH of sewage water ranged from 8.0-8.94 with a mean value of 8.58 as shown in Table-3. Shaunberg and Ouster [9] reported that the pH of the irrigation water is not an accepted criterion of water quality because it tends to be buffered by soil and most crops can tolerate a wide range. Similarly, James [2] concluded from his experiment that pH from 5-9 was fit for irrigation. The pH of soil samples ranged from 7.2-8.3 with a mean value of 8.0. These results show that the pH of the study area is alkaline in nature.

Table-3: pH, electrical conductivity (EC) and organic matter (OM) content of irrigation water and soil.

	Water Samples		Soil Samples		
Parameters	pH	EC (dS m^{-1})	pH	EC (dS m^{-1})	OM (%)
Range	8-8.94	0.30-1.72	7.20-8.30	0.1-0.85	0.62-3.31
Average	8.58	0.63	8.01	0.33	1.36

Electrical Conductivity

Water under natural condition contains salts (carbonates, chloride, sulfates, and nitrates) and cations like calcium, magnesium, sodium *etc.* However, natural concentration of salts is largely influenced by geological formation of underlying area and by its climate. Electrical conductivity (EC) of sewage water ranged from 0.3 -1.72 dS m^{-1} with a mean value of 0.63 dsm^{-1} as shown in Table-3. All the water samples were found non-saline and would not contribute any harmful effect to agricultural land and crops. Hameed *et al.* [10] stated that water having electrical conductivity of 1.5 dS m^{-1} was safe for irrigation, those having 1.5 to 3.0 dsm^{-1} was marginal and water having electrical conductivity more than 3.0 dS m^{-1} was unsafe. The EC of soil samples ranged from 0.1 to 0.85 dS m^{-1} with a mean value of 0.33 dS m^{-1}as shown in Table-3. These results show that these soils have low content of the soluble salts and there is no danger of salinity.

Soil Organic Matter

The organic matter content of soil ranged from 0.62-3.31% with a mean value of 1.36% as shown in Table-3. The variations in the organic matter content of the analyzed soil might be due to the addition of different quantities of domestic sewage, industrial waste and storm water at different sites, low organic matter might be due to restricted application of farm yard manure (FYM).

Heavy Metal Content of Sewage Water

The water samples from twenty-eight different localities in Peshawar were analyzed for heavy metals. Data is presented in Table-4. Copper content of sewage water ranged from 0.60-1.60 µg mL^{-1}, Mn 1.19-1.87, Zn 0.1-1.09, Fe 0.29-0.86, Ni 0.48-0.76, Pb 0.35-0.55, Cd 0.17-0.35 and Cr 0.07-0.26 µg mL^{-1}, respectively. From the result (Fig. 2), it is clear that among the heavy metals, Cu, Mn, Pb and Cd were found in excessive concentration in sewage water while Fe, Zn, Cr, and Ni were found in normal range of the national environmental quality standards [8], continuous use of such water for irrigation over longer period may cause accumulation of Cd, and Pb, up to toxic levels for plant and animal health [4, 11]. Although certain natural processes may cause some of the water pollution, however, human activity is the largest cause of our seas, rivers and lakes getting polluted [12]. We need to use water every day both in our industries as well as our homes. We get this water from groundwater sources, rivers, and lakes and after using it, most of this water gets back into the rivers, lakes and oceans. Levels of heavy metals in sewage contaminated water were determined and its impact on underground water, soil, and crop, plants in Alluvial Soils of Northwestern India was also calculated [13].

Table-4: Range, average and CV of heavy metal contents of sewage water

Heavy metal	Range (µg mL^{-1})	Average (µg mL^{-1})	CV (%)	Sample above safe level (%)
Cu	0.60-1.60	1.03	23.55	55
Mn	1.19-1.87	1.49	13.33	43
Zn	0.10-1.09	0.52	50.87	-
Fe	0.29-0.86	0.58	29.35	-
Ni	0.48-0.76	0.61	16.12	-
Pb	0.35-0.55	0.45	6.63	32
Cd	0.17-0.35	0.27	8.49	100
Cr	0.07-0.26	0.16	5.46	-

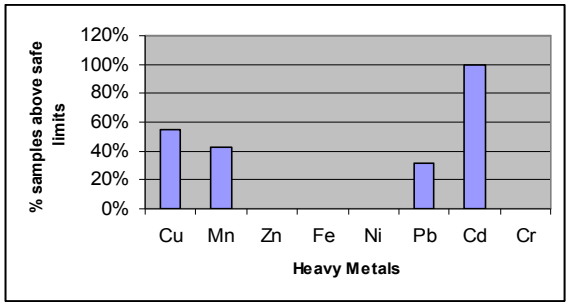

Fig. 2: The % samples above safe limits of heavy metals in water samples.

Heavy Metal Content of Soil

AB-DTPA (ammonium bicorbonate diethylene triamin penta acetic acid) extractable heavy metals of soil samples, collected from the same point where the water samples were collected are presented in Table-5. Cu content of soil ranged from 0.94-2.97, Mn 1.16 -2.10, Zn 0.29-1.96, Fe 3.11-4.95, Ni 9.48-18.4, Pb 53.24-75.08, Cd 0.25-0.42 and Cr 32.96-48.87 mg kg^{-1}, respectively. From the result it is clear that all the samples were in safe limits. In contrast to the heavy metal content of water, the content of heavy metal in soil may be due to the insolubility of the metals due to high pH as these metal ions generally accumulate in the surface soil layers [14] as a result adsorption on the soil particles factors like soil pH, amount of organic matter redox potential of soil and rate of addition of metals mainly effect their adsorption and retention in soil [15].

Table-5: Range, average and CV of heavy metal contents of soil.

Heavy metal	Range (mg kg^{-1})	Average (mg kg^{-1})	CV (%)	No of samples above safe limits (%)
Cu	0.94-2.97	2.05	31.60	-
Mn	1.16-2.10	1.62	17.45	-
Zn	0.29-1.96	0.83	49.67	-
Fe	3.11-4.95	3.84	14.99	-
Ni	9.48-18.46	14.28	2.79	-
Pb	53.24-75.08	61.34	10.06	-
Cd	0.25-0.42	0.35	3.97	-
Cr	32.96-48.87	39.23	10.68	-

Heavy Metals Content of Vegetable (Leaves)

Heavy metals were investigated in all samples of plants, collected from the same point where the water and soil samples were collected. Copper content of vegetable leaves ranged from 17.26 - 44.27, Mn 43.97-75.38, Zn 6.29-23.87, Fe 223-398, Pb 11.86-22.31 Cd 2.98-3.63 Ni 2.92-4.12 and Cr 1.32-2.07 µg g^{-1}(dry weight basis), respectively. From Table-6 and Fig. 3, it is clear that Cu and Fe content of vegetables leaves were found above the normal range while other elements were found in normal range [16]. Metal ion uptake is not only affected by plant species and physico-chemical characteristics of soil but also climatic condition (mainly temp and rain fall) exert considerable effect. Plants grown in a warm environment (25 °C) accumulated higher concentration than those raised in relatively cooler environment 15 °C. Ahmad and Rizvi [17] reported conc. of Cd, Cr, Ni and Zn in spinach, fenugreeks and bitter guard irrigated with city effluent higher than their critical permissible concentration.

Table-6: Averages, range, and CV of heavy metal content of leaves

Heavy metal	Range (µg g^{-1})	Average (µg g^{-1})	CV (%)	Sample above the safe level (%)
Cu	17.26-44.27	30.89	26.50	58
Mn	43.97-75.38	59.49	16.07	-
Zn	6.29-23.87	14.11	40.44	-
Fe	223-398	302.40	19.14	100
Ni	2.92-4.12	3.58	8.83	-
Pb	11.86-22.31	15.56	19.52	-
Cd	2.98-3.63	3.40	5.88	-
Cr	1.32-2.07	1.66	11.97	-

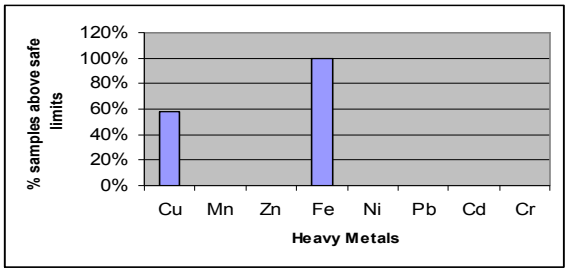

Fig. 3: The % samples above safe limits of heavy metals in plant leaves.

Heavy Metal Analysis of Edible Portion

Edible portion (21) which were collected from different vegetable fields around Peshawar city were analyzed for heavy metal (Cu, Mn, Zn, Fe, Ni, Pb, Cd, and Cr) contents. Results are given in Table-7 and presented in Fig. 4. The heavy metals (Cu, Mn, Zn, Fe, Ni, Pb, Cd, Cr) content ranged from 13.81-43.73, 18.2-201, 5.4-46.21, 148-359, 8.1-28.36, 12.6-48.90, 7.6-23.10, and 7.6-27.90 µg g^{-1}(dry weight basis). By comparing the values with the critical values reported by Kabata Pendias [16]. It is clear that Fe, Ni, Cr, and Cd in plant (edible portion) were observed above the safe level while other elements were found in normal range. Samad [18] reported that the number of samples having Cr above the safe limit was higher in edible portions than in leaves. Many metals such as As, Be, Cd, cr, Hg, Ni, Pb, Rb, Se, Sr, Ti, V, and others (both essential and non-essential) accumulate in plant tissues, particularly in lower plants [19]. In order to assess the importance of vegetables cultivated in industrialized regions in Greece as a

dietary factor, the daily intake of trace elements *via* vegetables were estimated. The intakes of Cr, Pb, Zn, Co, and Hg were highest in spring, whereas the intakes of As and Se were highest in winter [20].

Table-7: Range, average, and CV of heavy metal contents of edibles.

Heavy metal	Range ($\mu g\ g^{-1}$)	Average ($\mu g\ g^{-1}$)	CV (%)	Sample above the safe level (%)
Cu	13.8-43.7	27.12	31.02	23
Mn	18.2-201	65.70	72.66	-
Zn	5.40-46.2	20.49	60.33	-
Fe	148-359	232.6	38.62	100
Ni	8.10-28.4	16.63	32.32	90
Pb	15.1-48.9	28.32	34.65	54
Cd	7.70-23.1	14.41	49.25	100
Cr	12.6-27.9	18.65	13.31	100

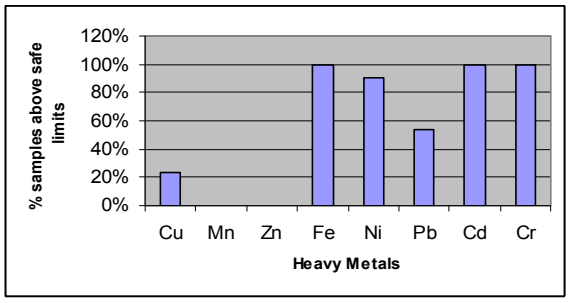

Fig. 4: The % samples above safe limits of heavy metals in plant edibles.

The zinc concentration was in the range of 0.10-1.09 $\mu g\ mL^{-1}$, 0.29-1.96 mg kg^{-1}, 6.29-23.87 $\mu g\ g^{-1}$ and 5.40-46.20 $\mu g\ g^{-1}$ in sewage water, soil, leaves and edible portion of plants, respectively. The data clearly show that there is unsystemic increase or decrease of Zn in different samples.

Variation in the environment (soil and water) and agronomic factors could exert significant effects on the concentration of various metals. In general the levels of different elements were in order of plants, soil and water. Leaves and edible portion of plants contained highest levels of examined elements. Sewage water contains heavy levels of toxic metals and so did the vegetables grown with this water. Soil samples from the roadside showed the effects of vehicular traffic [21]. Concentration of essential trace elements and toxic metals in biological materials vary depending upon the origin, type of food and places of production [22].

On the basis of some probable reasons *i.e.* input of pollutants from various possible sources, are generally classified in four main categories. For the first category, the main source of contamination is the used or sewerage waters. The second category is the area of industrial sector. In Peshawar, many industries are situated in the residential areas. The effluent of these industries is disposed into seepage drains. In the third category, the chemicals, fertilizers, pesticides *etc.* are also used in the fields. The plants up take most of these chemicals. The last category includes samples affected from roadsides. Smoke and wastes of vehicles are deposited on the soil surface and in rainy season it results in considerable rise in the contamination of water. The other possible sources of heavy metals pollution, for all categories, include leaching from pipes; Pb/Cd based solder pipe joints and use of sub standard chemicals for water treatments.

To protect the aquatic environment and check that water is suitable for its recognized uses, such as drinking, irrigation or fisheries, and the quality of water should be according to environmental quality standards (EQSs) [23]. The joint FAO/WHO Expert Committee had set tolerable weekly intake limits for Pd and Cd 3 mg and 315-330 µg respectively per person [24]. In traces, Ni is not highly toxic however; in excess it affects enzymes, brain and lungs. When inhaled it becomes carcinogenic. Average human diet contains 0.3–0.5 mg Ni/day. Copper is also an essential element but excess causes Wilson's disease. The daily adult Cu requirement is 2 mg. Iron is essential micronutrient and its supply should be adequate to maintain proper functioning of hemoglobin in blood circulation. Similarly Cr is essential nutrient having average intake of 30-100 µg/d. its deficiency increases the toxicity of Pd while excess causes skin disease and bronchogenic carcinomas. Another trace element is Mn. Its salts, serve as an activator liver and other enzymes. Due to inhalation, it becomes poisonous and causes mental disorder and damages respiratory system. Zinc is a ubiquitous metal and essential for the normal growth and development of animals. It plays a critical physiological role in structure and function of biomembrane. Interatesticular injection of Zn leads to testicular tumors while deficiencies include acrodermetitus entospathica and cardiovascular diseases [1].

Statistical Analysis

Correlation Between Water and Soil

The data was analyzed for mean values and standard deviation as per standard procedure. In addition, statistical correlations were studied and regression lines were drawn for heavy metal content of water vs AB-DTPA extractable soil heavy metal content (Table-8). A positive significant correlation was observed between Cu, Mn, Fe, Ni, Pb, Cd, Cr, and a non significant

correlation was observed between Zn content of irrigation water and soil.

Table-8: Correlation between water and soil contents.

S. No.	Water/ Soil	Y	Regression (R)
1	Cu	2.1563x – 0.1909	0.6765
2	Mn	1.1429x – 0.0923	0.7484
3	Ni	26.025x – 0.0923	0.8606
4	Fe	2.0535x – 2.6238	0.3303
5	Pb	68.34x + 30.245	0.5124
6	Cd	0.9392x + 0.0977	0.8777
7	Cr	47.87x + 31.471	0.4882

Correlation Between Soil and Plant

Simple statically correlations were calculated and regression lines were drawn for AB-DTPA extractable soil heavy metals content and heavy metals content of vegetable leaves (Table-9). A positive significant correlation was observed between Cu, Mn, Zn, Fe, Ni, Pb, Cd, and Cr content of soil, and plant (vegetable leaves).

Table-9: Correlation between soil and vegetable contents.

S. No.	Soil/Plant	Y	Regression (R)
1	Cu	6.7523x + 17.074	0.2877
2	Mn	34.12x + 4.2449	0.9543
3	Zn	13.229x + 3.085	0.932
4	Fe	88.261x - 35.991	0.7751
5	Ni	0.0839x – 2.3837	0.3514
6	Pb	0.4755x - 13.604	0.9325
7	Cd	3.5169x + 2.1505	0.917
8	Cr	0.0305x + 0.4702	0.4207

Experimental

A total of 111 samples were taken. These samples were analyzed for different parameters.

Sampling

Water Sampling

Thirty water (used for irrigation of vegetables) samples were collected in plastic bottles from different locations in between Peshawar city *i.e.* (Phando Road, Ring Road, Hazra Khawani and Landi Arbab etc). These water samples were taken directly from a sewer, labeled and transported to the laboratory of Soil and Environmental Sciences, NWFP Agricultural University, Peshawar. The water samples were filtered from Whatman filter paper No. 42.

Soil Sampling

Similarly, thirty representative soil samples were collected from 5 locations of vegetable growing areas by dividing each field into zigzag manner at a depth of 0-30 cm. All these samples were combined to make composite and representative samples. These samples were labeled and brought to the laboratory, air dried, and grounded with wooden mallet and passed through a 2mm sieve for various physical and chemical analyses.

Plant Sampling

Thirty vegetable leaves samples and 21 samples from the edible portion of vegetables were collected from the same selected points, where the water and soil samples were obtained. Samples were washed with distilled water to remove dust and impurities and then spread on a clean plastic sheet, and air dried at room temperature followed by drying in an oven at 72^0C for 48 hours. The dried samples was grounded to powder form and stored in clean dry plastic bags for the determination of heavy metals.

Analysis

The water and soil samples were analyzed for pH, EC and heavy metals [25] and the plant samples (leave + edible portion of some vegetables) were analyzed using wet digestion method [26]. The heavy metal content of soils was determined using AB-DTPA (ammonium bicorbonate diethylene triamin penta acetic acid) extractable method [27]. Levels of selected heavy metals (Cu, Mn, Zn, Fe, Ni, Pb, Cd and Cr) were determined by atomic absorption spectrophotometer (Model 2000 Perkin Elmer Inc. USA).

Following procedures for standard stock solutions certified reference materials to get accurate and quality assurance data.

Standard Stock Solutions

1. Stock solution of 1000 ppm for Fe: 1 g of pure iron metal was dissolved in minimum amount of HCl and was made to the volume with deionized water in one litre volumetric flask.
2. Standard stock solution of 1000 ppm: 1 g of copper metal was dissolved in 30 ml of (1:1) HNO_3 and was made to the volume of one litre with deionized water.
3. Standard stock solution of 1000 ppm: 1.598 g of lead nitrate Pb $(NO_3)_2$ was dissolved in 1% HNO_3 and was diluted to 1 litre with deionized water.
4. Standard stock solution of 1000 ppm: 1g of Ni metal was dissolved in a minimum volume of (1:1) HNO_3 and was diluted to 1 litre with deionized water.

5. Standard stock solution of 1000 ppm: 3.735g of K_2CrO_4 was dissolved in deionized water and diluted to one litre with deionized water.
6. Standard stock solution of 1000 ppm: 2.03 g of cadmium chloride ($CdCl_2$-2½H_2O) was dissolved in 1% HNO_3 and was diluted to 1 litre with deionized water.
7. Standard stock solution of 1000 ppm: 1.0 g of zinc metal was dissolved in 30 ml of (1:1) HCl and was diluted to one litre with deionized water.
8. Standard stock solution of 1000 ppm: 1 g of manganese dissolved in 30 ml of (1:1) HNO_3 and was made to the volume of one litre with deionized water.

Procedures for Working Solutions

1. Stock solution of 1 ppm: 0.1 ml from 1000 ppm stock solution was taken in 100 ml volumetric flask and made to the mark with deionized water.
2. Working standard solutions: 25, 50, 100 and 200 ppm working standard solutions were prepared by taking 2.5, 5, 10 and 20 from the 1 ppm stock standard solution in a 100 ml volumetric flask and made to the volume with deionized water.
3. Procedure: The atomic absorption spectro-photometer was set according to the above conditions. The instrument was calibrated with the iron working standard solutions of 25, 50, 100 and 200 ppm ppm. These working standards were then run as unknown. The results were compared with the certified values and were found within the confidence limit. After making sure that the instrument is properly calibrated the water samples were run on the atomic absorption and the concentrations of iron were determined.

Statistical Analysis

Statistical analysis of the data, on the basis of dry weight, was conducted by measuring mean and standard deviation [28].

Conclusions

Cu, Mn, Pb and Cd concentration in irrigation water were found above the safe level. The pH and EC of the soil and water of the study area are with in acceptable limits and will not contribute any harm to the environment. Zn was found deficient in water and soil samples. Organic matter ranged from 1.36 to 3.36%. Iron and Cu in vegetable leaves were found in excessive amount. Fe, Ni, Pb, Cd and Cr in edible portion were found above the safe level in edible portion. To summarize, the data obtained in this study would present a baseline for the planners, health authorities, scientists and consumers to adopt appropriate remedial measure. The following recommendations were formulated from the present research:

- As Cu, Mn, Pb and Cd content were found in excessive amount in irrigation water and also vegetables irrigated with this water were found with excessive concentration of heavy metals therefore irrigation of vegetable with this water should e avoided.
- Zinc was found to be deficient in water and soil. Therefore zinc fertilizer should be added to the soil irrigated with this water.
- If the addition of municipal and sewage sludge were continued it will raise the concentration of certain heavy metals like Cu, Mn and Pb to toxic level. Therefore safe ways should be used for their disposal.

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