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Spatial Distribution of Cd, Cu, Pb, and Ni in Dust, Plants, and Water along Jhang Road, Faisalabad

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Abstract

Air pollution is a global problem. It adversely affects the quality of soil, plants and water bodies. Air pollution on road side is damaging air quality on a regular basis. Previous studies and daily reports from the Ministry of Environment show that there is an increase in particle filtration in Pakistani air. To quantify the focus of specific issues pertinent to air quality this study was conducted on Jhang Road Faisalabad. Samples of dust, plants, and water were collected along the road and analysis of selected heavy metals (Cd, Cu, Ni and Pb) was done. Pollution data near se-lected sites and the effect of selected air pollution on the growth parameters of the selected plant were recorded. The concentrations of Cu (1.95mg kg^{-1}), Pb (0.858mg kg^{-1}) and Cd (0.735mg kg^{-1}) in maize crop were the highest in the Babu Wala area of Jhang Road and Ni concentration was the highest (4.525mg kg^{-1}) in the Said Abad site. The concentrations of Cu and Cd in the dust collected from Babu Wala were2.14 and 0.80mg kg^{-1}, respectively. The concentration of Ni was the highest (2.32mg kg^{-1}) in the Risala Wala area and the concentration of Pb (0.98mg kg^{-1}) was the highest at the Said Abad site. In the Risala Wala area, Cu and Cd concentration in irrigation water was 0.15 and 0.11mg L^{-1}, respectively. However, the Ni and Pb concentrations in irrigation water were found higher in Liaqat Abad area than any other area. The concentration of heavy metals was maximum in samples collected from road side and the concentration decreases as we move away from the road.

Keywords: Heavy metals; Dust; Spatial distribution; Soil quality; Air pollution

Abbreviations: HM: Heavy Metals; WHO: World Health Organization; EPA: Environment Protection Agency; AAS: Atomic Absorption Spectrophotometer; GPS: Global Positioning System; GIS: Geographic Information System

Introduction

The atmospheric pollution is deteriorating the air quality worldwide. The industrialization is an asset for the growing economies but unplanned and misuse is badly affecting the quality of life. Road dust is one of the most significant fleeting sources of inhalable particles, and particularly smaller components of road dust may be transported by wind or vehicle to the atmosphere. Road dust is often composed of particulate matter from many sources, such as dry and wet ambient aerosol tyre break and vehicle exhaust. Atmospheric particulate matter is a complex combination of materials. Road side dust serves as a significant contributor of trace elements due to a re-suspension in the atmosphere that cannot be kept in one location [1,2].

The issue of environmental heavy metal emissions is more severe in developing countries. With rapid urbanization and industrialization and increase in vehicle transport operation increased the accumulation of HMs in roadside environmental pollution. Release of excessive quantities of HMs from vehicles are deposited in the soil and then transported to plants. Transportation of vehicles along the roadside contributes to greater concentration of HMs in soil along the road [3]. The main contributor of most HMs to road dust is brake filth, leaded gas, silencer valve emissions, corrosion of parts of the vehicle and abrasion of the tyres [4].

The smoke emitted from traffic produces large concentrations of Pb. The wear and tear of vehicle parts induces heavy metal deposition and road construction also leads to the deposition of Cd, Cu, Pb and Zn along the roadside [5]. HMs also affect the health of living organisms and cause numerous diseases, including skin rashes, dizziness, mental retardation, reduced immune system [6]. The spatial data and the HMs distribution can be correlated in a manner that the HMs concentrations are always higher in the urban areas. Traffic intensity, industrial location and topographical conditions may influence the HMs distribution in the environment [7]. Metals released from high concentrations of automobiles can be deposited in soil, and then taken up by plants [3].

Soil along the road is the most important pollutant for vehicle-based particles from exhaust from automobiles and tyre particles and resulting from road surface erosion [8,9]. Heavy metal contamination of soils is a serious threat worldwide. This problem affects not only crop quality and production, human and animal health but also the environment [10]. The HMs remain for a long time, they are taken up by the plants and then stored in the tissues of the plants, thereby entering the food chain. The accumulation of HMs in edible plant parts is the main cause of toxicity of the metals in human food. Cu, Zn and some other trace elements are important for the health of human, but more concentration of Cu can cause problems of health including blood, anemia, liver, and kidney failure, stomach and intestinal irritation.

Like other nations, a large part of the roads pass through farmland in Pakistan and the surrounding ecosystems often exert their effect on the roadside soils. Roads typically cross heavily fertilized crop fields in rural areas. As a result, HMs can accumulate to toxic level in the soil. Long term use of untreated wastewaters is also cause of HMs build up in soil. These HMs leak into groundwater and can reach to the body of human through dust inhalation, intake of polluted drinking water, direct soil intake and consumption of that food which grow in soil which is contaminated by heavy metals. Table 1 & 2 describes the permissible limits of Cd, Cu, Ni, and Pb in plants and soil, respectively.

Table 1: Permissible maximum concentrations of Cd, Cu, Ni, and Pb in plants.

Metal	Concentration (mg kg^{-1})	Reference
Cd	0.01	[11]
Cu	10	[12]
Ni	10	[13]
Pb	2.5	[14]

Table 2: Permissible maximum concentration of Cd, Cu, Ni and Pb in soil.

Metal	Concentration (mg kg^{-1})	Reference
Cd	1-3	[15]
Cu	50-140	[16]
Ni	30-75	[15]
Pb	50-300	[16]

Many studies have been conducted to assess the heavy metals concentration in dust and plants along road side in different parts of the world [17-20]. Faisalabad is Pakistan's 3rd-largest city, the 2^{nd} largest after Lahore in the province of Punjab and has over 328 major textile units. Industrialization as well as motor vehicles is adversely affecting the climate, trees, soil, animals and humans. All of these led to rising air, soil, water, and plant pollution levels. Therefore, the present study was carried out to quantify heavy metal pollution in urban roadside dust, plants and irrigation water and to examine the effect of heavy metals on maize plants grown along roadside.

Materials and Methods

Study area and sample collection

This survey study includes sampling of road dust, maize plants growing alongside of roads, and irrigation water used for irrigation of selected maize plants at Jhang Road Faisalabad, Pakistan. Plant samples were taken from 6 sampling sites, each sampling location was two meter away from the road. First, second and third sample of each site was taken from 5, 25, and 50m away from the muddy end of metaled road. Irrigation water samples were also taken from each site. The sites were Said Abad, Rashid Abad, Babu Wala, Chack 230RB, Risala Wala, and Liaqat Abad.

Preservation and digestion of samples

Plants were washed with distilled water to remove the contamination. Further samples were cut down into smaller pieces and placed in storage bags. Samples were oven dried at 65°C. After oven drying, then grinding was done with the help of grinder and placed in zipped polythene bags and digestion was performed. For digestion, 5g of the dried grinded sample of plants with mixture of di-acid, nitric acid and per chloric acid (1:2v/v) were put on hot plate and heated until color of the samples were changed. The volume (25ml) of the digested samples was made with distilled water. The prepared samples of plants were filtered through Whatman 40 flitter paper and stored in bottle and stayed overnight. Digested samples were taken into laboratory for determination of Cd, Cu, Ni and Pb. Heavy metals were determined by using atomic absorption spectrophotometer (Analytica Gena, Germany).

Agronomic parameters of plants

The height of plants was measured with measuring rod. The measuring rod was set to the lowest and upper end of the plants. Fresh weight (g) of the maize plants was recorded soon after collection of plants samples. For this the portable electrical balance was used. The plants dry weight (g) was recorded via an electrical balance after oven drying at 65^{o}C.

Physiological parameters

Total chlorophyll contents

Total chlorophyll contents (SPAD value) of fully expanded leaves of maize plants from each site were determined at 10:00 to 11:00am.

Preparation and analysis of dust samples for heavy metals

Dust samples were passed from sieve for the removal of contamination and debris and 5g sample of dust were stored in polythene bags for each sampling site. Dust sample digestion was done on hot plate by taking 0.5g dust material using di-acid mixture (HNO_3: HCl: 1:3v/v) after digestion digested sample of dust were filtered and final volume was made to 50 ml by adding distilled water. The metals (Cd, Cu Ni, and Pb) concentration were determined by using atomic absorption spectrophotometer (Analytica Gena, Germany).

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Analysis of irrigationwater samples

For water analysis, samples were taken into laboratory for determination of Cd, Cu, Ni and Pb by using Atomic Absorption Spectrophotometer (Analytica Gena, Germany).

Mapping

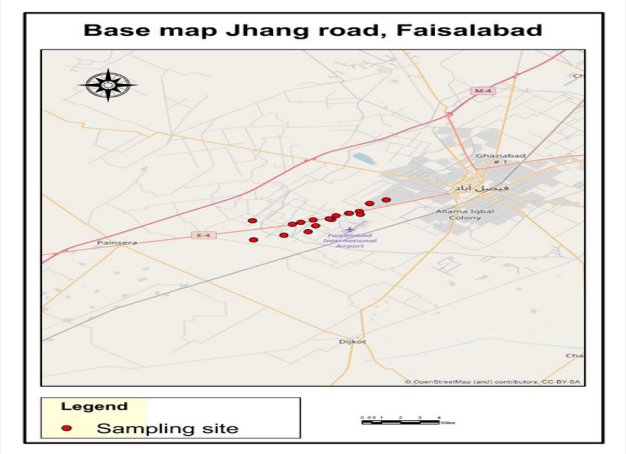

Figure 1: Base map of sampling site.

The x and y coordinates of every sampling site were recorded by using Garmin GPS (global poisoning system) portable meter. Analytical data which was obtained during sampling collection time were used for preparation of GIS maps. Both spatial and analytical data were linked using Arc GIS v 10.0 software (Figure 1).

Results and Discussion

Agronomic parameters of maize plants collected

The data about the agronomic parameters of maize plants is presented in Table 3. The mean, maximum, and minimum fresh weight of maize plants was 10.277g, 25g, and1g, respectively. After oven drying the sample, significant weight loss was recorded and mean dry weight was 3.055g. Maximum dry weights recorded was 8g and minimum was 1g. The mean height recorded was 83.33cm, maximum height was 155cm and minimum height was 50cm. The mean, maximum and minimum concentrations of spade value were 38.53, 45.2 and 31.7, respectively. It was observed that the mean weight, height and chlorophyll content are less in the plants grown alongside the road as compared to the plants grown away from the roadside. Figure 2 depicts the spatial variation of chlorophyll content in maize plants along Jhang Road, Faisalabad.

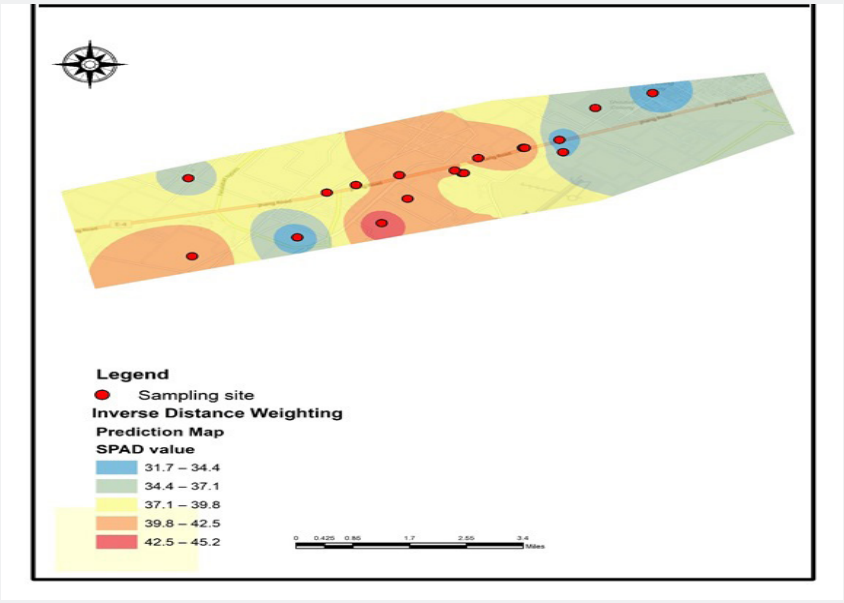

Figure 2: Spatial variation of chlorophyll contents in maize plants along Jhang Road, Faisalabad.

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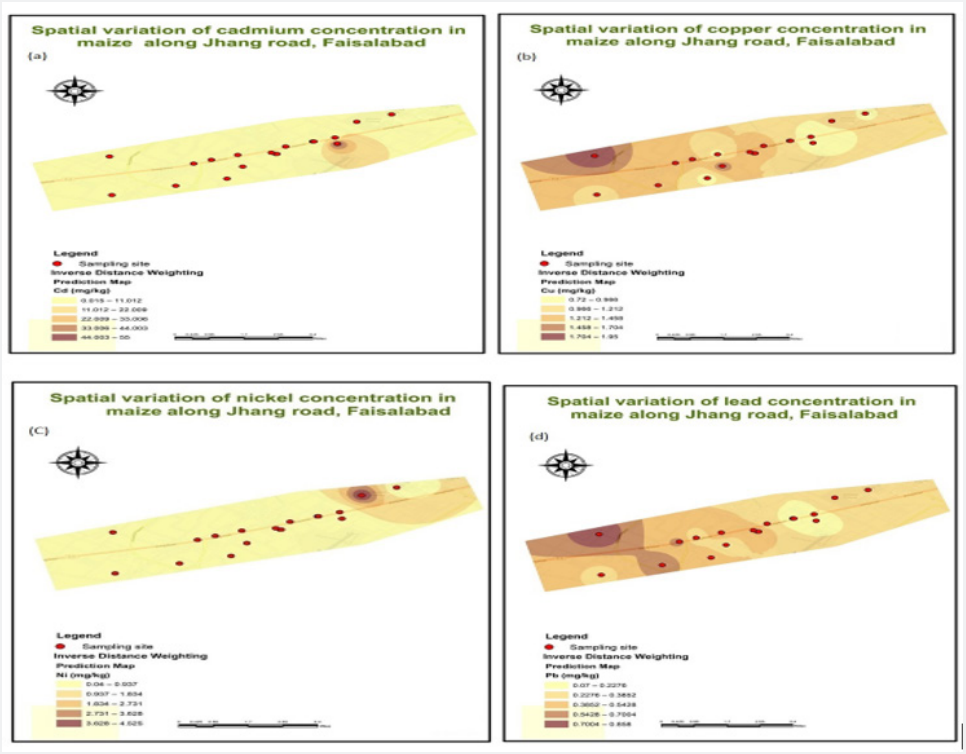

Figure 3: Spatial variation of (a) Cadmium (b) Copper (c) Nickel (d) Lead in maize plants along Jhang Road, Faisalabad.

Table 3: Agronomic parameters of maize plants collected along Jhang Road, Faisalabad.

Sr. No.	Location	X cod	Y cod	Fresh Weight (g)	Dry Weight (g)	Plant Height (cm)	Spade Value
1	Said Abad	73.0082	31.4	22	3	97	36.9
2	Said Abad	72.9973	31.4918	1	1	50	33
3	Said Abad	73.0003	31.3896	8	1	155	31.7
4	Rashid Abad	73.0011	31.3856	2	1	64	34
5	Rashid Abad	72.9924	31.387	16	8	145	43.4
6	Rashid Abad	72.9921	31.387	9	6	60	40.9
7	Babu Wala	73.00,00	31.2833	12	3	74	45.2
8	Babu Wala	73.00,00	31.3835	10	2	78	36.5
9	Babu Wala	72.9793	31.3837	12	3	77	43.1
10	Chack 230/RB	72.9797	31.3788	25	4	122	32.3
11	Chack 230/RB	72.9757	31.3788	4	2	59	37.6
12	Chack 230/RB	72.9656	31.3781	10	3	100	42.5
13	Risala Wala	72.9674	31.3704	23	6	92	40
14	Risala Wala	73.00,00	31.3797	3	1	72	44.9
15	Risala Wala	72.9562	31.3749	5	1	77	39.3
16	Liaqat Abad	72.9435	31.3578	4	3	56	32.3
17	Liaqat Abad	73.00,00	31.3724	6	3	55	37.6
18	Liaqat Abad	73.00,00	31.2699	13	4	67	42.5
Mean				10.277	3.055	83.333	38.53
Maximum				25	8	155	45.2
Minimum				1	1	50	31.7

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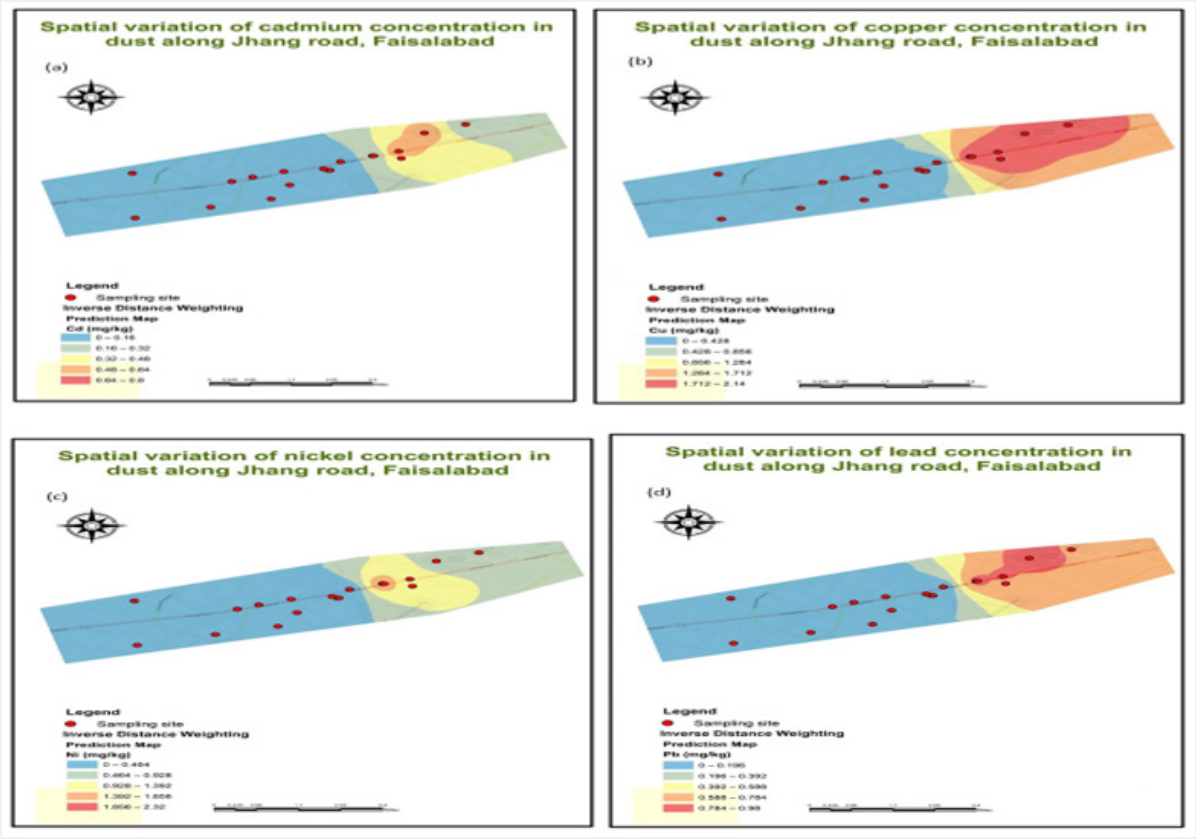

Figure 4: Spatial variation of a) Cadmium b) Copper c) Nickel d) Lead concentration in dust collected from Jhang Road, Faisalabad.

Concentration of Cd, Cu, Ni and Pb in maize plants

The concentration of Cd, Cu, Ni, and Pb in maize plants is given in Table 2. The mean concentration of Cd was 0.092mg kg^{-1}. Maximum concentration (0.735mg kg^{-1}) was recorded at Babu Wala site which is located at congested population and having more traffic intensities as compare to other sites. Minimum concentration of Cd (0.015mg kg^{-1}) was found in plants at Said Abad site. The mean Cu concentration was 1.172mg kg^{-1}, with maximum (1.95mg kg^{-1}) at Babu Wala site and minimum (0.72mg kg^{-1}) at Said Abad site. The mean concentration of Ni was 0.586 mg kg^{-1} with maximum 4.525mg kg^{-1} at Said Abad site while was minimum (0.04mg kg^{-1}) at Risala Wala site. The mean concentration of Pb in maize plants was 0.379mg kg^{-1}. The maximum concentration was 0.858mg kg^{-1} at BabuWala and minimum concentration was 0.07mg kg^{-1} at Rashid Abad.

Heavy metals found in the airborne particles along roadsides may find their path into crop plants grown along roadsides [21]. The concentration of Cu and Ni in maize plants was found below the safe limit proposed by [12] while due to overcrowding. Cadmium concentration was above the safe limit proposed by [11]. Heavy metals concentration may increase over time due to the continued use of chemical fertilizers and burning of fossil fuels in vehicles. The concentration of Ni measured at various places around Asia, which varies from 4.2-88mg kg^{-1}. The concentration of Cu is reported from 11.3-350mgkg^{-1}. The Cd concentration, show a large range of values, i.e., from 1.17-5.0mg kg^{-1} [22]. Atmospheric particulate matter deposition could involve damage to the vegetative surface with concomitant uptake of metals Table 4 & Figure 3 [23].

Total Cd, Cu, Ni, and Pb concentration in dust

Total concentration of HMs (Cd, Cu, Ni, and Pb) in dust samples is presented in Table 5. The mean value of Cd was 0.4mg kg^{-1}. Maximum Cd concentration was 0.8mg kg^{-1} at Babu Wala. The mean concentration of Cu in dust samples was 2.02mg kg^{-1} with maximum concentration 2.14mg kg^{-1} at Babu Wala site and minimum 1.8mg kg^{-1} at Said Abad site. The mean value of Ni in dust samples was 1.21mg kg^{-1}. Maximum concentration recorded was 2.32mg kg^{-1} at Risala Wala site and minimum was 0.71mg kg^{-1} at Said Abad site. The mean concentration of Pb in dust samples recorded was 0.835mg kg^{-1} with maximum concentration of 0.98mg kg^{-1} at Said Abad and minimum concentration was 0.68 at Chack 230 RB site.

This high concentration of Cd might be due to high traffic intensities. While Cu and Ni were found below permissible limit. Spatial distribution of Cd, Cu, Ni and Pb in dust along Jhang Road, Faisalabad was analyzed by using interpolation method of inverse

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distance weighing (IDW). The GIS maps for Cd, Cu, Ni and Pb is presented in Figure 4. Similar results have been reported by [8] who investigated the Pb and Cd contamination of different roadside soils and plants in Peshawar City, Pakistan.

Table 4: Concentration of Cd, Cu, Ni, and Pb in maize plants.

Location	X cod	Y cod	Cd mg kg^{-1}	Cu mg kg^{-1}	Ni mg kg^{-1}	Pb mg kg^{-1}
L1A	73.0082	31.4	0.045	0.995	4.525	0.325
L1B	72.9973	31.4918	0.015	0.96	0.41	0.285
L1C	73.0003	31.3896	0.025	0.72	0.315	0.24
L2A	73.0011	31.3856	0.055	0.86	0.135	0.155
L2B	72.9924	31.387	0.035	1.25	0.135	0.155
L2C	72.9921	31.387	0.03	0.775	0.1	0.07
L3A	73.00,00	31.2833	0.735	0.795	0.615	0.5
L3B	73.00,00	31.3835	0.07	1.95	0.858	0.858
L3C	72.9793	31.3837	0.06	1.555	0.34	0.24
L4A	72.9797	31.3788	0.02	1.385	0.295	0.63
L4B	72.9757	31.3788	0.12	1.03	0.245	0.585
L4C	72.9656	31.3781	0.06	0.825	0.13	0.54
L5A	72.9674	31.3704	0.085	1.675	0.665	0.175
L5B	73.00,00	31.3797	0.015	1.25	0.625	0.285
L5C	72.9562	31.3749	0.07	1.23	0.04	0.25
L6A	72.9435	31.3578	0.08	1.285	0.46	0.63
L6B	73.00,00	31.3724	0.11	1.435	0.39	0.585
L6C	73.00,00	31.2699	0.03	1.13	0.27	0.325
Mean			0.092	1.1725	0.586	0.379
Maximum			0.735	1.95	4.525	0.858
Minimum			0.015	0.72	0.04	0.07
Median			0.0575	1.18	0.327	0.305

Table 5: Concentration of selected Heavy metals in dust samples.

Location	X cod	Y cod	Cd mg kg^{-1}	Cu mg kg^{-1}	Ni mg kg^{-1}	Pb mg kg^{-1}
L1	73.0082	31.4	0.6	1.8	0.71	0.98
L2	72.9973	31.4918	0.19	1.98	0.89	0.78
L3	73.0003	31.3896	0.8	2.14	1.01	0.87
L4	73.0011	31.3856	0.4	2.11	1.12	0.68
L5	72.9924	31.387	0.15	2.1	2.32	0.75
L6	72.9921	31.387	0.26	1.99	1.25	0.95
Mean			0.4	2.02	1.216	0.835
Maximum			0.8	2.14	2.32	0.98
Minimum			0.15	1.8	0.71	0.68
Median			0.33	2.045	1.065	0.825

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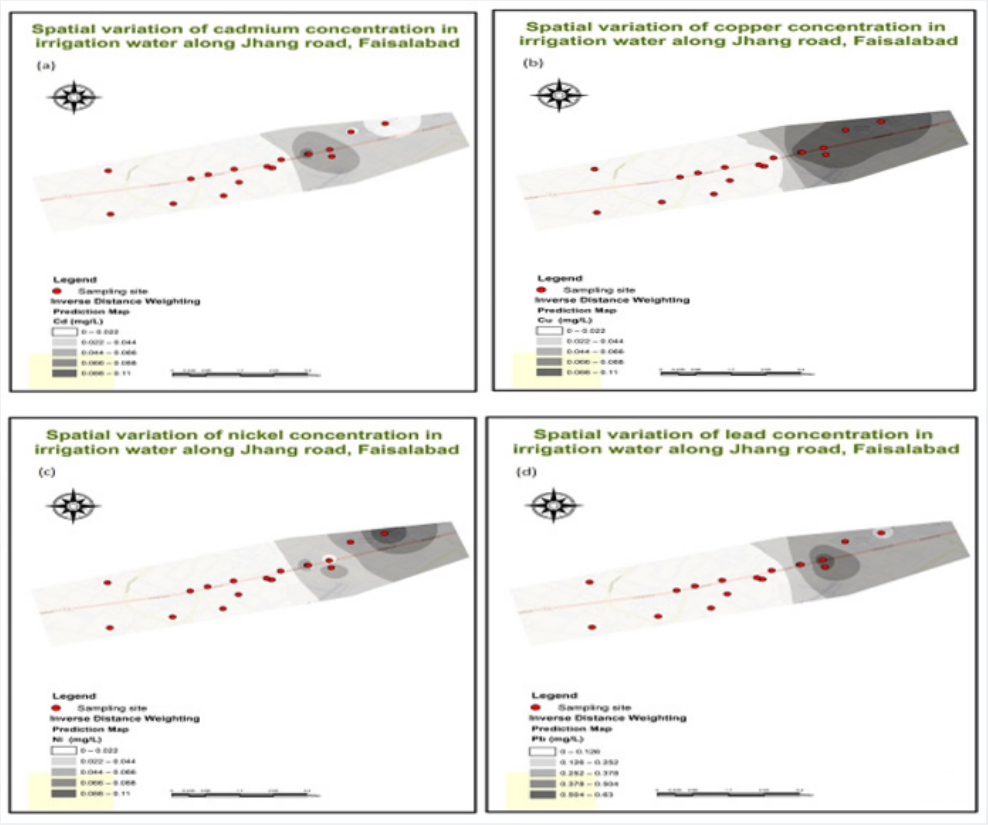

Figure 5: Spatial variation of a) Cadmium b) Copper c) Nickel d) Lead concentration in irrigation water along Jhang Road, Faisalabad.

Concentration of HMs (Cd, Cu, Ni and Pb) in irrigation water

Table 6 presents the data of the concentration of Heavy Metals in irrigation water. The mean concentration of Cd was 0.483mg L^{-1}. Maximum concentration of Cd was 0.11mg L^{-1} at Risala Wala site and minimum was 0.01mg L^{-1} at Rashid Abad site. The mean Cu concentration was 0.0733mg L^{-1}. The maximum and minimum concentrations of Cu were 0.15 and 0.02mg L^{-1} at Risala Wala and Liaqat Abad sites, respectively. The mean concentration of Ni was 0.203mg L^{-1}. Maximum Ni concentration was 0.4mg L^{-1} at Liaqat Abad site. Minimum concentration was 0.01mg L^{-1} at Babu Wala site. The mean concentration of Pb was 0.375mg L^{-1}. The maximum and minimum concentrations of Pb were 0.63mg L^{-1} and 0.22 at Babu Wala and Liaqat Abad sites, respectively.

Table 6: Concentration of Cd, Cu, Ni, and Pb in irrigation water along Jhang Road, Faisalabad.

Location	X cod	Y cod	Cd mgL^{-1}	Cu mg L^{-1}	Ni mgL^{-1}	Pb mgL^{-1}
L1	73.0082	31.4	0.02	0.05	0.2	0.34
L2	72.9973	31.4918	0.01	0.05	0.4	0.24
L3	73.0003	31.3896	0.06	0.08	0.01	0.63
L4	73.0011	31.3856	0.05	0.09	0.24	0.53
L5	72.9924	31.387	0.11	0.15	0.33	0.29
L6	72.9921	31.387	0.04	0.02	0.04	0.22
Mean			0.0483	0.0733	0.203	0.375
Maximum			0.11	0.15	0.4	0.63
Minimum			0.01	0.02	0.01	0.22
Median			0.045	0.065	0.22	0.315

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The concentration of Cd was observed above permissible limit in irrigation water. Irrigation water distribution, administrative region and the different distribution of Cd content is dependent upon the sources of discharge untreated wastewater into nearby canals, which causes heavy metal contamination in the irrigation water as well as by other man-made routes such as usage of phosphate fertilizers. The Cd content in all fertilizers (n = 284) ranged from 0.05 to 5.55mg kg^{-1}, with an average concentration of 2.1 ± 1.3mg kg^{-1}. The levels in phosphate fertilizers and NPK fertilizers produced in China were 1.5-3.2 and 0.5-1.5mg kg^{-1}, respectively [24]. The concentration of Cu, Ni, and Pb was found within the permissible limit (Figure 5).

Conclusion

Samples of maize crop, irrigation water and dust were collected from different sites at Jhang Road, Faisalabad. Chemical properties of collected samples showed the varying concentrations of Cd, Cu, Ni and Pb. The results revealed the samples collected from near roadside had higher concentrations then those away from the road. The concentration of heavy metals in maize was found more than the permissible limits proposed by WHO. Irrigation water showed higher concentration of Cd than the permissible limit while Cu, Ni and Pb were within the range of permissible limits. It is concluded that the maize crop cultivated nearby the roads could be problematic due to higher levels of Cd, Cu, Ni and Pb. It is therefore recommended that immediate and effective legislative measures must be adopted to grow safe food crops.

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