



Original article

# Chromium accumulation in soil, water and forage samples in automobile emission area



Tasneem Ahmad<sup>a</sup>, Kafeel Ahmad<sup>b</sup>, Zafar I. Khan<sup>b</sup>, Zunaira Munir<sup>b</sup>, Ahlam Khalofah<sup>c,d</sup>,  
Rahmah N. Al-Qthanin<sup>c,e</sup>, Moodi Saham Alsubeie<sup>f</sup>, Saad Alamri<sup>c,e</sup>, Mohamed Hashem<sup>c,g</sup>, Shahid Farooq<sup>h</sup>,  
Muhammad Mudassar Maqbool<sup>h</sup>, Sarfraz Hashim<sup>i</sup>, Yong-Feng Wang<sup>j,\*</sup>

<sup>a</sup> Pakki Thatti Research & Development Farm, Toba Tek Singh, Pakistan

<sup>b</sup> Department of Botany, University of Sargodha, Sargodha, Pakistan

<sup>c</sup> Department of Biology, Faculty of Science, King Khalid University, P.O. Box 9004, Abha 61413, Saudi Arabia

<sup>d</sup> Research Center for Advanced Materials Science (RCAMS), King Khalid University, P.O. Box 9004, Abha 61413, Saudi Arabia

<sup>e</sup> Prince Sultan Bin-Abdul-Aziz Center for Environment and Tourism Studies and Researches, King Khalid University, P.O. Box 960, Abha 61421, Saudi Arabia

<sup>f</sup> College of Sciences, Biology Department, Imam Mohammad Ibn Saud Islamic University, Riyadh, Saudi Arabia

<sup>g</sup> Assiut University, Faculty of Science, Botany and Microbiology Department, Assiut 71516, Egypt

<sup>h</sup> Department of Agronomy, Faculty of Agricultural Sciences, Ghazi University, 32200 Dera Ghazi Khan, Pakistan

<sup>i</sup> Department Agricultural Engineering, Muhammad Nawaz Shreef University of Agriculture, Multan, Pakistan

<sup>j</sup> Academy of Environmental Health and Ecological Security, Jiangsu University, 301Xuefu Road, Zhenjiang 212013, PR China

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## ABSTRACT

Environmental contamination caused by various pollutants due to automobile emissions is an alarming issue. One important type of the pollutants are heavy metals, including chromium (Cr) added by the exhaust of toxic smoke of vehicles. These pollutants are added to forage crops cultivated near roadsides, soil and irrigation water. However, rare studies have been conducted to infer Cr accumulation near heavy automobile emission areas. This study was conducted to determine Cr concentration in irrigation water, soil and forage. Water, forage and soil samples were collected from area impacted by heavy traffic. Atomic absorption spectrophotometer was used to appraise Cr values in the collected samples. Chromium values ranged from 0.50 to 1.14 mg/kg in water samples and from 0.04 to 2.23 mg/kg in soil samples. It was highest in *Zea mays* grown soil, whereas minimum in *Brassica campestris* soil. The Cr values in forages ranged from 0.09 to 1.06 mg/kg. *Z. mays* observed the highest Cr accumulation, whereas the lowest Cr accrual was noted for *B. campestris*. The pollution load index (PLI) was the highest for *Trifolium alexandrinum*, while the lowest for *Z. mays*. Bio-concentration factor (BCF) ranged from 0.14 to 8.63. The highest BCF was noted for *T. alexandrinum*, while the lowest for *Z. mays*. The highest and the lowest daily intake of metal (DIM) was noted for *Z. mays* at different sites. Health risk index (HRI) was highest for *Z. mays* and lowest for *B. campestris*. The results add valuable information on heavy metal accumulation in water, soil and forage samples near to automobile emission area.

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## 1. Introduction

Environmental contamination is an alarming issue caused by various pollutants being released into the atmosphere by

automobile emissions (Anwar et al., 2020; Hanfi et al., 2020). These pollutants finally become part of food chain and create health hazards for consumers (Anwar et al., 2020; De Silva et al., 2021). The pollutants are heavy metals including chromium by exhaust smoke of vehicles that are accumulated in forage (Yang et al., 2020). The contaminated and polluted environment is a cognizant entry source of heavy metals into crops and the food as well (Hanfi et al., 2020). The consumption of the forage, contaminated with heavy metals by cows, is a pathway of the heavy metals to get absorbed by living bodies (Yang et al., 2020). Nonetheless, non-secreting and removal of the heavy metals out of the body, continues their accumulation in the blood and vital organs of living

\* Corresponding authors.

E-mail address: [david\\_hku@qq.com](mailto: david_hku@qq.com) (Y.-F. Wang).

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organisms (Sriuttha et al., 2017). Inorganic metals emitted by the automobiles' exhausts are get absorbed in soil and water and from where the root system of plants take up the obnoxious metals (Eludoyin and Ogbé, 2017).

The plants growing on roadside are deeply contaminated with heavy metals caused by vehicles' smoke pollution, hence certain physiological disorders and diseases may occur by consumption of vegetation infested with vehicular smoke pollution (Anwar et al., 2020). Fertilizers applied are also a significant source of these metals in soil. Being hazardous, the heavy metals are considered a factual threat to the environment and ultimately to the living bodies (Stoica et al., 2020; Unver et al., 2015). The occurrence of heavy metals, due to any reason, in the environment results in hazard to the biosphere and ecosystem, especially in developing countries (Baslar et al., 2009; Ugulu et al., 2016). Substantial toxicity is caused by such metals as they are available in any shape (Dinu et al., 2018). Emission of heavy metals-rich smoke from motor vehicles causes severe air and soil pollution (Anwar et al., 2020). The green plants and vegetation on roadsides are harshly affected by the smoke of heavy traffic, and smoke rich with these metals becomes a part of plant bodies (Kurnaz and Cobanoglu, 2017).

The region rich with such metals, poses severe risks to human bodies through the use of contaminated crops (Liu et al., 2005; Ugulu et al., 2019). Legume crops accumulate more chromium unlike the other crops of food. Chromium (Cr) affects the nucleic acids structure with affecting immune response, body growth and metabolism of lipids etc. (McDowell, 2003). The Cr is useful and helps in growth of different ruminants, but only in lower concentrations (Levander, 1990). Soil and forages contents of chromium significantly vary (Abdelhafez and Li, 2014). The reasons behind are drinking water, streams and rivers. Appropriate management strategies are recommended to avoid unnecessary Cr accumulation in bodies of small ruminants (Khan et al., 2009, 2020).

A significant positive soil-forage correlation has been reported (Rasheed et al., 2020; Yang et al., 2020). Conversely, significant negative blood-forage correlation was noticed for Cr accumulation (Yang et al., 2020). Pollution load index, daily intake and health risk index had significant variations among different sites (Yang et al., 2020). Lastly, the highest bio-concentration factor (BCF) value of Cr was reported for soil, while BCF values of Cd were highest for buffaloes' blood plasma. The correlation between soil and blood plasma was positive for Cd, Cr and Cu (Rasheed et al., 2020).

The assessment of heavy metal accumulation, particularly Cr in the automobile emission areas will provide empirical information about heavy metal pollution and associated damages. Therefore, the current study was conducted to appraise Cr accumulation caused by the roadside automobile emissions in water, soil and forage samples at different sites. It was hypothesized that the sampling sites will significantly affect Cr accumulation and related attributes because of different traffic.

## 2. Materials and methods

### 2.1. Study area

The study was carried out in Sahiwal town, district Sargodha, Pakistan. Two different types of sites were selected for the study, one 1 km away from roadside (only one site) and others 5–10 m away (5 sites) from the busy road. The sites near roadsides were randomly selected to exclude any bias in the study. The forage, soil and water samples were collected during December 2016 and January 2017 from each site. The samples were collected from Dera Jara, Radhan, Majoka, Sial Sharif, and Nehang. Vijh was the site chosen away from the road. The forages chosen were *Zea mays* L.,

*Avena sativa* L., alfalfa *Trifolium alexandrinum* L. and *Brassica campestris* L.

### 2.2. Sample collection

Water samples were collected from all sites and standard procedures were followed for determining Cr concentration. The forage samples were collected at the harvest maturity of the forage crops included in the study. Thirty samples for each forage crop were collected from each site. Similarly, soil samples were collected from the studied sites following Ozaşlan et al. (2016). Soil and forage samples were air and oven dried at 70–75 °C till constant weight. Forage (1 g) and soil (0.5 g) samples were digested in 10 ml of aqua regia (HNO<sub>3</sub> and HCl, keeping 1:3) in digestion flask at 460 °C for almost 24 h. The resultant clear solution was filtered and diluted to 50 ml (Rasheed et al., 2020). Atomic absorption spectrophotometer was used to analyze Cr in all samples. Repetitive sample analysis following National Institute of Standard Technology, was employed to ensure precision and accuracy with standard reference material (CRM-NIST 1567a for forage and SRM 2709 for soil samples).

### 2.3. Bio-concentration factor (BCF)

The formula of Yoon et al. (2006) for BCF was used to calculate BCF. The formula is given below:

$$BCF = \frac{CF}{CS}$$

Here, CF = Cr concentration in forage and CS = Cr concentration in soil.

### 2.4. Daily intake of metal (DIM)

The formula of Cui et al., (2004) was followed to calculate daily metal consumption by dividing daily forage consumption with the mean Cr concentration. The daily consumption of cows was taken as 12.5 kg as suggested in earlier studies (Cui et al., 2004).

### 2.5. Health risk index

Health risk index (HRI) is defined as the exposure of animals to Cr. The equation devised by Liu et al. (2005) was used to compute HRI. The equation is given below;

$$HRI = \frac{\text{Daily metal intake}}{R_{fd}}$$

Daily Cr intake was calculated by dividing Cr concentration in forage by oral reference dose and multiplying with body weight of cow. By integrated risk information system, Cr RfD value has been determined as 1.5 mg/kg/day (IRIS, 2007).

### 2.6. Pollution load index

The pollution load index was calculated by following Liu et al. (2005).

$$PLI = \frac{\text{Metal concentration in soil}}{\text{reference value of the metal in soil}}$$

For Cr the reference value is 0.07 mg/kg (Singh et al., 2010).

### 2.7. Statistical analysis

The collected data were statistically analyzed by one-way Analysis of variance (ANOVA). The normality was tested by Shapiro-Wilk normality test (Shapiro and Wilk, 1965). The means were sep-

arated by least significant difference test where ANOVA indicated significant differences (Steel et al., 1997).

### 3. Results

The ANOVA indicated a non-significant effect of different sites on Cr concentration in soil grown with, while significant effect of sites was observed on the concentration of Cr in water.

#### 3.1. Cr accumulation in water samples

A significant effect of sites was observed on the concentration of Cr in water (Table 1). Water samples exhibited different Cr concentration at all sites. The Cr concentration ranged from 0.501 mg/kg to 1.14 mg/kg. Maximum Cr concentration was found at site 4, whereas the minimum was recorded at site 2 (Fig. 1).

#### 3.2. Cr accumulation in soil samples

Vehicles emissions had non-significant effect on Cr accumulation in soil samples (Table 1). Soil of all the forages, showed different concentrations of Cr at all sites that ranged from 2.23 mg/kg to 0.041 mg/kg. Cr concentration was maximum in *Zea mays* grown at site 2, whereas it was minimum in *Brassica campestris* grown at site 5 (Fig. 2).

#### 3.3. Cr accumulation in forage samples

Forage samples exhibited different concentration of Cr at diverse sites that were ranging from 0.097 mg/kg to 1.068 mg/kg. Minimum value of Cr 0.097 mg/kg was in *Brassica campestris*, while it was maximum 1.068 mg/kg in *Zea mays* (Fig. 3).

#### 3.4. Pollution load index

The PLI for Cr in all forages at six sites ranged from 0.04 to 9.97. It was highest for *Trifolium alexandrinum* at site 2, while lowest for *Zea mays* at site-6 (Table 2). The ascending order of PLI for *Zea mays* at different sites was site 6 < site 3 < site 5 < site 4 < site 1 < site 2. For *Avena sativa*, PLI at different sites was in the order site 2 < site 4 < site 3 < site 1 < site 6 < site 5. The order of PLI for *Trifolium alexandrinum* at different sites was in the increasing order with site 1 < site 6 < site 5 < site 3 < site 4 < site 2. For *Brassica campestris*, order of PLI at different sites was site 2 < site 3 < site 1 < site 5 < site 6 < site 4.

#### 3.5. Bio-concentration factor

The BCF for Cr at all sites in all forages ranged from 0.14 to 8.63. It was maximum for *Trifolium alexandrinum* at site 5, while it was lowest for *Zea mays* at site 4 (Table 3). The ascending BCF order at site 1 for all forages was *Avena sativa* < *Zea mays* < *Trifolium*

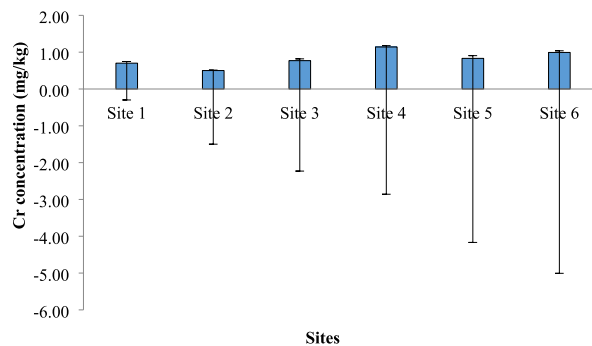


Fig. 1. Chromium concentration in water samples collected from different sampling sites included in the study.

*alexandrinum* < *Brassica campestris*. The order of BCF at site 2 for all the given forages was *Zea mays* < *Brassica campestris* < *Avena sativa* < *Trifolium alexandrinum*. The order of BCF at site 3 for all the given forages was *Avena sativa* < *Zea mays* < *Trifolium alexandrinum* < *Brassica campestris*. The order of BCF at site 4 for all the given forages was *Avena sativa* < *Zea mays* < *Brassica campestris* < *Trifolium alexandrinum*. The order of BCF at site 5 for all the given forages was *Avena sativa* < *Zea mays* < *Brassica campestris* < *Trifolium alexandrinum*. The order of BCF at site 6 for all the given forages was *Avena sativa* < *Brassica campestris* < *Trifolium alexandrinum* < *Zea mays*.

#### 3.6. Daily intake of metals (DIM) & health risk index (HRI)

The DIM was highest for *Zea mays* at site 6, while it was lowest for *Zea mays* at site 4 (Table 4). HRI was the highest for *Zea mays* at site 3, while it was lowest for *Zea mays* at site 4 and for *Brassica campestris* at site 2 and 3. The order of health risk index (HRI) for *Zea mays* at different sites were site 4 < site 1 < site 2 < site 5 < site 6 < site 3. For *Avena sativa*, DIM at different sites was in the order site 4 = site 5 < site 1 < site 2 < site 6 < site 3. For *Trifolium alexandrinum* at different sites the order site 1 < site 3 < site 2 < site 5 < site 4 < site 6. For *Brassica campestris*, order of DIM at different sites was site 2 = site 3 < site 4 < site 6 < site 5 < site 1.

## 4. Discussion

Pollution created by heavy traffic emissions is contaminating the healthy food chain by adding Cr and other toxic metals, which is an alarming problem for healthy life. Such hazardous inorganic metals may originate from other sources too like industries and mines. However, vehicular emission is a reckoning source of toxic metals in environment. The instant study was focused to observe

Table 1 Analysis of variance for chromium concentration in water, soil and forage samples collected from the studied sites.

SOV	DF	Water	Soil			
			<i>Zea mays</i>	<i>Avena sativa</i>	<i>Trifolium alexandrinum</i>	<i>Brassica campestris</i>
Sites	5	0.001**	1.783 ns	0.446 ns	0.746 ns	1.232 ns
Error	18	0.021*	2.83 ns	0.573 ns	1.262 ns	0.168 ns
Forage						
Sites	5		<i>Zea mays</i>	<i>Avena sativa</i>	<i>Trifolium alexandrinum</i>	<i>Brassica campestris</i>
Error	18		0.449 ns	0.216 ns	0.178 ns	0.454 ns
			0.266 ns	0.145 ns	0.281 ns	0.281 ns

SOV = source of variation, \* = significant at p < 0.05, \*\* = significant at p < 0.01, ns = non-significant.

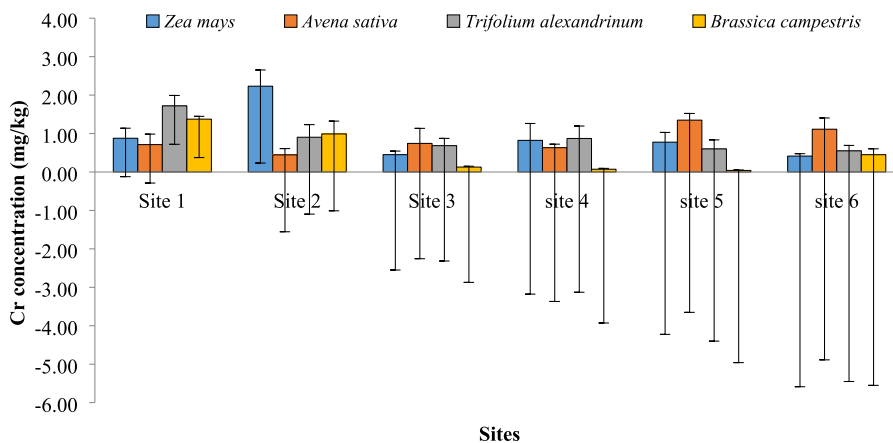


Fig. 2. Chromium concentration in soil samples collected from different sampling sites included in the study.

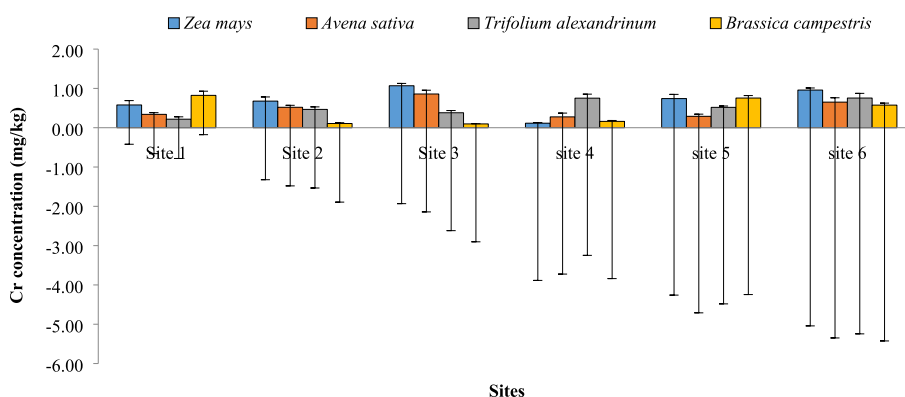


Fig. 3. Chromium concentration in forage samples collected from different sampling sites included in the study.

Table 2  
Pollution load index (PLI) for chromium at different sampling sites included in the study.

	<i>Zea mays</i>	<i>Avena sativa</i>	<i>Trifolium alexandrinum</i>	<i>Brassica campestris</i>
Site 1	0.10	0.09	1.90	1.52
Site 2	0.25	0.05	9.97	1.09
Site 3	0.05	0.08	7.55	1.41
Site 4	0.09	0.07	9.61	7.94
Site 5	0.08	0.15	6.62	4.52
Site 6	0.04	0.13	6.06	4.96

Table 3  
Bio-concentration factor (BCF) for chromium in soils of different forages at different sampling sites included in the study.

Sites	<i>Zea mays</i> -soil	<i>Avena sativa</i> -soil	<i>Trifolium alexandrinum</i> -soil	<i>Brassica campestris</i> -soil
Site 1	0.66	0.48	1.26	5.99
Site 2	0.30	1.17	5.15	1.08
Site 3	2.37	1.15	5.56	7.58
Site 4	0.14	0.44	8.62	2.24
Site 5	0.95	0.21	8.63	1.84
Site 6	2.31	0.58	1.37	1.28

the effect of vehicular emission on accumulation of chromium in roadside forages, water, soil, and cow’s blood in the vicinity.

The mean Cr value was less than that reported (4.309 mg/kg) by Nazir et al., (2015) and found by Yang et al. (2020) (2.363 mg/kg). The lower values of Cr suggested lesser traffic in this area of sampling as compared to larger cities with heavy traffic. Addition-

ally, the type of soil also affected Cr accumulation in soil. The lesser contents of Cr in these soil samples were resulted by thin traffic in area of sampling made.

The levels of heavy metal studied by Yang et al. (2020) (3.063 mg/kg) and Moreki et al. (2013) found higher contents of Cr as compared to contents assessed by this study. It means lower

**Table 4**

Concentration of daily intake of metals &amp; health risk index for chromium in soils of different forages at six sites.

Study Sites	DIM & HRI	<i>Zea mays</i>	<i>Avena sativa</i>	<i>Trifolium alexandrinum</i>	<i>Brassica campestris</i>
Site 1	DIM	0.013	0.008	0.005	0.019
	HRI	0.009	0.005	0.003	0.013
Site 2	DIM	0.015	0.017	0.011	0.003
	HRI	0.01	0.008	0.007	0.002
Site 3	DIM	0.024	0.02	0.009	0.002
	HRI	0.016	0.013	0.006	0.002
Site 4	DIM	0.003	0.006	0.017	0.004
	HRI	0.002	0.004	0.011	0.003
Site 5	DIM	0.017	0.007	0.012	0.017
	HRI	0.011	0.004	0.008	0.012
Site 6	DIM	0.022	0.015	0.017	0.013
	HRI	0.015	0.01	0.012	0.009

concentration of Cr in the forage samples may be due to significantly lesser traffic on highways near the forage samples site. Smith (1995) reported formation of carbonates, organic complexes and hydroxides in the soil were caused by the bigger mobility of the metal and less soil pH. Increased mobility of heavy metals increases their movement in forages.

The PLI for Cr was different and higher than as found in earlier studies (Ashfaq et al., 2015; Rasheed et al., 2020; Yang et al., 2020). The values of PLI for Cr were found highest in our study as compared to (Cr-0.02 mg/kg) earlier findings (Ashfaq et al., 2015). The PLI > 1 indicates that the area surrounding was polluted by heavy traffic emissions, confirming that PLI for Cr was very high due to the increasing number of heavy vehicles in the area.

The BCF for Cr as found in present study was higher as compared to earlier reports (Kamal et al., 2015; Yang et al., 2020) (Cr- 0.113). Higher BCF of Cr suggests retention of metals in soil is low and heavy metal is readily transported into the forages. Zou et al. (2006) reported that if BCF is higher than 1.0, it suggested that plants could accumulate toxic metals in their parts. Additionally the uptake extent the heavy metals by forages depended upon factors including their age, edaphic and climatic factors (Alloway and Ayres, 1997).

Unlike the DIM found in present study, Lente et al., (2014) determined lesser values of DIM. As clear the DIM is < 1.0 in present study hence no health risk is associated by feeding of above referred forages (Radwan and Salama, 2006).

## 5. Conclusion

The results suggested that although study area was comparatively safe from Cr accumulated by smoke of the automobiles yet was polluted with hazardous metal, which may pose toxic effects on the healthy life after crossing the acceptable limits. This study recommends cogent steps in making environment free from such pollutants.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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