Transfer and accumulation of cadmium in soil, forages and animals: Risk assessment

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Abstract

Over past several years pollution in industrialized areas is the most attention seeking issue. Higher level of heavy metals especially cadmium is accumulated in atmosphere evolved from smoke of automobiles. Living system present around the contaminated areas accumulate heavy metals in their bodies. Heavy metals have been accumulated in soil, water, forages and animals so study was conducted in industrialized area Faisalabad to evaluate the possible risk. Three sites was selected to check the accumulation of cadmium in soil, water, forages and animals. These sampling sites was areas along the roadsides of Chak Jhumra, Jaranwala and Samundri. Sample of soil, forages,water and blood,hair feces of animals was collected from these sites. The digestion of samples was carried out with the help of nitric acid and hydrogen peroxide. Atomic absorption spectrophotometer was used to evaluate heavy metal analysis. Analysis of variance was done by using SPSS Software (version no. 20) and two ways ANOVA. Result indicated that concentration of Cd was higher in soil irrigated with municipal wastewater and concentration of Cd was highest in forages C. *album* present at site III. Higher concentration of Cd was observed in blood of sheep higher than critical value. Concentration of cadmium was higher than critical in blood of animals indicating transfer of metal via intake of contaminated forages. The sample collected from site III showed high daily intake of metals (DIM), health risk index (HRI), pollution load index (PLI), enrichment factor (EF) and Bioconcentration factor (BCF). This study will bring consideration concerning the development of approaches in order to overcome the toxic effects of cadmium.

Introduction

Any metallic element that have higher density than water are termed as heavy metal(1a) many natural as well as anthropogenic activities (scorching of fossil fuel, mining operations, metallurgy industry, means of traveling) have distributed toxic metals in environment. these metals linger for extended duration ultimately effecting all the components of environment (Kaplan *et al.*2010). Over the past several years these toxic metals contamination associated with the ecologic as well as public health issues. Use of toxic metals in various daily based activities including (technical, manufacturing activities, household, farming) have increased human exposure to toxic metals (Bradl, H.,2005). separate researches have been conducted to investigate the effect of various metals in soil, water air and plants (Kabata Pendias.,2001; Kabata Pendias.,2007). plant considered as good bio-indicators for presence of metal at particular soil as plant could absorb metals naturally. They are intermediate medium by which metals move from soil, forages to animals and humans (Kabata Pendias.,2007) in case of lead small quantity of Pb absorbed by the roots of plants and its subsequent transfer to aerial parts limited (Kabata Pendias.,2001). Toxic metals are gathered in vegetation, and faunas nourished on these vegetation resulting in accumulation of lethal metals. Wastewater contain most persistent contaminants known as heavy metals and trace metals. Many environmental danger are produced by the liberation of toxic metals into water especially in enormous amount. Heavy metals are exposed to humans by different ways some of these are by eating and drinking contaminated food and water, evaporation, breathing in air full of dust and smoke. Toxicity due to pollutants may be long or short term basis and water ecological unit is also effected by the heavy metals by expiring biota, eutrophication, reduction of locale as a result of sediment formation and waterlogging. Metabolism and functional processes that result in nutrient uptake and growth of fodder crops can be prevented by the heavy metals in soils present in large number and lessen the superiority and magnitude of food obtain. Animals are also threatened by the heavy metals as some effects caused by metals can lead to death these effects includes ,tumor formation, malfunctioning of nerves and different body parts. Numerous chemical or natural strategies are suggested by the researchers in order to overcome the destructive effects of toxic material on all the organisms living or non-living. For the avoidance of availability of heavy metals in soil and water treatment method of wastewater supplied to the irrigated fodder crops are vital by using natural avoidance method by the plants or different microbiota (bacteria, fungi, algae, protozoa) living in soil near the crops grown these help to restore the surrounding (Akpor *et al.*2014). Various districts of Punjab was studied to examine heavyweight elements metals pollution and their occurrence in soil, water, forages, animals and humans and appraisal of health problems due to different activities which may be related to industries, farming, extraction of minerals and other ordinary procedure. Cadmium concentration in Sargodha, Mianwali and Bhakkar higher concentration found in Sargodha 4.57 to 4.94, 2.98 to 3.95 in mianwali, and least concentration found in bhakar which is from 1.65 to 2.98mg/kg. forages of Sargodha contain cadmium level from 2.745–3.432 in Mianwali forages have 2.245–3.196 cadmium values and forages of bhakkar contain cadmium 1.9-2.036 mg/kg. blood of goat and sheep grazing on a contaminated forages which is grown in contaminated soil is examined and it shows that the values of cadmium in goat and sheep of Sargodha is between 2.152–2.436, 2.152 to 2.436 mg/L correspondingly. Goat and sheep of Mianwali contain cadmium level 1.727–2.39, 1.794 to 2.286 mg/L respectively and in district bhakkar cadmium level in blood of goat and sheep is 2.3–2.62, 1.97 to 2.066 mg/L correspondingly. These values are within the acceptable values as set by the WHO (Khan *et al.*2019). Aim of present study was to investigate the concentration of cadmium in soil and transfer of cadmium in soil-plant-animal systems

Materials And Methods

Location

The study area Faisalabad district is an area of Punjab, Pakistan. This is a industrial area where most of the crops are grown in wastewater. Different fodder crops and forages are being cultivated in a wastewater directly or indirectly. This city of Pakistan is well-known for its industrial activities are contributing to the economy of country as well as to the growing pollution in the region. High traffic are being observed in this city which is largely due to the population explosion which is ultimately increasing demand for food. Conferring to the 1998 survey of Pakistan. Faisalabad is the 3rd biggest city of Pakistan after Karachi and Lahore. Faisalabad ranges above an area of 5856 Square kilometers comprehending of subsequent eight tehsils. The specimens of available soil, forages, fodder crops and blood of animals are collected from three different sites of GW I Chak Jhumra, CW II Jaranwala, MWW III Jaranwala of District Faisalabad. Three replicates of sample are collected from each site. Sampling was done in Aug-2019 to May 2020.

Climate

Regular yearly precipitation is around 615 millimeters (24.2 in).Summer season is hot and dry but during the month of July and August monsoon season brings rainfall. Monsoon season ends in September passes precipitation beginning loud overflowing. July is the rainiest duration yearly result in flood. winter season brings considerable rainfall accompanying with hail**.**

Vegetation

District Faisalabad is primarily urban area with industrial and agricultural activities. Along with the large production of vegetables food crops are also cultivated to fulfill the feeding requirements of livestock as well as human beings. These crops includes kharif crops and Rabi crops **Kharif Fodder Crops** Guar maize, sorghum S.S. Hybrid, millet etc **Rabi Fodder Crops berseem** Lucerne mustard Rape & Mustard. Major fruit production includes citrus, guava and mangoes

Collection of sample

Forage samples

samples of four forages have been collected. This specimens selection ware executed in five duplicates of every specimen for each place. Samples of Berseem, Brassica, sugar beet, sugar cane have been collected from the roadsides of each site. Samples of forages have been exposed to dry in the air and in oven at 75°C for week. When sample was completely dried this was subjected to grind into powder form and 2g sample was taken for further digestion process.

Table:1 List of studied forages

Sr. No	Botanical name	Common name
1	*Beta vulgaris*	Chokandar
2	*Brassica campestris*	Mustard or SAAG
3	*Trifolium alexandrinum*	Barseem
4	*Saccharin officinarum*	Sugarcane

Soil Samples

1kg soil sample were collected along with forages about 30 soil sample were collected. Soil sample were weighed in order to check the moisture content then soil sample were air dried for 24 hours then these sample were further dehydrated in microwave to remove moisture content was removed from the soil. Then these samples have been beaten using pestle mortar and about 2g of every sample used to be saved for the in addition technique after sieving of all samples.

Water samples

Water which is supplied to the relevant fodder collected were also taken in 1Litre bottles from each site. 5ml were stored for additional digestion

Apparatus and chemical

Gloves, hotplate, four beakers 100ml and 250ml, two hydrogen peroxide(H_2O_2) 50%, filter paper, two digestion flasks of 100 ml, Sulphuric acid 2ml, Tripod stands, stirrer, freshly prepared distilled water, 50ml measuring cylinder and small plastic bottles.

Dry digestion

Dry digestion was carried out in order to decompose all the natural rely in the samples of forage and soil. Principally made to obtain:

- Thorough disintegration of biological environment
- Avoiding impurity
- A whole solution of matrix (Jones, 1984)

Weighing each crucible

Before performing dry digestion each crucible were weighted and noted by using weigh balance.

Forage

Forage (5g) were added in each crucible and again weight of crucible+ forage noted. It was heated until the formation of ash and then after drying this ash is kept for 24 hours. Ash weighted again and dissolve in 50ml water and kept it for metal analysis.

Soil

Soil (5g) added in digestion chamber along with 2ml sulfuric acid.Entire concentration of toxic minerals in soil has been investigated afterward the digestion. About 2.5ml of nitric acid, 0.5ml 30% hydrogen peroxide and 7.5ml of hydrochloric acid have been used (Kilburn, 2000).

Water

Few drops of sulfuric acid were added in beaker containing 5ml of water and boil it until the appearance of smoke then 2ml of hydrogen peroxide was added process was repeated until and unless water becomes clear by using filter paper water was filtered and filled in a bottle.

Dilution and filtration

All the digested samples have been diluted via freshly prepared distilled water making their extent up to 50ml. The dilution of the samples used to be followed through their filtration and labeling. All the samples have been then saved in plastic bottles

Metal analysis

All the processed samples are then analyzed through Atomic Absorption Spectrophotometer to find heavy metal concentration in samples**.**

Statistical analysis

Data obtained from soil, forage, and blood samples were investigated and mean contents of heavy metals were present in each replicate. Variance and correlation were determined using SPSS Software and two way ANOVA.

Indices for pollution exposure assessment

Pollution load index

Pollution load index was calculated (Liu et al. 2005).

$$\textbf{PLI} = \frac{\text{Concentration of metal (mg/kg) in investigated soil}}{\text{Reference value of metal in soil}}$$

Bioconcentration factor

Bioconcentration factor (BCF) was used by Cui et al. 2004

$$\textbf{BCF soil-f orage} = \frac{\text{Concentrations of metals in forage}}{\text{Concentrations of metals in soil}}$$

$$\textbf{BCF forage-plasma} = \frac{\text{Concentrations of metals in plasma}}{\text{Concentrations of metals in forage}}$$

Enrichment factor (EF)

Enrichment factor is calculated by formula

$$\textbf{Enrichment factor (EF)} = \frac{\textbf{(Conc. of metal in plant/Conc. of metal in soil) sample}}{\textbf{(Conc. of metal in plant/Conc. of metal in soil) standard}}$$

Daily intake of metals

The formula to find the daily intake of metals (DIM) is:

$DIM = C_{metal} * D_{food\ intake} / B_{average\ weight}$

Health risk index.

Health risk index abbreviated as HRI and used to find out health risk associated with intake of contaminated forage. (Cui et al. 2004; USEPA 2002).

$HRI = DIM / R_f D$

DIM = Daily intake of heavy metal

$R_f D$ = Oral reference dose

Cadmium

Result of variance analysis indicated that there was significant effect on Cd concentration by site and non-significant effect at soil and site*soil. Analysis of variance for data of forages indicated that significant effect was showed on concentration of Cd at site, forages and site* forages. Analysis of variance of data Indicated Significant Effect on Cd concentration at site and animal*source while non-significant effect of metal in animal, source, site*animal, site*source, site*animal*source. Analysis of variance for data showed significant effect on cd concentration in water as presented in (Table 2).

Soil

Amount of cadmium diversified from to 0.80 to 1.93 mg/kg in soil samples collected from different sites. Greatest concentration was present in soil of *Trifolium alexandrinum* at site provided with municipal wastewater and lowest concentration was present in soil of *Saccharin officinarum at* site watered with ground water. (Table 3) (figure 2). Present value lower than the reference values given by EU, 2002 FAO/WHO, 2001 which is 3mg/kg.

Forages

The mean concentration of cadmium varied from 0.35 to 1.76 mg/kg in forages. Study indicates maximum level of metals was present in C. *album* which was initially provided with municipal wastewater. Minimum concentration was observed in *S. officinarum* (Table 3) (figure 3). Observed concentration of Cd is higher than Concentration given by FAO/WHO (2001) which is 0.2 mg/kg.

Animals

Result of Cd analysis in blood of animals showed values ranging from 0.864 to 1.98mg/L. Concentration of Cu was highest in blood of cow at CW II while blood of sheep at GW I Showed lowest Cd concentration. Result of hair analysis showed variation from 0.91 to 2.03mg/kg. Maximum values present in hair of Buffalo at canal watering site and minimum concentration observed in hair of Buffalo at Municipal wastewater irrigated site. Feces of animals had shown Cd values varying from 0.961 to 2.32mg/kg .Largest amount was observed in feces of sheep at canal water irrigated site and smallest values was found in feces cow at municipal wastewater irrigated site (Table 4)

Water

Heavy metal analysis showed result of concentration of Cd in ground water varied from 0.42-0.71 mg/L, while in canal water values varied from 1.06 to 1.29 mg/L. Municipal waste water showed values from 0.94 to 1.12 mg/L (Table 5) (fig 4)

Pollution load index (PLI), Bio-concentration factor (BCF), Enrichment factor (EF) of cadmium

Higher BCF value was found in *C .album at municipal waste water irrigated site while lower BCF value was observed in S. officinarum.* Pollution Load index varied from 0.286 to 0.689 mg/kg. Highest concentration was present in *T .alexandrinum and lowest concentration was observed in S. officinarum.* EF values ranged from 1.77 to 10.32 mg/kg. Maximum concentration was found in *C .album* at municipal wastewater irrigated site while minimum concentration was found in *S. officinarum* at municipal wastewater irrigated site (Table 6)

Daily intake of metal (DIM) and Health risk index (HRI)

Highest DIM of Cd was observed in sheep grazing at *C. album* while lowest DIM of metal was present in cow feeding on *T.alexandrinum.* Maximum HRI was observed in sheep eating *C. album* while minimum value was present in cow feeding *S. officinarum.* (Table 7)

Discussion

Nawab *et al.* (2015) noted that Cd concentration ranged from 0.5 to 8 mg kg^{-1} which is higher than our present concentration. Khan *et al*. (2013) studied the effect of wastewater irrigation in soil and reported Cd concentration 0.098–0.52mg/kg lower than those observed by present study. Faiz *et al*. (2009) observed Cd concentration in the soil ranged between 5.8–6.1 mg kg collected from Islamabad city higher than present study. Cd can be toxic for human if exposed for a longtime it can damage kidney. Similar result was found by Liang *et al.* (2012) that Cd concentrations surveyed in five sites was ranging from 0.90 to 1.76 mg/kg. Concentration of Cd revealed by current observation found higher than Iqbal *et al.* (2016). Karimi *et al.* (2020) reported higher concentration than current concentration. Similar result has been found by Yu *et al*. (2016) studied metal concentration in soil with sewage irrigation Different factor are responsible in transferring metal from soil to growing plants. Various researcher reported that availability of metal in soil effected by different factors for example PH, carbon content age of growing fodder crops etc. it is obvious that availability depends upon metal content in soil its PH and type of soil. (Yu *et al*., 2016 : Mapanda et *al*., 2005). Current values lower than values observed by Khan *et al*., (2015). Similar finding was observed by Ruchuwararak *et al.*(2019). Our value was greater than critical limit (1.1 mg/L) noted by FAO/WHO (1996). Current result of Cd illustrated higher than reported by Yu *et al.* (2016)Absorption of cd by forages is largely greater as compared to other metals higher concentration of Cd surpasses the permissible limit and considered harmful for humans (Li et al., 1994).Cd is easily absorbed by forages and its buildup in human beings results in damage to vital organs including liver, brain and heart.(Tataruch and Kierdorf 2003).Khan *et al*. (2015) observed 2.15 to 9.50mg/kg in different forages irrigated with wastewater these values are higher than our values. Okareh and Oladipo (2015) reported concentration of Cd in blood ranged from0.01 6.11 mg/L which was higher than current concentration. Present concentration were found above the critical limit which is 0.1 mg /L (WHO 1983) Present study reported larger content than those informed by Gowda *et al.*(2003).Ubwa *et al*. (2017) reported lower concentration of cd in blood than present observed concentration. Reason of different concentration of Cd in blood of animals was due to Grazing of animals on contaminated area and drink contaminated water originated from different sources for example river, streams and ponds similar result was reported by Nwude *et al.*(2010). Present content of Cd was higher than critical limit of Cd in blood of animals 0.5 mg/L as observed by WHO (2000). (Krupa *et al*., 2006: Cygan-Szczegielniak *et al*., 2014 : Gabryszuk *et al*.,2008:Su *et al*., 2017) reported lower concentration of Cd in hair of animals than current observed concentration. Yang *et al.*(2017) studied cd content in feces of animals ranged from 0.01–8.7mg/kg. Sharma *et al*. (2006) suggested values of Cd in water varied from 0.02- 0.04mg/L while Ahmed *et al*.

(2010) noted values ranged from 0.02 to 0.08mg/L both of the findings were Found lower than current observed concentration of Cd in irrigation water while safe limit of Cd in water was reported 0.01mg/L (Pescod ,1992) our concentration of Cd surpass this concentration. Alrawiq *et al.*(2014) reported BCF values varied from 0.221–0.490 mg/kg lower than present study. Liu *et al.*(2005) reported that BCF > 1 indicates that metal is present. Rabee *et al.*(2011) studied greater PLI concentration than present observed concentration. Pollution load index is measurement tool to assess the heavy metal pollution. PLI greater than 1 indicate contamination by metal but PLI less than 1 showed metal is not causing pollution.(Chakravarty and Patgiri 2009) .Enrichment Factor varied from 44.3-102mg/kg showed very high enrichment of metal reported by suzuk *et al.*(2009) Which is higher than our value.

Conclusion

Heavy metal pollution becomes serious concern now a days.in this research heavy metals analysis of soil, forages and animals indicated higher concentration of cadmium in forages than allowable limit. Cadmium concentration in blood of animals was higher than critical limit.so consumption of such forages may not safe for animals grazing on it however further investigation on contamination of other forages is necessary.

Declarations

Ethics declarations

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical approval: The authors declare that the manuscript has not been published previously.

Consent to participate: All authors voluntarily to participate in this research study.

Consent to publish: All authors consent to the publication of the manuscript.

Availability of data and materials: All data generated or ana-lyzed during this study are included in this published article.

Contributions: RS and AA were responsible for writing the manuscript. KA and ZIK supervised the study. Ayesha maqsood, Mudasra Munir, Ifra Malik ,Sonaina Nazar, Mehwish amjad,Shahzad Akhtar and Muhammad Nadeem was responsible for conducting the experiments and the data analysis. Tasneem Ahmed, Fu chen, jing Ma and ilker ugulu helped in proof reading of Manuscript.

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Tables 2-8

Table: 2 Analysis of variance of data for cadmium in soil, forages and animals treated with Ground, canal and municipal wastewater

Source	Degree of freedom	Mean Square
Site	2	2.021***
Soil	4	0.343^{ns}
Site * Soil	8	0.197^{ns}
Forages		
Site	3	1.572***
Forage	4	0.435*
Site * Forage	12	0.586***
Animals		
Site	2	7.471***
Animal	2	1.576^{ns}
Source	2	1.244^{ns}
Site * Animal	4	0.583^{ns}
Site * Source	4	0.818^{ns}
Animal * Source	4	2.785***
Site * Animal * Source	8	0.779^{ns}
Water		
Between Groups	2	0.284**
Within Groups	6	0.015

Table: 3 Concentration of Cadmium (mg/kg) in collected soil and forage sample (Mean± S.E)

Sites		FORAGE			SOIL		
		GWI-I	CWI-II	MWW-III	GWI-I	CWI-II	MWW-III
Soil of	*B. vulgaris*	0.62±0.25	0.73±0.08	0.90±0.07	0.817±0.05	1.03±0.11	0.850±0.16
Soil of	*B. campestris*	0.503±0.06	1.39±0.19	1.45±0.16	0.830±0.09	1.79±0.23	1.36±0.10
Soil of	*T .alexandrinum*	0.393±0.05	1.35±0.41	1.68±0.65	0.833±0.09	1.43±0.23	1.93±0.49
Soil of	*S. officinarum*	0.68±0.12	0.66±0.20	0.35±0.068	0.797±0.16	1.59±0.32	1.46±0.40
Soil of	C .album	0.49±0.01	1.15±0.14	1.76±0.30	0.830±0.08	1.75±0.27	1.27±0.26

Table: 4 Concentration of Cadmium mg/kg in animals (Mean+ S.E)

Sources	Animals	Study sites		
		GW I	CW II	MWW III
Blood	**Cow**	1.39±0.27	1.98±0.35	1.66±0.28
	Buffalo	1.26±0.18	1.45±0.21	1.03±0.11
	Sheep	0.864±0.05	1.48±0.26	1.05±0.19
Hair	**Cow**	1.30±0.23	1.96±0.39	1.33±0.22
	Buffalo	1.21±0.19	2.03±0.35	0.91±0.13
	Sheep	2.025±0.18	1.98±0.360	1.10±0.12
Feces	**Cow**	1.19±0.25	1.06±0.27	0.961±0.20
	Buffalo	1.21±0.19	1.19±0.26	1.141±0.15
	Sheep	1.75±0.20	2.32±0.32	1.14±0.25

Table: 5 Concentration of cadmium mg/kg in collected water sample (Mean ± S.E).

Sources	Mean S.E	Minimum	Maximum
GW I	0.583 0.08	0.42	0.71
CW II	1.16 0.06	1.06	1.29
MWW III	1.057 0.05	0.94	1.12

Table: 6 pollution load index, Bioconcentration factor and Enrichment factor for cadmium from soil to Forage

Forages	EF			PLI			BCF		
	GW I	CW II	MWW III	GW I	CW II	MWW III	GW I	CW II	MWW III
B. vulgaris	5.654	5.280	7.862	0.292	0.368	0.304	0.756	0.709	1.055
B. campestris	4.515	5.785	7.959	0.296	0.639	0.486	0.606	0.777	1.068
T.alexandrinum	3.515	7.033	6.484	0.298	0.511	0.689	0.468	0.944	0.870
S. officinarum	6.356	3.107	1.77	0.285	0.568	0.521	0.850	0.417	0.238
C. album	4.398	4.895	10.32	0.294	0.625	0.454	0.598	0.657	1.386

Table: 7 Daily intake of cadmium by animals via intake of contaminated forages.

Forages	Cow			Buffalo			Sheep		
B. vulgaris	0.00105	0.00124	0.0015	0.00119	0.0014	0.00173	0.00913	0.0107	0.0132
B. campestris	0.00085	0.0023	0.0024	0.00097	0.00268	0.0028	0.00741	0.0204	0.0213
T.alexandrinum	0.00066	0.0022	0.0028	0.00075	0.0026	0.00324	0.0057	0.019	0.0247
S. officinarum	0.00115	0.0011	0.00058	0.0013	0.00128	0.00067	0.01001	0.0097	0.0051
C. album	0.00083	0.00195	0.0029	0.00094	0.00222	0.0034	0.0072	0.0169	0.025

Table: 8

Table 8: Health risk index of cadmium for animals via intake of contaminated forages

Cd	Cow			Buffalo			Sheep		
B. vulgaris	1.05	1.24	1.52	1.19	1.41	1.73	9.13	10.76	13.22
B. campestris	0.855	2.36	2.47	0.972	2.69	2.80	7.41	20.48	21.36
T.alexandrinum	0.668	2.29	2.86	0.759	2.61	3.25	5.79	19.89	24.75
S. officinarum	1.16	1.13	0.589	1.31	1.28	0.669	10.01	9.77	5.11
C. album	0.833	1.95	2.99	0.947	2.22	3.40	7.22	16.94	25.93

Figures

Figure 1

Map of study area.

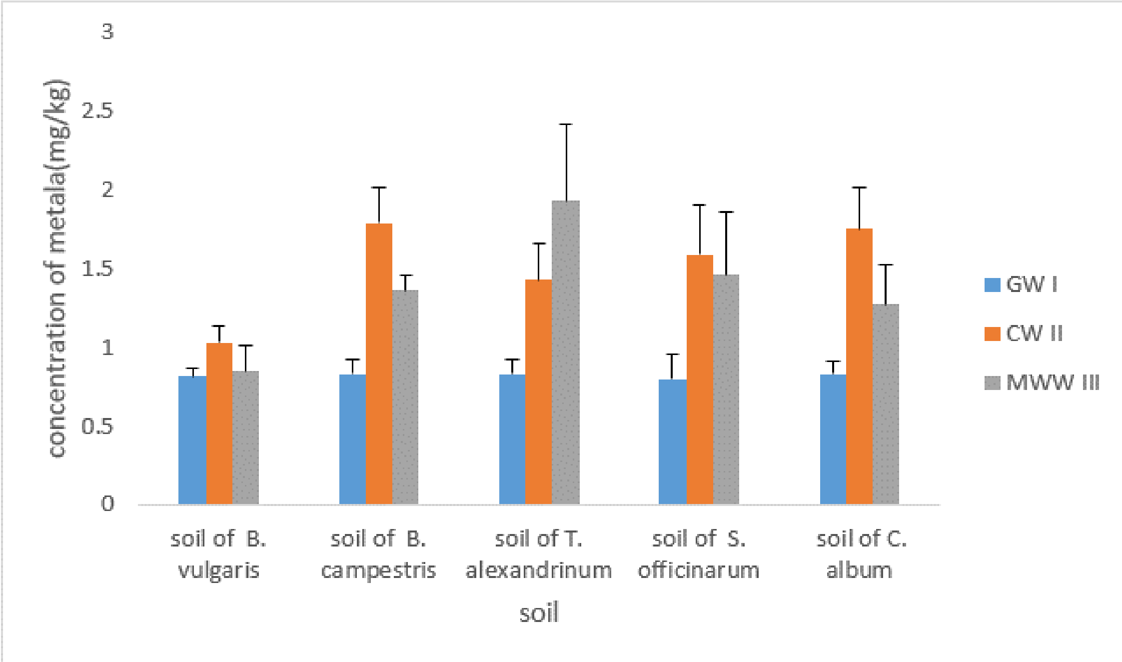

Figure 2

Fluctuation in level of cadmium in soil treated with Ground, canal and municipal wastewater

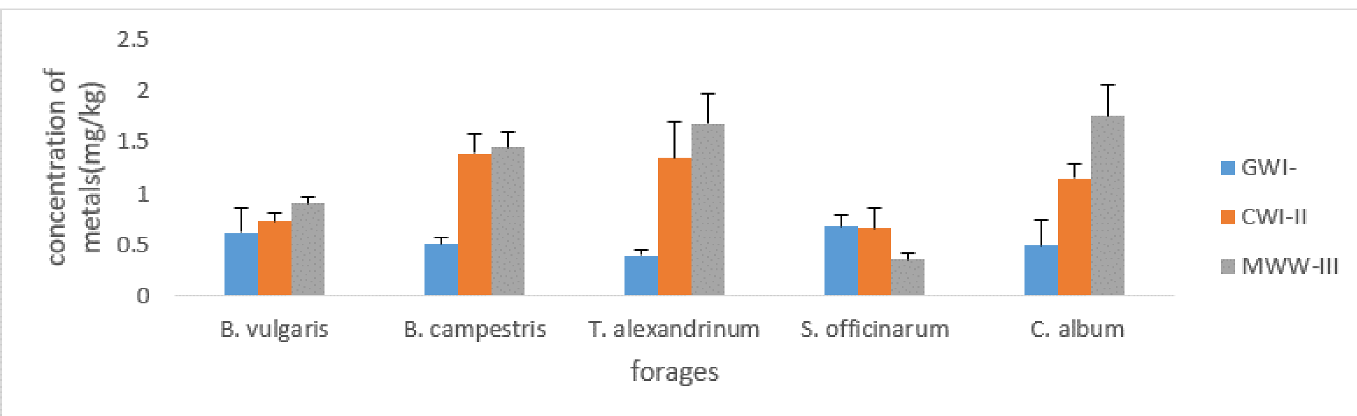

Figure 3

Fluctuation in level of cadmium in forages

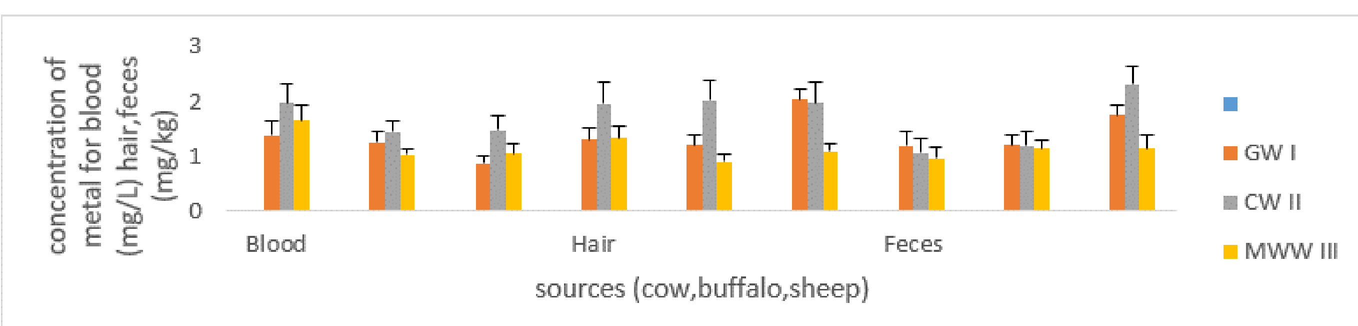

Figure 4

Fluctuation in level of cadmium in animals