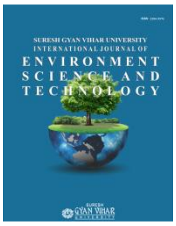

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Research article

Comparative Heavy Metal Profiling of Industrial and Rural areas: Using Bird's Fecal pellets as Biomonitor

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Trace metals,
Blue Rock pigeon,
industrial activities,
industrial region,
rural area,
metal pollution

Abstract

The buildout of industrial activity in the past few years has increased the metal pollution in this environment which threatens health of resident biological communities. In 2016-2017, intending to check the influence of different industrial activities in trace metals concentration (Cd, Cu, Cr, Ni, Pb and Zn) and their subsequent accumulation in birds, fecal samples of Blue Rock Pigeon (*Columba livia*) from seven different industrial regions (S1-S7) and rural sites (R1 and R2) in Jaipur and in its outskirts, Rajasthan, India. In general, between the two study sites, Industrial and Rural, the high concentrations of trace metal were recorded at former site. Further, results obtained in this study, as well as the comparison with literature data indicated that fecal samples from all industrial areas (S1-S7) have high concentration of Cr. Furthermore, Cd was high at Bias Godam (S1) and Sitapura (S6) industrial areas; Cu, Pb at Bias Godam (S1), Jhotwara (S2) and Sitapura (S6) industrial areas; Zn at Malviya (S3) and Sitapura (S6) industrial areas. This may indicate the influence of the urban-industrial anthropogenic activities on the deposition of heavy metals in the surrounding area. The results of this study will contribute to the environmental management of the Jaipur industrial areas.

Introduction

The hasty urbanization and industrialization has coaxed in increased deposition of contaminants like heavy metals, radioactive nuclide and numerous kinds of inorganic and organic substances into the surrounding environment. It is well acknowledged that pollution of the environment with heavy metals led to serious predicament due to their negative impact on all abiotic and biotic components of ecosystem. Usually, the most commonly encountered metals in polluted areas are Lead, Chromium, Mercury, Arsenic, Zinc, Cadmium, Copper and Nickel. Unfavourable consequences of environmental contamination with heavy metals are appearing more acutely in urbanized territories characterized with a high density of population and industrial enterprises.

Jaipur is urbanized territory of Rajasthan state in India, where many industrial areas have spring up during the last 20 years. Such areas include Bais Godown, Jhotwara, Malviya, Mansarover, Sanganer, Sitapura, Sudershanpura and Vishwakarma which contributed in creating caricature of industrial activity throughout the city. industrial areas consists of various types of industries including food based industries, beverages & tobacco based industry, leather based, rubber, plastic/ petro based, paper based, wooden based, mineral based, metal based, engineer and textiles units, electrical industry/machinery & appliances, misc. mfg. industries, transport & parts and service & repairing. In general, these industrial areas differ markedly in extent and type of industrial activities which are thought-out as main source of metal contamination in ambient environment. One of the most interesting studies carried out in this area by Singh and Chandel (2006) showed that wastewaters of the major industrial areas of Jaipur city consists high concentration of certain trace metals. Research suggests that risk heavy metal contamination is pronounced in the environment adjacent to large industrial complexes (Velea et al. 2009). Hence, it is important to investigate the level of heavy metals around these industries. On the other hand, most of industrial areas are not free from human residential localities and located within the city, so emission and abrasion from automobiles as well as urban activities may also be the source of trace metals in these areas. Therefore, Present study investigates the influence of different industrial activities in trace metals concentration (Cd, Cu, Cr, Ni, Pb and Zn) and their subsequent accumulation in birds by comparing metal concentrations between areas (Industrial vs. rural and rural R1 vs. rural R2).

Material and Methods

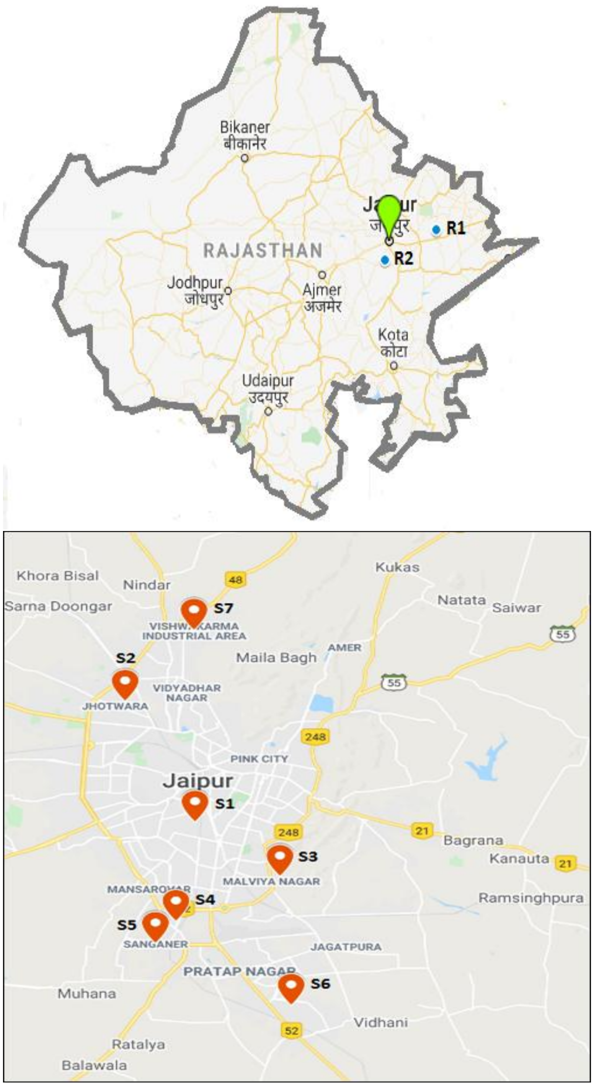
Data Source and methods

Present work took data on toxic metals in excrements of blue rock pigeon from seven industrial regions and two rural regions, of Jaipur, Rajasthan (Figure 1) i.e. Bais Godam, Jhotwara, Malviya, Mansarover, Sanganer, Sitapura, Vishwakarma, Chittora and Narayanpura recorded in our similar previous studies (Bala et al. 2017ab; 2020, 2021(under publication)) and pooled them as single value. Some of these industrial regions of part of Jaipur city (26.9124° N, 75.7873° E) and remaining lay its exterior. These industrial regions comprise production units for wires and cables, steel fabrication, paper, automobile, electronics, textile, pharma, wooden handicrafts, Gems & Jewellery, chemical and edible oils etc. Further, out of two rural sites, one is Chittora (26.6376° N, 75.7042° E) and other is Narayanpura (27.0608° N, 76.5672° E), located in Phagi Tehsil in Jaipur district, Rajasthan. As rural regions have direct contact with nature and are under minimal anthropogenic input. This gives a unique opportunity make comparison between industrial and rural regions and to determine the possible contamination, arising from different industrial activities. In present study, considered industrial and rural areas are allotted with site no; S1-Bais Godam, S2-Jhotwara, S3-Malviya, S4-Mansarover, S5-Sanganer, S6-Sitapura, S7-Vishwakarma, R1-Chittora and R2-Narayanpura.

In our previous studies which are considered in present work, dry fecal pellets were collected in month of January and February and in month of July and August in 2016 -2017. Samples were picked up from windows, rocky shelf or accessible ledge on building or in roof void of a building in industrial environment as well as from rural sites in grip seal plastic bags with the help of laboratory spatula. After that Samples were marked with source, date and time of collection. The excreta samples were dried at 60 ℃ for 24 h to attain a constant weight. 0.5g of sample was weighted and their digestion was performed by keeping excreta samples on water bath with Conc. Nitric acid and Perchloric acid in 4: l. After complete digestion, solution was filtered using Whatman filter paper 1 and volume was made 25 ml with distilled water. Further, till analysis, samples were stored at ambient temperature. For analysis of six trace metals i.e. Cd, Cr, Cu, Pb, Ni and Zn, samples were subjected to atomic absorption spectrophotometer. The same is calibrated with standard solutions for respective metals. Each analysis was performed three times and single blank was run for 5 samples to ensure quality control. Obtained data (mg/l) was converted into μg/g. The data recorded, on dry weight basis, were illustrated as mean ± standard deviation.

In present study**,** to examine variation in contamination among industrial regions, a one-way

ANOVA was performed. Further, elemental concentration in excreta of blue rock pigeon were compared between areas (Industrial vs. rural and rural R1 vs. rural R2) using independent samples t-test. The level of significance was set at p<0.05. All statistical analysis was carried out using the Statistical Packages of Social Science (SPSS).



Source: Base map from Google Earth

Figure 1 Study area with sampling locations (industrial regions: S1-Bais Godam, S2-Jhotwara, S3-Malviya, S4-Mansarover, S5-Sanganer, S6-Sitapura, S7-Vishwakarma and rural sites: R1-Chittora, R2-Narayanpura)

Results and Discussion

The mean concentrations of Cd, Cr, Cu, Ni, Pb and Zn in fecal pellets of pigeon at different industrial regions (S1-S7) in Jaipur and rural sites (R1&R2), Rajasthan are shown in Table 1. All the studied metals were detected in fecal pellets from all selected industrial regions and rural sites (except Cd at rural site, R2). Among those six elements all birds displayed the proportionally highest accumulation for Zn, followed by Cu>Pb>Cr>Ni>Cd for Bais Godam (S1), Sanganer (S5) and Sitapura (S6) industrial regions while Cu>Cr>Pb>Ni>Cd for Jhotwara (S2) industrial regions. Further, chemical profile of trace metals followed an order Cr>Cu>Pb>Ni>Cd for Malviya (S3) and Cr>Cu>Ni>Pb>Cd for Mansarover (S4), Vishwakarma (S7) Chittora (R1) and Narayanpura (R2) regions.

There was no significant difference in the concentration of the trace metals among seven industrial regions that have been investigated in present study except Cu. Although the cause for this outcome is still unclear, possible explanations could be given as follows: controlled metal emission and discharge from industries or may be contaminants can be transported e.g. by winds or variable metal burden due to other factors such as human population, traffic proximity and urbanisation has overcome the regional differences. Moreover, disparity in concentration of the contaminants which pigeons experience relay upon type of foraging behaviour. According to Frantz et al. (2012) pigeons can be dependably employed as bioindicators of heavy metal pollution even for a "restricted zone" i.e. experience local pollution levels and have limited movements within their local environment. Therefore, we supposed that the phenomenon of metal contamination during bird migration is minimal, although it could never be ruled out completely. Further, in the industrial site, similar to ours, it is hard to predict the routes and directions of elemental transfer in the ambient environment, due to various sources of contamination: different extent and type of industrial activities, metal loads from traffic and roads, many anthropogenic activities in high density zones and urban activities (Turzanska-Pietras et al. 2018).

Although a detailed comparison was not possible due to the facts that in those studies either a different suite of elements was examined, different bird species were studied or birds from very different habitats were investigated, however, the results obtained in this study, as well as the comparison with literature data (Table 2, Table 3 and Table 4) indicated that fecal samples from all industrial areas (S1-S7) has high concentration of Cr. Further, Cd was high at Bias Godam (S1) and Sitapura (S6) industrial areas; Cu, Pb at Bias Godam (S1), Jhotwara (S2) and Sitapura (S6) industrial areas; Zn at Malviya (S3) and Sitapura (S6) industrial areas. The reason for such high levels in our study may be related to extensive industrial activities, traffic and urban activities.

Table 1 Comparison of mean concentrations (μg/g) of Trace element in fecal pellets of pigeon at different industrial regions (S1-S7) in Jaipur and Rural sites (R1&R2), Rajasthan (n=4)

Sampling sites	**Concentration of Heavy metals (Mean±SD)**					
	Cd	**Cr**	**Cu**	**Pb**	**Ni**	**Zn**
Industrial						
BaisGodam (S1)	0.73±0.71	11.31±7.35	100.88±68.11	15.57±4.95	6.57±1.07	157.54±16.3
Jhotwara (S2)	0.14±0.27	16.66±1.74	28.40±21.35	13.31±18.7	6.69±3.28	102.84±50.73
Malviya (S3)	0.12±0.21	13.61±4.48	11.55±7.83	5.39±7.25	5.33±2.68	333.33±458.16
Mansarover (S4)	0.16±0.31	11.42±3.85	13.90±12.57	3.63±5.32	5.11±2.77	75.71±58.03
Sanganer (S5)	0.20±0.29	7.26±1.98	11.55±6.40	7.89±7.90	2.46±0.49	98.48±57.60
Sitapura (S6)	0.45±0.48	9.46±6.16	45.40±56.54	20.5±39.41	7.73±6.85	625.21±1084.15
Vishwakarma(S7)	0.11±0.18	13.81±1.52	16.03±6.90	6.75±5.15	8.09±3.54	123.83±38.21

F-value	1.446	2.064	3.448	1.181	0.507	0.800
***p*-value**	0.245	0.102	0.016[a]	0.354	0.796	0.581
Rural						
Chittora (R1)	0.23±0.47	5.93±2.75	11.29±5.56	2.98±4.97	4.94±3.18	74.64±54.30
Narayanpura (R2)	ND	3.31±0.14	10.13±2.38	2.72±1.37	3.0±0.42	64.67±30.56
***t*-value**		1.90	0.39	1.207	0.098	0.320
***p*-value**	---	.052	.713	.273	.925	.760

F-value and *p*-value for ANOVA to compare among industrial areas (S1-S7) and *t*-value and *p*-value for independent samples t-test between rural sites (R1&R2); [a]significant level at $p < 0.05$, ND = concentration lower than the instrument detection limit

Moreover, Ni levels at studied industrial areas in our study were markedly lower, which suggests a low contamination of Ni at the industrial areas. In present work, Sitapura (S6) industrial area seems to be highly polluted with heavy metals as compared to remaining industrial areas under study. Probable reason stems from the fact that Sitapura (S6) industrial area has largest number of manufacturing units under production among analyzed industrial areas i.e. approximately more than two thousand units under production for food, paper, oil, cable, electronics, pharma, automobile, textile, Engineering, Readymade Garment, Gems and Jewellery (Brief Industrial Profile of Jaipur District, 2015-2016) which were probably the main source of metals release into its ambient environment. Moreover, low levels of metal contamination recorded at Sanganer (S5) and Mansarover (S4) industrial areas correlates with low number of metal pouring production units in these areas. In addition, relocation of industries from Sanganer to Sitapura (S6) industrial area causes reduction in number of industrial activities which pour toxic elements in this area. Therefore, it possibly inferred that industrial operations impacts heavy metals accumulation in pigeon in industrial areas of our study, though other factors such as population, traffic proximity and urban activities were critical factors influencing the concentration of heavy metals in same.

On the other hand, metal concentrations were however also recorded in both rural sites. However, these results of present study showed a lower amount of studied metals than the findings of Kaur and Dhanju (2013) and Kler et al. (2014), who reported these metals in excrement of pigeon from orchids, agrifield and residential areas of Ludhiana, India. Possible source of metals in rural sites i.e. R1 and R2 of our study include vehicle emission, residential burning (burning of firewood) and nearby agriculture practices. We therefore expected pigeons to harbour higher levels of toxic metals in industrial regions close to main roads and in urbanized areas than rural sites. However, we recorded that pigeon excrement from industrial regions had considerably higher concentrations of most of studied metals i.e. Cr, Cu, Ni, Pb and Zn (except Ni at Sanganer industries) than rural sites. This validate the denouement formerly stressed by various researcher (Balaji et al. 2016; Dauwe et al. 2003; Eeva et al. 2005; Scheifler et al. 2006; Swaileh and Sansur 2006) that metal exposure to birds dwelling in urbanized and industrialized areas is greater than to those areas where anthropogenic influence is negligible or less. Moreover, results of independent samples t-test for industrial-rural differences reported a highly variable data; the only trend that was found was Cr differed significantly between most of industrial and rural sites. The reason for such outcome in our study may be related to extensive Cr involving industrial activities i.e. steel fabrication, textile and leather manufacturing and urban-traffic in industrial environment. Pigeon from the rural site, R1 closer to pollution source (industrial regions of Jaipur city) had higher concentrations of metals in their excrement than did pigeon at other rural site, R2. This may indicate the influence of the urban-industrial anthropogenic activities on the deposition of heavy metals in the surrounding area.

Furthermore, Concentration of all studied metals in the excreta did not differ significantly among rural sites. The lack of significant differences is presumably caused by the similar source of metal exposure at sites. Further, source of pollution and environmental status of the study site pedal an important role, because of elemental interaction with one another and the concentration and composition of various metals may influence their impact on aves (Turzanska-Pietras et al. 2018). In addition to site, sex, age, morphological and physiological aspects are relevant factors to consider in biomonitoring studies (Zarrintab et al. 2016) that can account for variation in the pattern of bio-accumulation and ultimately excretion in wild populations with recent exposure to high concentrations of these metals.

Table 2 Concentration of trace metals (µg/g) in avian excreta from previous studies conducted in India

Author	Bird species	Cd	Cr	Cu	Ni	Pb	Zn
Gaba and Vashishat (2018)	Spotted Owlet	0.42-0.78	3.52-12.05	12.66-54.0	3.02-9.64	9.28-29.2	48.83-289.83
Pannu and Kler (2018)	House Sparrow	0.37- 0.62	7.65-16.1	19.15-22.67	1.72-8.11	8.68-25.16	137.5-240.3
Sharma and Vashishat (2017)	House Crow	0.39-1.05	5.58-12.45	7.70-17.01	2.09-9.05	2.59-10.17	42.86-196.93
Kler et al. 2014	House Crow	0.120	2.65	9.86	2.564	3.90	52.63
	Pigeon	0.192	6.75	119.5	6.43	5.75	154.2
	Common Myna	0.553	12.85	26.19	8.530	11.73	189.23
	Ring Dove	0.564	9.401	20.74	6.67	5.775	155.67
	Cattle Egret	1.880	16.29	22.74	12.51	8.325	137.53
Kaur and Dhanju (2013)	Blue rock pigeon	0.28	3.42	32.35	9.98	12.15	196.94
	Eurasian collared dove	2.73	55.37	85.49	33.07	38.08	412.36
	Rose ringed parakeet	2.13	29.94	40.25	24.71	33.82	229.77
	Common myna	9.98	109.16	66.96	53.78	122.14	721.81
	House crow	3.78	7.11	44.13	11.02	61.71	358.61
	Common babbler	2.07	33.77	150.75	19.20	25.86	464.97
	Cattle egret	2.05	23.45	18.65	10.83	7.23	128.14
	Red wattled lapwing	48.79	86.32	87.43	43.37	864.03	473.99

Table 3 Concentration of trace metals (µg/g) in avian excreta from previous studies conducted worldwide

Author	Bird species	Study area	Cd	Cr	Cu	Ni	Pb	Zn
Costa et al. (2013)	Great Tit	Portugal, Industrial site (MU)	1.08	---	98.5	1.20	1.10	391.7
		Reference site (MQ)	1.58		81.6	1.21	0.86	409.8
Morrissey et al. (2005)	American dipper	Chilliwack River, Canada	5.97	--	53.28	--	3.65	396.10
Bravo et al. (2005)	Black vulture	Municipio Santa Rita, Venezuela	13.93	--	20.26	15.19	--	202.57
Dauwe et al. (2004)	Great tit	Non-ferrous smelter Belgium, Site1(Closest)	16.3	--	67.7	9.1	60.7	443.9
		Site2	8.9	--	27.4	1.7	17	241.2
		Site3	5.3	--	24.1	1.2	8.2	223.0
		Site4 (farthest)	5.3	--	29.7	1.7	4.5	246.1
Janssens et al. (2003)	Great tit	Non-ferrous smelter, Belgium, UM(closest)	9.4	4.7	209	45	28.8	261
		F8	4.2	2.0	66	13.6	7.2	207
		F7	2.7	3.2	167	58	1.9	255
		UIA (farthest)	2.9	2.9	201	24	1.1	526
Dauwe et al (2000)	Great tit	Polluted Site (near industry)	16.81	--	90.28	--	80.40	429.4
	Blue tit	Polluted Site (near industry)	9.35	--	92.74	--	124.80	317.4

Table 4: Concentration of trace metals (µg/g) in feathers of Pigeon from previous studies

Author	Study area	Cd	Cr	Cu	Ni	Pb	Zn
Manjula et al. 2015	India, Urban	2.33 +0.16	63.14 +11.23	125.66 +11.33	8.57 +2.1	---	65.76 +8.42
(mean ± S.D)							
	Rural	1.64 +1.22	51.65 +2.34	44.42 +1.22	7.3 +1.23	---	48.86 +2.53
Frantz et al. 2012 (mean ± S.E)	Urban areas, Paris	0.80±0.10	---	13.15±0.70	---	13.82±1.21	204.80±9.25
Brait and Filho 2011 (mean ± S.D)	Brazil, Civic square	0.20±0.14	1.48±0.83	8.87±1.27		5.02±6.01	90.21±28.72
	Zoo	0.04±0.08	0.84±1.12	8.89±1.56	---	2.04±3.30	125.21±30.72
	Jatai	0.08±0.07	0.28±0.45	8.06±1.92	---	0.58±0.85	137.6±35.41
Adout et al. 2007 (mean ± S.D)	Israel- Industrial	2.64 ± 0.4	---	10.3 ± 2.8	---	10.3 ± 6.00	146 ± 40
	Rural	1.84 ± 0.74	---	9.77 ± 2.87	---	5.63 ± 4.38	118 ± 29
	Urban	3.23 ± 2.9	---	11.8 ± 4.6	---	6.99 ± 6.21	131 ± 96
	Natural	0.91 ± 0.32	---	5.72 ± 1.22	---	1.47 ± 0.75	63 ± 27
	Control	2.63 ± 1.07	---	5.45 ± 1.26	---	0.29 ± 0.11	28.7 ± 23.7

Further, comparison of the repercussions of toxic metals in fecal matter of avian species is very challenging, due to interspecies variation in bionomics, particularly diet, including their potential to stand against and eliminate metal load (Koivula and Eeva 2010). There are studies which spotlighted considerable differences in metals accumulation and excretion in even closely-related species (Burger and Gochfeld 2009; Eeva et al. 2009; Hofer et al. 2010) such as pigeon and ring dove i.e. trace metals content in pigeon faeces were lower than ring dove inhabiting the same area (Kler et al. 2014). This may be associated to variations in their detoxification capacity or antioxidant defence.

Conclusions

In conclusion, outcomes of present study portray that trace metal pollution in avifauna is howbeit a moot issue, chiefly in regions with higher anthropogenic activates. Between the two study sites, Industrial and Rural, the high concentrations of trace metal were recorded at former sites (with exception at few places). Further, results obtained in this study, as well as the comparison with literature data indicated that fecal samples from all industrial areas (S1-S7) have high concentration of Cr. Furthermore, Cd was high at Bias Godam (S1) and Sitapura (S6) industrial areas; Cu, Pb at Bias Godam (S1), Jhotwara (S2) and Sitapura (S6) industrial areas; Zn at Malviya (S3) and Sitapura (S6) industrial areas. On the other hand, metal concentrations were found to decrease with increasing distance from the Industrial environment of Jaipur city as rural site R1 (closer) has higher metal concentrations than rural site R2 (far). All these may indicate the influence of the urban-industrial anthropogenic activities on the deposition of heavy metals in the surrounding area. Specifically concerning toxicity in avian species it is purposed to determine the elemental burden regularly to refrain environmental hazards to provincial and regional birds.

References

1. Adout A, Hawlena D, Maman R, Paz-Tal O, Karpas, Z (2007) Determination of trace elements in pigeon and raven feathers by ICPMS. Int J Mass Spectrom 267(1-3):109-116.
2. Balaji S, Baskaran S, Pandiarajan J (2016) An Opportunistic Evaluation of Heavy Metal Accumulation in House Sparrow (*Passer domesticus*). RRJOB 4(1):38-41.
3. Bala M, Sharma A, Sharma G (2017) Blue Rock Pigeon (Columba livia) as Bioindicator of Heavy Metal Pollution in Industrial Ambient Air. International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET) 6(9):18634-18639.
4. Bala M, Sharma A, Sharma G (2017) Assessment of Heavy Metal Residues in

Excreta of Blue Rock Pigeon in Jaipur, Rajasthan. IJA 5(9): 983-988.

5. Bala M, Sharma A, Sharma G (2020) Assessment of heavy metals in faecal pellets of blue rock pigeon from rural and industrial environment in India. Environ Sci Pollut Res 27: 43646-43655.
6. Bala M, Sharma A, Sharma G (2021) Annual and Spatial variation of Heavy Metals in Industrial Environment of India. Nature Environment and Pollution Technology (Under Publication).
7. Bravo A, Marinela C, Azuero S, Salas R (2005) Heavy metal levels in plasma and faecal material samples of the black vulture (*Coragyps atratus*). Rev Cient 15(4):319-325.
8. Burger J and Gochfeld M (2009) Comparison of Arsenic, Cadmium, Chromium, Lead, Manganese, Mercury and Selenium in feathers in bald eagle (*Haliaeetus leucocephalus*), and comparison with common eider (*Somateria mollissima*), glaucous-winged gull (*Larus glaucescens*), pigeon guillemot (*Cepphus columba*), and tufted puffin (*Fratercula cirrhata*) from the Aleutian Chain of Alaska. Environ Monit Assess 152:357-367.
9. Brait CHH, Antoniosi Filho NR (2011) Use of feathers of feral pigeons (*Columba livia*) as a technique for metal quantification and environmental monitoring. Environ Monit Assess 179(1-4):457-467.
10. Costa RA, Eeva T, Eira C, Vaqueiro J, Vingada JV (2013) Assessing heavy metal pollution using Great Tits (*Parus major*): feathers and excrements from nestlings and adults. Environ Monit Assess 185(6):5339-5344.
11. Dauwe T, Bervoets L, Blust R, Pinxten R, Eens M (2000) Can excrement and feathers of nestling songbirds be used as biomonitors for heavy metal pollution? Arch Environ Contam Toxicol 39(4):541-546.
12. Dauwe T, Bervoets L, Pinxten R, Blust R, Eens M (2003) Variation of heavy metals within and among feathers of birds of prey: effects of molt and external contamination. Environ Pollut 124:429–436.
13. Dauwe T, Bervoets L, Blust R, Pinxten R, Eens M (2004) Relationships between metal concentrations in great tit nestlings and their environment and food. Environ Pollut 131(3):373-380.
14. Eeva T, Ryoma M, Riihimaki J (2005) Pollution-related changes in diets of two insectivorous passerines. Oecologia 145:629-639.
15. Eeva T, Ahola M, Lehikoinen E (2009a) Breeding performance of blue tits (*Cyanistes caeruleus*) and great tits (*Parus major*) in a heavy metal polluted area. Environ Pollut 157: 3126-3131.
16. Eeva T, Hakkarainen H, Belskii E (2009b) Local survival of pied flycatcher males and females in a pollution gradient of a Cu smelter. Environ Pollut 157:1857-1861
17. Frantz A, Pottier MA, Karimi B, Corbel H, Aubry E, Haussy C, Gasparini J, Castrec-Rouelle M (2012) Contrasting levels of heavy metals in the feathers of urban pigeons from close habitats suggest limited movements at a restricted scale. Environ Pollut 168:23-28.

18. Gaba Y and Vashishat N (2018) Estimation of heavy metal residues in excreta of spotted owlet (*Athene brama*) and barn owl (*Tyto alba*) from agro ecosystems of Punjab. J Entomol Zool Stud 6(3):525-529.
19. Janssens E, Dauwe T, Pinxten R, Bervoets L, Blust R, Eens M (2003) Effects of heavy metal exposure on the condition and health of nestlings of the great tit (*Parus major*), a small songbird species. Environ Pollut 126(2):267-274.
20. Hofer C, Gallagher FJ, Holzapfel C (2010) Metal accumulation and performance of nestlings of passerine bird species at an urban brownfield site. Environ Pollut 158:1207-1213.
21. Kaur N and Dhanju CK (2013) Heavy metals concentration in excreta of free living wild birds as indicator of environmental contamination. The Bioscan 8(3):1089-1093.
22. Kler TK, Vashishat N, Kumar M (2014) Heavy metal contamination in excreta of avian species from Ludhiana district of Punjab. IJAR 2(7): 873-879.
23. Koivula MJ and Eeva T (2010) Metal-related oxidative stress in birds. Environ Pollut 158(7):2359-2370.
24. Manjula M, Mohanraj R, Devi MP (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):1-10.
25. Morrissey CA, Bendell-Young LI, Elliotti JE (2005) Assessing trace-metal exposure to American dippers in mountain streams of southwestern British Columbia, Canada. Environ Toxicol Chem 24:836-845.
26. Pannu KK and Kler TK (2018) Heavy metal contamination in excreta of house sparrow (*Passer domesticus*) from rural areas of Ludhiana. J Entomol Zool Stud 6(1):77-81.
27. Sharma C and Vashishat N (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.
28. Scheifler R, Coeurdassier M, Morilhat C, Bernard N, Faivre B, Flicoteaux P, De Vaufleury A (2006) Lead concentrations in feathers and blood of common blackbirds (*Turdus merula*) and in earthworms inhabiting unpolluted and moderately polluted urban areas. Sci Total Environ 371(1–3):197-205.
29. Singh V and Chandel CPS (2006) Analytical Study of Heavy Metals of Industrial Effluents at Jaipur, Rajasthan (India). J Environ Sci Eng 48(2):103-108.
30. Swaileh KM and Sansur R (2006) Monitoring urban heavy metal pollution using the house sparrow (*Passer domesticus*). Environ Monit Assess 8(1):209-213.
31. Turzanska-Pietras K, Chachulska J, Polechonska L, Borowiec M (2018) Does heavy metal exposure affect the condition of Whitethroat (*Sylvia communis*) nestlings? Environ Sci Pollut Res Int 25(8):7758-7766.
32. Velea T, Gherghe L, Predica V, Krebs R (2009) Heavy metal contamination in the vicinity of an industrial area near Bucharest. Environ Sci Pollut Res Int.16 (1):S27-32.
33. Zarrintab M, Mirzaei R, Mostafaei G, Dehghani R, Akbari H (2016)

Concentrations of metals in feathers of magpie (*Pica pica*) from Aran-O-Bidgol City in Central Iran. B Environ Contam Toxicol 96(4):465-471.