Journal of Scientific Agriculture 2019, 3: 6-10
doi: 10.25081/jsa.2019.v3.5297
http://updatepublishing.com/journal/index.php/jsa

Research Article

ISSN: 2184-0261

Survey study for transfer of cadmium and chromium in soil and wheat (*Triticum aestivum* L.), grown on contaminated soils

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ABSTRACT

This study was conducted to evaluate the contamination and accumulation of heavy metals such as Cadmium (Cd) and Chromium (Cr) in soil and plant grown in contaminated soil. Orchard and relative non-orchard fields were chosen to carry out this study. For total and available metals, soil samples were collected equally from 24 different points of orchard and non-orchard field and were extracted with Mehlich-3 extracting solutions and aqua-regia. Wheat crops from orchard and non-orchard fields were analysed and collected with aqua regia for heavy metal contents. Irrigation water samples were also collected from fresh water irrigation canal (Lower Chenab) for analysis. Results indicated that average metal concentrations in soils of both orchard and non-orchard fields were Cadmium (Cd) 2.36 and 2.49 mg kg-1 and Chromium (Cr) 58.15 and 53.51 mg kg-1 respectively. Contribution of risk from Cd and Cr were significant in wheat (seeds) of orchard. In orchard field, the risk contribution from Cd and Cr were significant in crops seeds. The considerable load of toxic metals in fields revealed the anthropogenic source of pollution. Therefore, it is emphasize that the need of heavy metals monitoring in crops and soils is necessary.

Received: January 21, 2018
Accepted: March 25, 2019
Published: March 29, 2019

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KEYWORDS: Contamination, extraction, anthropogenic, pollution

INTRODUCTION

Heavy metals i.e. (Cadmium (Cd, Chromium (Cr), Nickle (Ni) and lead (Pb)) remain in soil for long times as soil serves as a basin for some lethal elements [1]. Heavy metals affect the quality of soils and crops [1]. Anthropogenic activities incorporate dangerous metals into soils which directly and indirectly attack human health, when these metals entered in food chain [2]. The Upper most layers of soils (25cm) are affected by toxic metals which is also hub of plant roots [3]. The anthropogenic activities contribute water pollution i.e industrial and sewage effluents, domestic sewage, organic matter of plants and animals, surface washing, agrochemicals and treatment works wastes [4]. Due to industrialization, improper environmental planning and urbanization lead to shortage of water, to cope with the issue of water shortage, wastewater has been used for irrigation purpose since few decades [5]. Waste water use for irrigation purpose is not only causing contaminated vegetables and crops but it also causing accumulation of heavy metals [6]. Sources of heavy metals in soil is; from waste water irrigation one or continuous irrigation. Capacity of soil to hold heavy metals loose and releases heavy metals to ground and this uptake affects safety and quality of food [7]. The availability of fresh water for irrigation purpose is not sufficient in Pakistan and wastewater is used by farmer as an alternative source for irrigation purpose [8]. In Pakistan, Morocco, Jordan, Saudi Arabia, and Middle East are the countries which use waste water for irrigation [9]. One of the most important pathway is food chain contamination, contributes 90% of heavy metals as compared to dermal and inhalation contact [10]. Agricultural products and soil quality affected by the use of contaminated water and harms human health [11]. Cadmium is toxic for human health and it is present in earth crust to about 0.52 ppm [12]. Sources of Cd are phosphate fertilizers, sewage sludge, and animal manure in agricultural fields [1]. Cadmium has no specific function in human or animal body, but it accumulates kidneys and cause kidney failure [13]. Chromium is carcinogenic in nature and a toxic element naturally occurring in soils with range of (10-50 mg/kg) [14]. A soil, water, and food system contamination by heavy metals is severe issue due to its threats to environmental quality degradation, human, and animal's health. Heavy metals accumulation in plants and soil is of major concern because of toxicity to food chain contamination. Presence of heavy metals above their permissible limits is considered a severe threat for food chain [15]. Some natural processes i.e. (weathering and erosion), use of poor quality water for irrigation, pesticides and application of fertilizers are important sources of soil contamination [16]. When plants are grown on this type of contaminated soil, they uptake these metals and also transferred to food chain [17]. Toxic heavy metals consumption cause incidence of cancer [18]. For the safety of assessment of environment and human health it is important to monitor these heavy metals. The objective of this study was to give the overview of toxic elements accumulation in edible parts of wheat and their transfer to food chain.

MATERIAL AND METHODS

The research work was carried out on guava orchards soils and adjacent non-orchard field soils which were taken from sharaqpur (Sheikhupura) famous area of Punjab-Pakistan which is famous area for horticulture.

Sampling and Preparation

Composite 24 samples of soils were randomly collected from selected sited of orchard and non-orchard fields with depth of 0.253 cm depth by the help of spade. Total area was 105530 m^2 (10.553 Hectare). At 24 different sites a field of 5* 10 m was selected. Four (04) points were randomly selected, two for orchard and two for non-orchard and after dividing selected field into 1 m^2 grids. By covering 10% each site each site consist of 10 randomly selected points. Sample was taken in polythene bag labelled and brought to the Laboratory of soil water and chemistry lab, University of Agriculture Faisalabad and Chemistry lab of soil salinity research institute (SSRI) Pindi Bhattiyan Pakistan. Collected samples were mixed then air dried and then ground to pass through 2 mm sieve and stored in labelled jars of plastics for further analysis. Representative seven fresh water samples from same region of lower Chenab irrigation channel of respective fields collected in two litres labelled plastic bottles. Each water sample was acidified by nitric acid (HNO^3) as per standard method, to stop adsorption on inner side of bottle and to stop bacterial activity inside. Samples were stored in laboratory for analysis at 4° C in refrigerator [19]. In the month of June (from same place of soil samples were collected) after harvesting of wheat crop was collected and oven dried separately by dividing in different four parts (seed, leaf, stem and root). Each part was then ground and crushed into a powdered like form through grinding mill and stored for further analysis.

Laboratory Analysis

By the use pH meter and conductivity meter, the soil and electrical conductivity were measured with suspension of 1:5, soil and water [20]. Soil texture was determined by pipette method as 20 g sample of each soil sample was dissolved in little amount of distilled water in shaker cup and sodium hexa-metaphosphate 5 ml added and stirred for 5 minutes, then poured out the extract into graduated cylinder of 500 ml and filled with water, it top covered with para-film, to re-suspend the soil inverted it several times and left the cylinder for 48 seconds. After 48 seconds removed the para-film, took the first aliquot from upper 10 cm of suspension and marked it as 10 cm pipette. The aliquot then transferred to weighted china dish and placed it in oven at 105° C. After 40 minutes from upper 5 cm another aliquot of 25 ml was taken in separate pre-weighted china dish and marked and put it in oven at 105° C. Removed china dishes after overnight and find their weights which gave second reading, Final readings were subtracted from initial readings and percentage values of sand, silt and clay were calculated by formulas [21]. Walkely Black method was used to determine Organic contents according the standard method of Nelson and Sommers [22].

$$\text{Clay } \% = \frac{20 \times \text{mass of clay} \times 100\%}{\text{Total mass of Soil}(20 \text{ g})}$$

$$\text{Silt } \% = \frac{20 \times \text{Mass of silt} + \text{clay} - \text{mass of clay} \times 100\%}{\text{Total mass of soil}(20 \text{ g})}$$

Sand %=100-(% silt+% clay)

A total of 1 g soil was taken in flask of 500 ml, and then added $K_2Cr_2O_7$ solution of 10 ml, 20 ml sulfuric acid and shacked for about a minute, then on hotplate heated for 5 minutes and for 30 minutes allowed to stand. It was diluted with distilled water up to 200 ml after 30 minutes then added 10 ml of H_3PO_4, 3 to 4 drops of o-phenanthroline indicator and 0.2 g of NaF, and titrated against $Fe(NH_4)_2 (SO_4)^{-2}$ solution (0.5 M). Till the color changed from greenish blue to reddish brown, black without soil was run and noted the reading. With the help of formula Organic Carbon was calculated:

$$\text{Organic carbon}(\%) = \frac{(\text{mL blank} - \text{ml sample})(\text{M Fe2}+)(0.3)}{\text{Weight of Dry soil}}$$

For the analysis of heavy metals, two digestion methods were used; (i) aqua-regia extraction method [23], (ii) Melich-3 extraction method [24]. In aqua-regia extraction method, 1 g of soil was digested in 15 ml of 5:1:1 HNO_3: H_2SO_4: $HCLO_4$ (Aqua-regia) at 80°C to 180°C temperature until solution become transparent in digestion block [25]. The solution was filtered and then diluted to 50 ml with distilled water, and subjected to (AAS 700) Atomic Absorption spectrophotometer. Soil samples were extracted with Mehlich-3 solution (0.25N NH_4NO_3 + 0.2N CH_3CHOOH + 0.013N HNO_3 + 0.015N NH_4F + 0.001M ETDA) to determine the available contents of metals. For 5 minutes, 2 g of each sample was disconcerted with Mehlich-3 solution of 20 ml. After filtration, samples were analyzed along with water samples through atomic absorption spectrophotometer [24, 26]. In crops, for metals extraction 0.5 g of crop sample was digested with 15 ml of aqua regia then alalyzed on Atomic absorption spectrophotometer [25]. Detection limits for Cd and Cr were 22.8 and 357.9 respectively.

Statistical Analysis

Descriptive statistical analysis like average, standard deviation and correlation of metals were done using MS Excel 2007. An independent t-test was employed to find the significant level of comparative fields using SPSS software at 0.05 significance level and 95% of confidence interval.

RESULTS AND DISCUSSION

Soil Properties

Orchard and non-orchard soils PH ranged from 6.7 to 7.1 respectively (Table-1). Orchard field pH was low due to good organic contents. Orchard and no orchard organic contents ranged as 1.5 and 0.7% respectively (Table-1) whereas electrical conductivity (EC) ranged as 137 μS/cm and 134 μS/cm in orchard and non-orchard field respectively. Orchard field showed high EC as compared to non-orchard but both type of fields were much below the permissible limits approximately (2000 μS/cm) [27].

Heavy Metals in Soil

In orchard field, average concentrations of cadmium (Cd) and chromium (Cr) were found above the permissible limits in aqua regia extracted soils where as in non-orchard fields Cd and Cr limits were within safe limits (Table 2-3). Higher values of heavy metals in aqua-regia extracted soils, showing an evidence of contamination. The comparative study of variances showed highly significant values for Cd contents as $p < 0.05$, insignificant results for Cr ($p > 0.05$), given in (Table-2). In both orchard and non-orchard fields the mehlich-3 extracted soils test results showed the available contents in order of Cr>Cd (Table-2). Low PH in orchard contributes towards the accumulation of Cd and Cr and other metals in soil solution in comparison with non-orchard with high pH (Table-1). Inputs of animal manure, composts and pesticide are very common in research area and these cause the risk of heavy metals in soil and then environmental risk [28]. Fertilizers and pesticide use increase economic growth but it also increases the risk of human health and environment. A high level of heavy metals in soils is due to anthropogenic activities especially by use of waste water for irrigation purpose [29].

Findings showed that for transportation of heavy metals to plants and soil, water is one of the major contributors (Table-5). For the longer period of time these metals remain in soil and easily available to plants [30]. In soil due to excessive concentrations of heavy metals, microbial activity affected and thus slows down control of pests, maintenance of soil structure and recycling of important nutrients [31]. Heavy metal contents in wheat crop grown in orchard field, gains showed significantly high Cd contents as compared to permissible limits (Table 3-4), further more Cd contents in grains were also significantly ($p<0.05$) higher over non-orchard field (Table-4). It was noted that Cd concentrations in stem, roots and leaves of both orchard and non-orchard were non-significant (Table 4).

Chromium contents in wheat crop (seed-grains) grown on orchard and non-orchard soil showed high limit and showed significant result <0.05 (Table-3). Uptake of Cr by crop is high and crossing permissible limit (Table-3). The increase of Cr contents to soil is due to the related source of irrigation water carrying Cr contents. In comparative study especially in seed parts of wheat grown on orchard field showed high contents, this variation is differences of organic matter, PH, temperature, humidity and physiology of plant, as [32] revealed that; heavy metals uptake was affected due to physiological properties of soil. [33] Reported that soil's low PH encourages metal availability to plants. So this study favours author's statement. Plant growth affected by high concentrations of toxic metals and they enters into human body by different pathways in which food chain is important one [34]. My findings of study revealed that, veggies or crop grown on contaminated sites or soils allow open pathway for toxic metals (heavy metals) to human/animal's body causing health risks. This can be alleviated by the use of non-polluted source of water for irrigation and by lowering the use of agrochemicals.

Heavy Metals in Water

Irrigation water was tested to find the source of heavy metals. For surface water, results were compared with World health organization (WHO) and United States environment protection agency

Table 1: Parameters of soil samples

Sample	pH			EC			Organic matter %			Sand %	Silt %	Clay %	Soil tex
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg				
Orchard	6.6	6.8	6.7	135	138	137	1.4	1.6	1.5	72	10	57	Sandy clay
Non-orchard	7.0	7.1	7.1	133	134	134	0.6	0.8	9.7	53	21	61	Sandy clay

Table 2: Total and available contents of heavy metals in soil (mg kg-1)

	Element	Orchard				Non-orchard				
		Min	Max	Avg	SD	Min	Max	Avg	SD	P (2tail)
Total content of HM	Cd	1.81	2.91	2.36	1.104	0.81	2.49	1.15	0.51	0.00
	Cr	56.2	60.1	58.15	1.78	51.6	55.4	53.51	17.23	0.034
Available content of HM	Cd	1.31	2.24	1.77	0.71	0.73	1.49	1.11	1.78	0.00
	Cr	5.62	9.91	7.76	3.12	3.43	7.21	5.32	1.76	0.014

Table 3: Permissible limits of heavy metals in soil and crop

Metal	Crops	Soil
Cd	0.1-0.2 mg kg −1 (Khan *et al.*, 2008)	0.58 mg kg −1 (Khanlari *et al.*, 2008)
Cr	1.30 mg kg −1 (Iqbal *et al.*, 2011)	50 mg kg −1 (Shanker *et al.*, 2005)

Table 4: Concentrations of heavy metals in wheat crops

Element	Sample	Orchard				Non Orchard				
		Min	Max	Avg	SD	Min	Max	Avg	SD	P (2-tail)
Cd	Seed	0.51	0.72	0.62	0.261	0.18	0.38	0.28	0.071	0.00
	Leaf	0.22	0.21	0.16	0.964	0.04	0.15	0.09	0.034	0.51
	Stem	0.25	0.24	0.24	0.068	0.01	0.28	0.14	0.017	0.12
	Root	0.01	0.02	0.01	0.198	0.002	0.02	0.01	0.011	0.19
Cr	Seed	1.51	2.91	1.53	0.692	1.12	1.21	1.65	0.336	0.00
	Leaf	0.59	0.75	0.67	0.263	0.29	0.81	0.55	0.243	0.00
	Stem	1.06	1.04	1.05	0.271	0.28	0.78	0.53	0.214	0.00
	Root	0.55	0.74	0.64	0.265	0.21	0.63	0.42	0.241	0.00

Table 5: Heavy metals concentrations in water samples (mg/L)

Samples	Cadmium	Chromium
W1	1.07	0.14
W2	0.46	0.85
W3	0.02	0.13
W4	0.33	0.43
W5	0.62	1.12
W6	0.19	0.98
W7	0.14	0.04
Min	0.02	1.12
Max	1.07	0.04
Avg	0.404	0.527
SD	0.4241	0.692
Who standards	0.003	0.005
USEPA-1986	0.005	0.1

(USEPA) standards. Comparison showed high concentrations of Cd and Cr in surface water (Table-5). Water contamination associated with erosion of mountainous areas, sugar mill, ghee and textile effluents and release of tannery waste which release these metals to soils and cause agricultural products accumulation [35]. Use of quality water for irrigation purpose has important role in crop yield.

Bio Accumulation Factor and Target Hazard Quotient

Metals showed high values of cadmium 0.29 and 0.21, and chromium is 0.03 and 0.01 respectively for orchard and non-orchard field (Table-6). Trend of Bio accumulation factor was Cd>Cr and results indicated high metal uptakes of metals in orchard field as compared to non-orchard field. In edible part of wheat crops (grain/seed), the target hazard quotient for Cd and Cr was calculated. The results indicated high target hazard quotient THQ for Cd and Cr (>1) in orchard field. Whereas for non-orchard fields, THQ for metals were below contamination level (Table-6). Therefore, according to results heavy metals in orchard field indicated that, wheat consumption could have risk to locality.

CONCLUSION

Present days study showed that overuse of agrochemicals and contaminated water for irrigation purpose led to heavy metals accumulation in soils and uptake in crops grown over there.

Table 6: Bio Accumulation factor and Target Hazard Quotient

Sample	Orchard		Non-Orchard	
	Cd	Cr	Cd	Cr
BAF				
Seed	0.29	0.03	1.21	0.01
Leaf	0.04	0.00	0.08	0.00
Stem	0.06	0.01	0.09	0.00
THQ				
Root	0.01	0.01	0.01	0.01
Adult	1.63	1.29	0.89	0.42
Children	2.02	1.48	0.83	0.69

Wheat crop uptake varied in different parts, the edible parts especially see/grains which showed high concentration of Cd and Cr. In orchard fields, local population THQ showed health risks associated with Cd and Cr contamination in wheat crops. Fine agricultural practices and daily soil monitoring, water quality and crops with prevention of toxic metals entry to agricultural products, is a way to alleviate health hazards for livings.

ACKNOWLEDGMENT

The authors are thankful to Laboratory Soil chemistry section of SSRI, department of Agriculture Government of the Punjab Pakistan for lab experimentations.

AUTHOR'S CONTRIBUTION

Fahad Iftikhar Virk is the original author who has experience in heavy metals analysis and human health exposure. This work was done with the contribution of Muhammad Qaisar Nawaz, Dr. Muhammad Sarfraz and Muhammad Waqas, who is currently working on boosting agriculture and agriculture related works, while; Dr. Sadia Bibi provided guidance in selection of research topic and analysis of survey, sample collections and laboratory analysis.

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