Journal of Animal & Plant Sciences, 32(5): 2022, Page: 1460-1468
ISSN (print): 1018-7081; ISSN (online): 2309-8694
https://doi.org/10.36899/JAPS.2022.5.0552

ESTIMATION OF METAL CONTENT IN AVIAN FAUNA OF SIALKOT, PAKISTAN USING FEATHERS AS BIO-INDICATOR

A. Shehzad[1], K. M. Anjum[1*], A. Yaqub[2], S. Zahid[3], M. Z. Yousaf[4], N. Khan[5], M. Yaseen[6], and A. Habib[1]

[1]Department of Wildlife and Ecology, University of Veterinary and Animal Sciences, Lahore, Pakistan
[2]Departement of Zoology, Government College University, Lahore, Pakistan
[3]Department of Biology, Faculty of Science & Technology, Virtual University of Pakistan, Lahore, Pakistan
[4]KAM, School of Life Sciences, Forman Christian College, A Chartered University Lahore, Pakistan
[5]Institute of Zoology, University of the Punjab, Lahore, Pakistan
[6]Department of Chemistry, Division of Science and Technology, University of Education, Lahore, Pakistan
*Corresponding author: khalid.mahmood@uvas.edu.pk

ABSTRACT

The intent of the present study was to determine the concentrations of metal content in feather samples of different avian species collected from different areas of Sialkot, Pakistan. For this purpose atomic absorption spectrophotometer was used to estimation the metals concentration. The estimated concentration (µg/g) of these metals were 104.89±22.39, 23.19±1.23, 15.68±3.50, 10.18±2.47, 5.38±1.50, 1.52±0.02 for Zinc> lead> chromium> copper> nickel> cadmium respectively. The concentration of cadmium was found to be lower than the threshold level. However, continuous exposer to metals may result in the bio-magnification of metals in body especially in soft tissues such as liver, kidneys which is harmful for avian fauna. The concentrations of lead and chromium in the feather samples were found to be more than the approved /required levels of these minerals may be the one reason for the decline of avian fauna in study area. The main sources of metal pollution are the tanneries and surgical industries in study area as these industries use lead, chromium and zinc salts extensively. Most of these industries dispose of their untreated waste water in the naturel water resources such as in river and canals threatening to the aquatic flora and fauna. Results of the present study revealed that feathers may be used as bio-indicator for estimation of environmental pollution. The findings will also highlight the threats to the ecology and diversified avian fauna of the study area.

Keywords; Avian fauna, Bio-indicator, Environmental pollution, Feathers, Metal contents.

Published first online April 30, 2022 Published final October 05, 2022

INTRODUCTION

Metals having density greater than 5 g/cm^3 and atomic number greater than 20 are known as heavy metals. Metals and metalloids contaminations may have harmful impacts on ecology and living organisms of that ecosystem. Metals are classified according to their density, relative atomic mass and atomic number (Ali and Khan 2018). As these heavy metals [Mercury (Hg), Chromium (Cr), Cobalt (Co), Copper (Cu), Selenium (Se), Zinc (Zn), Arsenic (As), Manganese (Mn)] can enter in to the food chain, thus, a continuous accumulation of these metals may cause bio-magnification. These heavy metals are reported to reduce the reproductive performance in birds (Abdullah *et al.* 2015). Although these metals are required in trace amount for the normal physiological functions and development, however a concentrations more than threshold level is toxic to fauna and flora (Einoder *et al.* 2018).

Due to their non-biodegradable nature and long half-lives these metals are serious threats to living organisms and have been led to the extinction of various wild species (Ullah *et al.* 2014). Findings reveal that heavy metals may accumulate in various body parts of the organism, particularly in the hairs, bones, eggs, liver, blood, kidney and plumes (Einoder *et al.* 2018). Metals are major anthropogenic source of pollution in industrial areas which routinely affect our food web (Einoder *et al.* 2018). The bioaccumulation of metals occurs if the uptake of metals is increased (Eagles-Smith *et al.* 2016; Altaf *et al.* 2014). Raised concentration of metals has caused many health related problems in birds e.g. deterioration of eggshell quality, reduction in reproductive performance, and immunosuppression thus rendering a serious threat to avian population. Morphometric parameters, for example, the weight; bone structure and wing length are directly affected by the accumulation of metals in the body of bird (Sharma and Vashishat 2017).

Just only the analysis of metallic contaminants in the soil, air and water do not provide sufficient information about the harmful aspects of these metals on the living organisms because the avian species feed on a wide range of varying diets. Thus estimation of metals level in birds may give better information about the ecological risks to the flora and fauna of the study area (Zarrintab *et al.* 2016). Avian fauna is best to be chosen as an ideal bio-indicators of an area because the ideal bio-indicators must be widely distributed and easy to capture, territory size should be well defined, individual size should be large if the organs are used for assessments, the biology of individual should be well known and the breading of species should be possible in captivity (Aazami and KianiMehr 2018). The delicate tissues (liver, kidney, spleen, heart, and lung etc.) are comprehensively used to investigate the accumulation of various metals from the ecosystem. Further, the accumulation of a metal by different organs of the same organism varies from organ to organ so it is necessary to estimate the level of metals in the different organs of the organism for the better evaluation (Wei and Ma 2011).

Feathers receive the metals from the circulatory system or from the food sources that they currently used as feed during the development of plumes. Feathers are associated with the circulatory system through the veins, and the metals can bind with molecules of protein in the feathers (Manjula *et al.* 2015). Avian quills can be used as bio-indicators for the assessment of metal contamination level. The level of these metals is greater in plumes (avian species discharge significant measures of metals through plume shed) than in other tissues, and consequently simpler to collect and evaluate for the estimation of metals contamination level (Abdullah *et al.* 2015).

Like other developing countries Pakistan is also under development and facing the issue of industrialization, urbanization, and over-population (Qureshi *et al.* 2015). There are various threats to the diversity of avian species among these; increase in cultivation of land; illegal hunting, loss of natural habitat and aquatic pollution (Altaf *et al.* 2013). Industrial wastewater hold many poisonous metals that continuously enter in the water ecosystem posing threats to life (Qadir and Malik 2009; Hashmi *et al.* 2013) and these metals may be carcinogenic, mutagenic and teratogen (Allen 1994; Alloway 2013).

Sialkot is known worldwide for its sports products, surgical and tanning industry. The tanning industry produces waste water containing more than 17 different types of lethal chemicals and metals used in leather industry (Iqbal *et al.* 1998). According to Mahmood and Malik (2014), Sialkot generated nineteen million cubic meter waste water every year and the production of waste water is continuously increasing due to the establishment of heavy industry in the area. Most of the industries have no waste water treatment system, so the contaminated water is thrown untreated in natural water bodies posing serious life threats to aquaculture and avian species. In the present study, the levels of (Cr, Ni, Cu, Zn, Cd and Pb) were investigated in various bird species of Sialkot by using bird's feathers as bio-indicator. Results of the current study will be helpful for management, protection and improvement of avian fauna and environment of the study area.

MATERIALS AND METHODS

Study Area: Feather samples from birds were collected from different sites of Sialkot, Pakistan as shown in Fig1. The GPS coordinates of sampling sites are given in Table 1.

Sampling: Birds were captured by using mist net with mesh size of 30-38 mm (Gushit *et al.* 2016). Mist net was placed randomly to capture the birds in the morning at varying time from 5am- 11am. Mist net was checked after every 15-20 minutes to prevent the captured bird from stress. Feather samples of 48 birds (n=48) belong to 18 different species were collected from different areas of Sialkot (see Table 1 and Figure 1). The captured birds were immediately released after taking feather samples. The feather samples were collected in plastic bags and shifted to the lab of the Department of Wildlife and Ecology, University of Veterinary and Animal Sciences Lahore-Pakistan and stored at -20 C in refrigerator as described by Abdullah *et al*. (2015).

Metal analysis: Metal (Cr, Ni, Cu, Zn, Cd and Pb) concentration was analyzed in the feather samples. The feather samples were washed with tap water first then cleaned with distilled water and 1 M acetone (3 times) for the removal of any external contaminants. Samples were air dried and then in an oven for 2-3 hours at 105 $^{\circ}$C. Then feathers were cut into small pieces by using stainless steel scissor to allow easy digestion. 0.5g of feather sample was transferred into quartz crucibles and 0.25 ml of $HClO_4$ and 1.0 ml of HNO_3 were added into the crucible, which were covered with lid. The digestion of samples were performed by using a hot plate, initially at low temperature and then on high temperature. The digestion of samples was continuing until the mixture become pale yellow. Completely digested samples were filtered and diluted with 50ml of distilled water and stored in sample bottles (Nighat *et al.* 2013). The analyses of metal contents in digested samples were performed as described by Gushit *et al.,* (2016).

Statistical Analysis: Descriptive statistical analysis was used for the analysis of data. The data were analyzed by one way analysis of variance (ANOVA) using the SAS (SAS 9.3 2011). A post hoc Tucky test was used to compare differences among individual means. $P < 0.05$ was considered statistically significant.

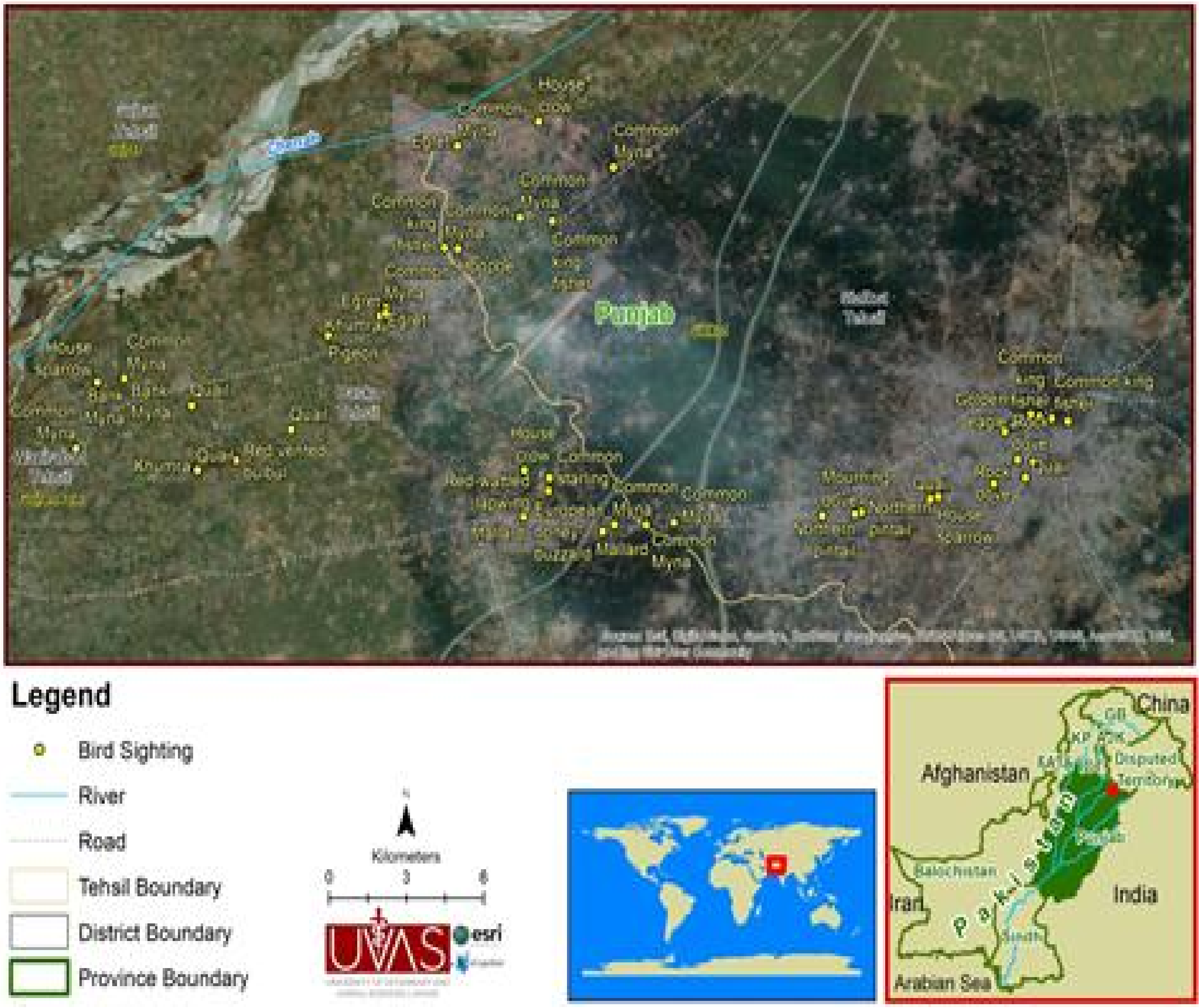

Fig 1. Sites from where feather samples were collected for estimation of metal contents (study area).

Table 1. Table shows the sampling of birds from various areas of Sialkot and their respective GPS location.

No.	Common name	Scientific name	Sample quantity	Longitude	Latitude
1	Common Myna	*Acridotheres tristis*	10	E074°18.458	N32°32.523
				E074°21.263	N32°34.123
				E074°23.221	N32°35.017
				E074°19.952	N32°35.394
				E074°19.676	N32°33.592
				E074°11.960	N32°30.045
				E074°12.971	N32°31.284
				E074°23.242’	N32°28.697’
				E074°23.908’	N32°28.692’
				E074°24.485’	N32°28.731’
2	Common king fisher	*Alcedo atthis*	4	E074°19.676	N32°33.592
				E074°21.938	N32°34.065
				E074°32.395’	N32°30.577’
				E074°32.153’	N32°30.611’
3	Egret	*Ardea alba*	3	E074°19.952	N32°35.394
				E074°18.337	N32°32.392

4	Quail	*Coturnix*	5	E074^{O}18.452 E074^{O}14.505 E074^{O}16.466 E074^{O}14.387 E074º31.853' E074º29.852'	N32^{O}32.430 N32^{O}29.652 N32^{O}30.376 N32^{O}30.804 N32º29.528' N32º29.146'
5	Bank Myna	*Acridotheres ginginianus*	2	E074^{O}12.971 E074^{O}12.971	N32^{O}31.284 N32^{O}31.284
6	House sparrow	*Passer domesticus*	2	E074^{O}12.415 E074º30.025'	N32^{O}31.218 N32º29.188'
7	Red vented bulbul	*Pycnonotus cafer*	1	E074^{O}15.315	N32^{O}29.834
8	Pigeon	*Columba livia*	1	E074^{O}17.243	N32^{O}32.038
9	House crow	*Corvus splendens*	2	E074^{O}21.653 E074º21.358'	N32^{O}35.828 N32º29.653'
10	Hoopoe	*Upupa*	1	E074^{O}19.956	N32^{O}33.575
11	Khumra		2	E074^{O}18.450 E074^{O}14.505	N32^{O}32.428 N32^{O}29.652
12	Red-wattled lapwing	*Vaneius indicus*	1	E074º21.628'	N32º29.053'
13	Mourning dove	*Zenaida macroura*	2	E074º27.595' E074º31.187'	N32º28.854' N32º29.418'
14	European honey buzzard	*Pernis apivou*	2	E074º32.015' E074º21.861'	N32º29.799' N32º29.290'
15	Common starling	*Strunus vulgaris*	2	E074º32.744' E074º21.880'	N32º30.521' N32º29.524'
16	Golden eagle	*Aquilla Chrysaetos*	2	E074º31.964' E074º31.622'	N32º30.650' N32º30.450'
17	Rock dove	*Columba livia*	2	E074º31.415' E074º31.686'	N32º30.340' N32º29.848'
18	Northern pintail	*13.Anas acuta*	2	E074º28.409' E074º28.280'	N32º28.915' N32º28.878'
19	Mallard	*Anas platyrhynchos*	2	E074º22.995' E074º21.333'	N32º28.570' N32º28.845'

RESULTS AND DISCUSSIONS

The findings of the current study about the concentrations of various metal contents in avian feathers are presented in Table 2. The results of the present study revealed that concentration of heavy metals in feathers samples of various species of birds were found in the folowing order, Zn> Pb> Cr> Cu> Ni> Cd measuring the concentration (µg/g) 104.89±22.39, 23.19±1.23, 15.68±3.50, 10.18±2.47, 5.38±1.50 and 1.52±0.02 respectively. These findings are comparable with the concentrarions of metal contents in avian feathers reported by various researchers from different parts of world (Table 3) and from various parts of Punjab, Pakistan (Table 4 and Figure 2).

Nickel: The concentration of nickel (Ni) reported in the avian feathers samples during this study was 5.38±1.50 µg/g. There are evidences that a high level of accumulated Ni in birds is toxic. According to Outridge and Scheuhammer (1993), if newly hatched chicken is fed with diet containing Ni over 300µg/g, may lead to reduction in growth and death of the chicks. The birds present in uncontaminated environment usually contain nickel in range of 0.1-5µg/g dry body weight while the birds inhabiting in polluted environment may accumulate nickel from 0.5-80µg/g dry weight. Further the high intake of nickel may lead to respiratory disorders, birth defects, and denaturing of DNA etc. (Van Wyk *et al.* 2001). The continuous exposure of nickel is also the one reason of many allergic reactions to human (Wilbur *et al.* 2008). The industries of oil and ghee are the major source of Ni in Sialkot (Qadir *et al.* 2008). The results of the present study revealed that the concentration of nickel in the feather samples were below than the reported level of Abdullah *et al.* (2015) from Lahore (41.7 µg/g) and Nighat *et al.* (2013) from Southern Punjab (153.4 µg/g), Central Punjab (90.3 µg/g) and Northern Punjab (42.4 µg/g). The present study reported a slightly high concentration of nickel in avian feather samples in comparison to those reported by Malik and Zeb (2009) from Chenab river (9 µg/g), Ravi river (8.1 µg/g) and Raval lake (7.8 µg/g) while greater than reported by Ullah *et al.* (2014) from Trimum headworks (0.1 µg/g), Shorkot (0.2 µg/g) and Mailsi (0.2 µg/g) in avian feathers.

Table 2. Table shows the concentration of metal contents (µg/g) in avian feathers.

Sr.No	Metals	Conc. (mean ± SE)
1	Nickel (Ni)	5.38±1.50
2	Lead (Pb)	23.19±1.23
3	Zinc (Zn)	104.89±22.39
4	Cadmium (Cd)	1.52±0.02
5	Chromium (Cr)	15.68±3.50
6	Copper (Cu)	10.18±2.47

Table 3. Table shows the concentration of various metal contents (µg/g) in avian feathers from present and previous international studies, a comparison.

Author	Study area	Ni	Pb	Zn	Cd	Cr	Cu
(Barbieri *et al.* 2010)	Pirajubaí, Santa Catarina	5.9	7.536	68.54	0.007	4.665	13.30
(Costa *et al.* 2011)	National Pine Forest of Quiaios)	0.78	2.35	109.78	0.12	-	11.00
	National Pine Forest of Urso)	2.15	4.89	140.10	0.38	-	10.43
(Mansouri *et al.* 2012)	Khuran, Iran	-	5.48	57.44	1.37	-	10.47
(Costa *et al.,* 2013)	Figueira da Foz (Portµgal) MQ	2.38	1.27	112.9	0.03	-	8.29
	Figueira da Foz (Portµgal)MU	2.24	1.29	111.0	0.03	-	9.11
(Lester and van Riper 2014)	Arizona's upper Santa Cruz River (NIWWTP)	-	-	201.97	0.728	-	11.619
	Arizona's upper Santa Cruz River (TUMA)	-	-	165.87	0.545	-	10.292
(Manjula *et al,* 2015)	Tiruchirappalli, India	6.11	-	71.60	1.70	55.48	86.9
(Zarrintab *et al.* 2016)	Aran-O-Bidgol City, Central Iran	-	9.26	167.16	1.583	-	26.74

Table 4. Table shows the concentration of various metal contents (µg/g) in avian feathers from present and previous studies from Pakistan.

Author	Study area	Ni	Pb	Zn	Cd	Cr	Cu
(Malik and Zeb 2009)	Chenab river	9	37.5	133.8	3.1	6.6	4
	Ravi river	8.1	76.5	155.8	2.4	7.1	3.7
	Rawal lake	7.8	60.2	138.2	2.7	5.4	4
(Nighat *et al.* 2013)	Southern	153.4	19.5	122.2	1.8	-	16.9
	Central	90.3	21	127.2	3.4	-	21.5
	Northern	42.4	18.6	158.5	1.1	-	16.8
(Ullah *et al.* 2014)	Trimum Headwork	0.1	30	18.5	3.3	26.2	0.9
	Shorkot	0.2	32.5	18.8	3	30.8	0.2
	Mailsi	0.2	43.1	10.7	1.7	35.8	0.2
(Abdullah *et al.* 2015)	Lahore	41.7	284	529.9	41.1	21.1	52.8
Present study	Sialkot	5.38	23.19	104.89	1.52	15.68	10.18

Zinc: zinc is an essential element that plays a significant role in different catabolic and anabolic processes. Zinc is obtained from both natural and anthropogenic sources and its concentration in avian fauna depends on the availability in the ecological or biological system (Morais *et al.* 2012; Ullah *et al.* 2014). According to the study of Abdullah *et al.* (2015) there are no harmfull effects for the accumulation of zinc in high concentration and in the current study the concentration of zinc reported in avian feathers was 104.89±22.39 µg/g.

The concentration of zinc in avian feathers reported in the current study are higher than the concentration of Zn reported by Ullah *et al.* (2014) in feather samples of birds from Trimum headwork (18.5µg/g), Shorkot (18.8 µg/g) and Mailsi (10.7 µg/g). The findings of current study revealed that the concentration of Zn in avian feathers samples are lower than the findings of Abdullah *et al.* (2015), Nighat *et al.* (2013) and Malik and Zeb (2009) as showen in Table 4. The results are also comparable with the findingd of several international researches in Table 3. According to Malik *et al.* (2010) different zinc salts such as zinc sulfate, zinc acetate and zinc chloride are used in leather industry are the major source of Zn contamination.

Lead: Lead is heaviest but non-radioactive element. The major sources of lead contamination are industries and vehicles. The industrial sewage containing salts of lead are drained in to natural water resources (Qadir and Malik 2011). In birds, the skeleton is the major storage site of lead and chromium. The abnormalities of reproductive system and body weight loss may occur in birds if exposed to high concentration of lead. Age and gender are associated with the accumulation of lead (Szefer and Falandysz 1986). Markowski *et al.* (2013) concluded that the accumulation of lead in female bones is higher than male bones, however the reason is unknown and needs to be investigated. According to the Trust *et al.* (1990) the number of white blood cells and immunity decrease in high lead-dosed Mallard ducks. The current study reported the concentration of lead in feathers is 23.19±1.23 µg/g that is greater than threshold level (4µg/g) possibly due to the heavy lead pollution from the study area (Gochfeld 2000). The current reported lead concentration in the avian feathers is below than the reported lead values of various scientists from Pakistan like Abdullah *et al.* (2015), Malik and Zeb (2009) and Ullah *et al.* (2014) as showen in Table 4. On the other hand the reported lead concentration is greater than the findings of Barbieri *et al.* (2010); Costa *et al.* (2011); Mansouri *et al.* (2012); Costa *et al.* (2013); Zarrintab *et al.* (2016) from various parts of the world (Table 3).

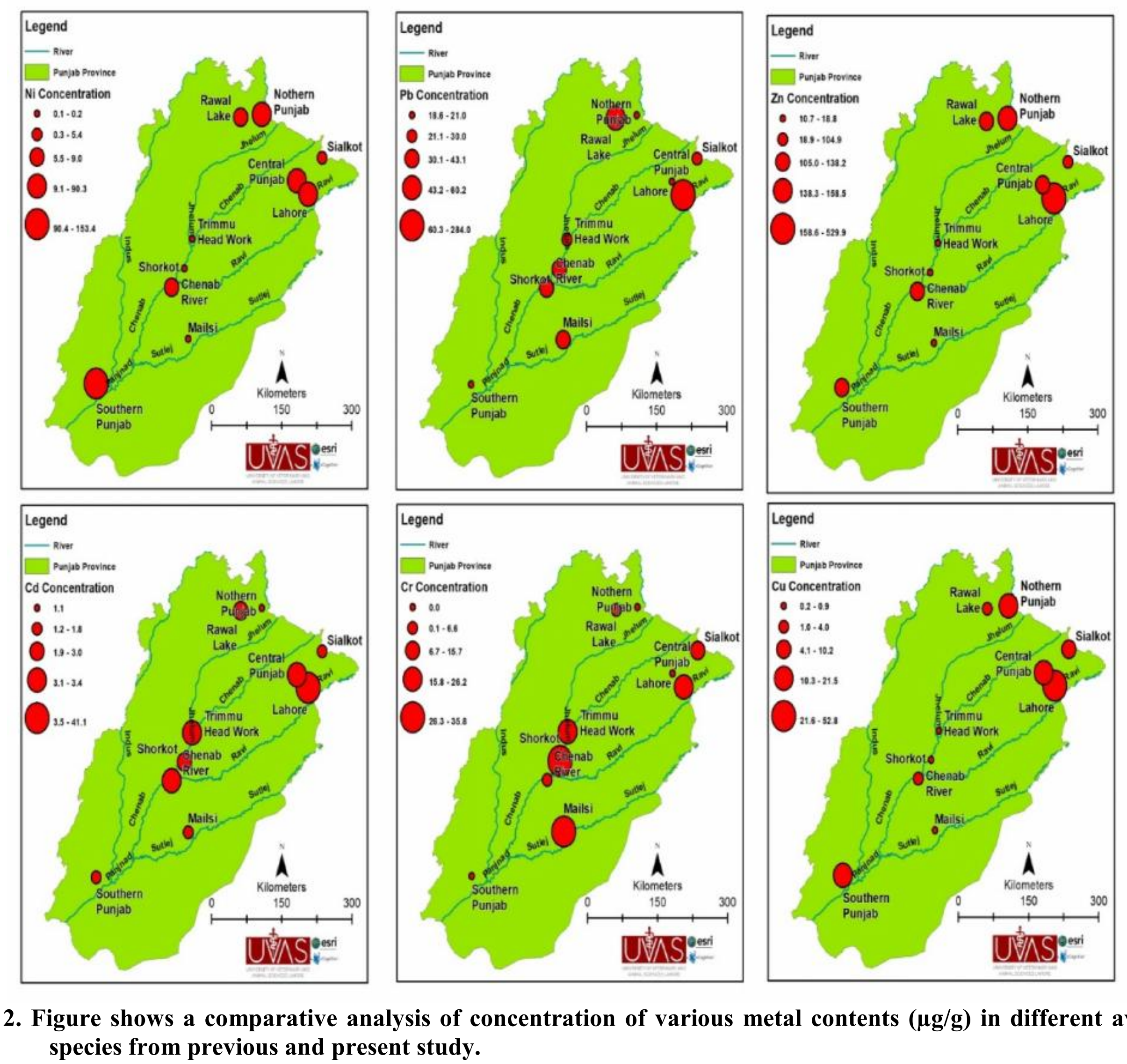

Fig 2. Figure shows a comparative analysis of concentration of various metal contents (µg/g) in different avian species from previous and present study.

Cadmium: Cadmium and its salts are more soluble making it more available to the living organisms. Once the cadmium contaminants enter in the body of organisms, it remains here for a very long period of time (half-life of 38 years). The cadmium contamination occurs through the use of various fertilizers and pesticides on crops (Qadir *et al.* 2000). Such crops are the major source of dissemination of Cd in living organisms. The coal combustion, iron and steel production, various industries (Cd batteries and paints etc.) and various pesticides are the major sources of Cd in air (Komarnicki 2005). It may affect the metabolic process by the replacement of essential elements so the exposure to cadmium may result the deficiency of essential elements (Abdullah *et al.* 2015). The concentration of cadmium in avian species in study area was 1.52±0.02 µg/g. The threshold limit for cadmium is considered as 2µg/g according to Gochfeld (2000). The reported cadmium concentrations in feather are lower than the values reported by Abdullah *et al.* (2015) from lahore (41.1 µg/g), Nighat *et al.* (2013) from central punjab (3.4 µg/g) and Ullah *et al.* (2014) from Trimium headworks and Mailsi (3.3 µg/g).

Chromium: Fertilizers, utensils, cigarette, cosmetics and jewelry are the major sources of chromium. Lungs, kidneys and hormones producing tissues are the target sites for accumulation of chromium (Malik and Zeb, 2009). Long term exposure of Chromium may result in reduction of body weight, liver damages, heart strokes, skin disease, cancer, headache and respiratory disorders are caused by the long term exposure to chromium (Gochfeld, 2000). The concentration of chromium reported in avian feathers is 15.68±3.50 µg/g which is greater than the findings of Malik and Zeb (2009) reported in the birds feathers from Chenab river (6.6 µg/g), Ravi river (7.1µg/g) and Rawal lake (5.4 50 µg/g). The major source of chromium contamination in the study area is use of chromium salts in leather industry and drainage of untreated water from these industries in the form of sewage and sludge (Qadir *et al.* 2008).

Copper: Copper is an essential element for some metabolic activities because it is the part of several enzymes such as tyrosinase, uricase, and cytochrome oxidase, which are mainly involved in oxidation reaction reactions (Turnlund, 1998), however long term exposer cause adverse effects on reproductive, respiratory and gastrointestinal system (Chen *et al.* 1993). The concentration of copper reported in the current study is 10.18±2.47 µg/g which is higher than the findings of Malik and Zeb (2009) and Ullah *et al.* (2014) but lower than the reported values by Abdullah *et al.* (2015) and Nighat *et al.* (2013) as showen in Table 4. Hematological, hepatic, endocrine and ocular defects may occur due to accumulation of copper in various body organs such as liver, brain, heart kidneys and skeletal muscles (Chen *et al.* 1993).

Conclusions: The feathers can be used as bio-indicators to assess the metal contamination level. Further, feathers are easy and safe to collect. The findings of the present study concluded that the metal contents reported in avian feathers are not at safe level which is a serious threats to the biodiversity as well as human being.

REFERENCES

Aazami, J. and N. KianiMehr (2018). Survey of heavy metals in internal tissues of Great cormorant collected from southern wetlands of Caspian Sea, Iran. Environ. Monit. Assess. 190(1): 52-59.

Abdullah, M., M. Fasola, A. Muhammad, S. A. Malik, N. Bostan, H. Bokhari, M. A. Kamran, M. N. Shafqat, A. Alamdar and M. Khan (2015). Avian feathers as a non-destructive bio-monitoring tool of trace metals signatures: a case study from severely contaminated areas. Chemospher. 119: 553-561.

Ali, H. and E. Khan (2018). What are heavy metals? Long-standing controversy over the scientific use of the term 'heavy metals'–proposal of a comprehensive definition. Toxcol. Environ. Chem. 100(1): 6-19.

Allen, P. (1994). Mercury accumulation profiles and their modification by interaction with cadmium and lead in the soft tissues of the cichlid *Oreochromis aureus* during chronic exposure. Bull. Environ. Contam. Toxicol. 53(5): 684–692.

Alloway, B. J. (2013). Sources of heavy metals and metalloids in soils. Heavy metals in soils, Springer**:** 11-50.

Altaf, M., A. Javid, M. Irfan, S. Ashraf, M. Umair, K. Iqbal, A. Khan and Z. Ali (2014). Diversity of wild mammalian fauna of Chenab riverine forest, Punjab, Pakistan. J. Anim. Plant Sci. 24: 1342-1347.

Altaf, M., A. Javid, M. A. Irfan, S. A. Munir, K. J. Iqbal and M. Umair (2013). Diversity, distribution and ecology of birds in summer season flathead Khanki, Punjab, Pakistan. Biologia (Pakistan). 59(1): 131-137.

Barbieri, E., E. de Andrade Passos, A. Filippini, I. S. dos Santos and C. A. B. Garcia (2010). Assessment of trace metal concentration in feathers of seabird (*Larus dominicanus*) sampled in the Florianópolis, SC, Brazilian coast. Environ. Monit. Assess. 169(1-4): 631-638.

Chen, R., L. Wei and H. Huang (1993). Mortality from lung cancer among copper miners. Occup. Environ. Med. 50(6): 505-509.

Costa, R., T. Eeva, C. Eira, J. Vaqueiro and J. Vingada (2013). Assessing heavy metal pollution using Great Tits (*Parus major*): feathers and excrements from nestlings and adults. Environ. Monit. Assess. 185(6): 5339-5344.

Costa, R., J. Petronilho, A. Soares and J. Vingada (2011). The use of passerine feathers to evaluate heavy metal pollution in central Portµgal. Bull. Environ. Contam. Toxicol. 86(3): 352-356.

Eagles-Smith, C. A., J. G. Wiener, C. S. Eckley, J. J. Willacker, D. C. Evers, M. Marvin-DiPasquale, D. Obrist, J. A. Fleck, G. R. Aiken and J. M. Lepak (2016). Mercury in western North America: A synthesis of environmental contamination, fluxes, bioaccumulation, and risk to fish and wildlife. Sci. Total Environ. 568: 1213-1226.

Einoder, L., C. MacLeod and C. Coµghanowr (2018). Metal and isotope analysis of bird feathers in a contaminated estuary reveals bioaccumulation, biomagnification, and potential toxic effects. Arch. Environ. Cont. Toxicol. 75(1): 96-110.

Gochfeld, J. B. Michael (2000). Effects of lead on birds (Laridae): a review of laboratory and field studies. J. Toxicol. Environ. Health B Crit. Rev. 3(2): 59-78.

Gushit, J., L. Turshak, A. Chaskda, B. Abba and U. Nwaeze (2016). Avian Feathers as Bioindicator of Heavy Metal Pollution in urban degraded woodland.

Hashmi, M. Z., R. N. Malik and M. Shahbaz (2013). Heavy metals in eggshells of cattle egret (*Bubulcus ibis*) and little egret (*Egretta garzetta*) from the Punjab province, Pakistan. Ecotoxicol. Environ. Safe. 89: 158-165.

Iqbal, M., I. Haque and J. Berns (1998). The Leather Sector, Environmental Report. Environmental Technology Programme For Industry (ETPI), Federation of Pakistan Chambers of Commerce and Industry, Federation House, Karachi, Pakistan.

Komarnicki, G. J. (2005). Lead and cadmium in indoor air and the urban environment. Environ. Pollut. 136: 47-61.

Lester, M. B. and C. van Riper (2014). The distribution and extent of heavy metal accumulation in song sparrows along Arizona's upper Santa Cruz River. Environ. Monit. Assess. 186(8): 4779-4791.

Mahmood, A. and R. N. Malik (2014). Human health risk assessment of heavy metals via consumption of contaminated vegetables collected from different irrigation sources in Lahore, Pakistan. Arabian J. Chem. 7(1): 91-99.

Malik, R. N., W. A. Jadoon and S. Z. Husain (2010). Metal contamination of surface soils of industrial city Sialkot, Pakistan: a multivariate and GIS approach. Environ. Geochem Health. 32(3): 179-191.

Malik, R. N. and N. Zeb (2009). Assessment of environmental contamination using feathers of *Bubulcus ibis L*., as a biomonitor of heavy metal pollution, Pakistan. Ecotoxicol. 18(5): 522-536.

Manjula, M., R. Mohanraj and M. P. Devi (2015). Biomonitoring of heavy metals in feathers of eleven common bird species in urban and rural environments of Tiruchirappalli, India. Environ. Monit. Assess. 187(5): 267.

Mansouri, B., H. Babaei and E. Hoshyari (2012). Heavy metal contamination in feathers of Western Reef Heron (*Egretta gularis*) and Siberian gull (*Larus heµglini*) from Hara biosphere reserve of Southern Iran. Environ. Monit. Assess. 184(10): 6139-6145.

Markowski, M., A. Kaliński, J. Skwarska, J. Wawrzyniak, M. Bańbura, J. Markowski, P. Zieliński and J. Bańbura (2013). Avian feathers as bioindicators of the exposure to heavy metal contamination of food. Bull. Environ. Contam. Toxicol. 91(3): 302-305.

Morais, S., F. G. Costa and M. d. L. Pereira (2012). Heavy metals and human health. Environ. Health–Emer. Issue. Practice. 10: 227-246.

Nighat, S., S. Iqbal, M. S. Nadeem, T. Mahmood and S. I. Shah (2013). Estimation of heavy metal residues from the feathers of *Falconidae*, *Accipitridae*, and *Strigidae* in Punjab, Pakistan. Turkish J. Zool. 37(4): 488-500.

Outridge, P. and A. Scheuhammer (1993). Bioaccumulation and toxicology of nickel: implications for wild mammals and birds. Environ. Rev. 1(2): 172-197.

Qadir, M., A. Ghafoor and G. Murtaza (2000). Cadmium concentration in vegetables grown on urban soils irrigated with untreated municipal sewage. Environ. Develop. Sustain. 2(1): 13-21.

Qadir, A. and R. N. Malik (2009). Assessment of an index of biological integrity (IBI) to quantify the quality of two tributaries of river Chenab, Sialkot, Pakistan. Hydrobiol. 621(1): 127-153.

Qadir, A. and R. N. Malik (2011). Heavy metals in eight edible fish species from two polluted tributaries (Aik and Palkhu) of the River Chenab, Pakistan. Biol. Trace Element Res. 143(3): 1524-1540.

Qadir, A., R. N. Malik and S. Z. Husain (2008). Spatio-temporal variations in water quality of Nullah Aik-tributary of the river Chenab, Pakistan. Environ. Monit. Assess. 140(1-3): 43-59.

Qureshi, I. Z., Z. Kashif, M. Z. Hashmi, X. Su, R. N. Malik, K. Ullah, J. Hu and M. Dawood (2015). Assessment of heavy metals and metalloids in tissues of two frog species: *Rana tigrina* and *Euphlyctis cyanophlyctis* from industrial city Sialkot, Pakistan. Environ. Sci. Pollution Res. 22(18): 14157-14168.

Sharma, C. and N. Vashishat (2017). Assessment of heavy metals in excreta of house crow (*Corvus* *splendens*) from different Agroecosystems of Ludhiana. J. Entomol. Zool. Stud. 5(4): 1891-1895.

Szefer, P. and J. Falandysz (1986). Trace metals in the bones of scaup ducks (*Aythya marila L*.) wintering in Gdańsk Bay, Baltic Sea, 1982–1983 and 1983–1984. Sci. Total Environ. 53(3): 193-199.

Trust, K. A., M. W. Miller, J. K. Ringelman and I. M. Orme (1990). Effects of ingested lead on antibody production in mallards (*Anas platyrhynchos*). J. Wildlife Dis. 26(3): 316-322.

Turnlund, J. R. (1998). Human whole-body copper metabolism. Am. J. Clin. Nutr. 67(5): 960S-964S.

Ullah, K., M. Z. Hashmi and R. N. Malik (2014). Heavy-metal levels in feathers of cattle egret and their surrounding environment: a case of the Punjab Province, Pakistan. Arch. Environ. Cont. Toxicol. 66(1): 139-153.

Van Wyk, E., F. Van der Bank, G. Verdoorn and D. Hofmann (2001). Selected mineral and heavy metal concentrations in blood and tissues of vultures in different regions of South Africa. South African J. Anim. Sci. 31(2): 57-64.

Wei Zhang, W. and J. Zhang Ma (2011). Waterbirds as bioindicators of wetland heavy metal pollution. Proc. Environ. Sci. 10: 2769-2774.

Wilbur, S., D. Wohlers, S. Paikoff, L. Keith and O. Faroon (2008). ATSDR evaluation of health effects of benzene and relevance to public health. Toxicol. Indust. Health. 24(5-6): 263-398.

Zarrintab, M., R. Mirzaei, G. Mostafaei, R. Dehghani and H. Akbari (2016). Concentrations of metals in feathers of magpie (*Pica pica*) from aran-O-bidgol city in central Iran. Bull. Environ. Contam. Toxicol. 96(4): 465-471.