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Biomonitoring of Selected Heavy Metals Using House Sparrow (*Passer Domesticus*) Residing in Tehran, Iran

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ABSTRACT

The present study aimed to determine the concentration of heavy metals (lead, cadmium and nickel) in the external and internal body tissues of house sparrow (Passer domesticus) living in Tehran, Iran, as a biological monitoring and also to identify possible sources of these pollutants. One of the challenges of this research was sampling and determining the population of city sparrows. The concentration of these heavy metals (in mg/kg) was measured in feather, muscle, blood, adipose tissue and diet samples of birds collected by systematic sampling (n = 96) from selected parks in the north, south, west and east of the city using inductively coupled plasma optical emission spectroscopy (ICP-OES) under optimal measurement conditions. Based on the results, the unwashed feather samples showed the highest concentration for cadmium, as Cd (449.23)> Ni (4.12)> Pb (3.67), and the washed feather samples indicated that the highest concentration of cadmium in the northern (456.75) and southern (449.23) regions. The concentration of lead in most of the regions had relatively similar values, but it was higher in the northern (5.11) and southern (3.67) regions. The highest concentration of nickel was related to the eastern (29.76) and western (9.76) regions. The comparison of our results reveals the correlation between the concentration of heavy metals studied in different tissues of house sparrows and the distribution of polluting sources in Tehran in terms of traffic load, the establishment of gas stations and industrial pollution transfer routes.To conclude, house sparrow can be used as a suitable biological indicator in determining the distribution of changes in the concentration of some heavy metals.

Keywords: *Biomonitoring, Heavy metals, House sparrow, Passerdomesticus, Tehran, Fuel, Soil contamination, Food chain.*

1. Introduction

Streets, as the most important lifelines in cities, face a number of vehicles and traffic. Combustion of fuel in car engines, and depreciation of car parts such as tires, batteries, and pads causes various pollutants to enter the streets. On the other hand, most of the industrial centers are gathered around the cities, which causes pollutants to enter the urban environments. Dustin the urban space contains a complex set of pollutants originating from traffic, buildings, industry, and erosion[1,2]. Heavy metals, which are capable of being accumulated in the bodies of living organisms, are present in street dust. Studies have shown that the concentration of heavy metals in urban dust is several times that of soil [3]. Tehran is the capital and largest city of Iran. Due to the large population of this city, the number of vehicles and traffic has been increasing. The establishment of factories around this metropolis has caused the release of pollutants, which are located in an industrial area. A study reported a lot of heavy metals in the dust of the streets of Tehran, with different origins from natural sources[4].

According to the known biology of birds, they can be used for appropriate biological monitoring to determine the level of environmental pollution with heavy metals[5].

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Birds are exposed to heavy metals through food, habitat, water, and physical contact, so they can potentially be used as biological indicators of the presence of heavy metals. They are exposed to pollutants such as pesticides and heavy metals [6,7]. They move to other places because of their ability to fly when the environment is unsuitable. The birds that feed in highly polluted areas may be at high risk [8]. It is possible to use such birds as a biological indicator. The birds are part of the regional food chain and may live in areas with high concentrations of heavy metals [9].

Bioindicators are species that can reflect the ecological status and health of their habitat and can be used for ecosystem monitoring. Birds are considered suitable environmental indicators in urban spaces due to their characteristics such as the ability to live in different environments, and the possibility of feeding and easily observing various food items. House sparrow, Passer domesticus, is one of the most widely distributed birds in the world [10]. It belongs to the family Passeridae (order Passeriformes) [11]. Endemic to Asia, North Africa, and parts of Europe, house sparrows have been dispersed around the world by ship for 170 years and now cover an area of 760,000 square kilometers on all continents except Antarctica. House sparrows have the chance to exploit human food waste and other nutritional episodes in urban environments, and as a result, their growth and reproductive opportunities increase in proportion to human territory expansion. These birds are highly dependent on the human environment [12].

Heavy metals can bioaccumulate in various tissues of birds, so measuring the content of heavy elements in tissues provides important information about the environmental conditions of birds [13]. There is a great need to monitor the levels of heavy metals in different parts of the environment because of their hazards to living organisms [14].

The levels of heavy metals accumulated in different bird tissues such as feathers, blood, muscle, liver, kidneys, skeleton, and feces enable biomonitoring studies on environmental metal pollution [15,16,17,18,19]. The use of feather samples has an undeniable advantage because they are easy to collect, non-degradable, and reproducible [20] . In addition, feather samples throughout the year can also show heavy metal pollution during flight as well as nutrition from inside the body. Therefore, they can reflect the long-term accumulation of metallic elements [21]. Bird droppings are also a mixture of feces and urine, which can reflect unabsorbed food residues and absorbed and excreted elements [22].

Birds are suitable biological indicators for environmental pollutants due to the possibility of contact with contaminated food and water, their special feeding habits, and their well-known biology. Accordingly, the present study was conducted with the aim of measuring selected heavy metals including lead, cadmium, and nickel using house sparrow as a biological monitor for heavy metal pollution and also determining the possible sources of these heavy metals in Tehran metropolis, Iran.

2. Materials and Methods

2.1.Study area and sampling stations

This study was conducted from late spring to early summer 2022 in Tehran based on ethical considerations in animal protection. To this end, sampling stations were selected to be seven large parks and one local park in this city. The geographical coordinates of sampling stations were determined by the Global Positioning System (GPS), as shown in Table 1. The inclusion criteria of these parks were proximity to highways and high-traffic streets and coverage of different parts of the city (north, south, west, and east).

Table 1. Geographical coordinates of sampling stations in Tehran (Iran, 2022) in various directions

	Stations	Geographical coordinates
1	Fadak park(West)	35.755139, 51.376501
2	Niavaran park(North)	35.808673, 51.471781
3	Saei Park (Northeast)	35.736338, 51.410691
4	City park (South)	35.683016, 51.409759
5	Laleh park (West)	35.714036, 51.390899
6	Mellat park(North)	35.778706, 51.411652
7	Yademan(AzadeganBLV)(South)	35.735785, 51.394949
8	Taleghani forest park(East)	35.753293, 51.423348

2.2.Collecting samples

A total of 96 house sparrows were collected from 8 designated urban points (12 birds from each station). Feed samples (generally millet and bread crumbs (bread waste) fed by visitors) were collected within the bird's reach and transported to the laboratory in a plastic bag.

2.3.Heavy metal measurements

All collected samples were kept in a dry and well-ventilated place until analysis. After preparing each of the samples (feathers, blood, adipose tissue, muscle, and feed) in a standard way, their heave metals were quantified by Vista MPX Varian inductively coupled plasma-optical emission spectroscopy (ICP-OES) under optimal measurement conditions. For comparison, the concentration of heavy metals in both washed and unwashed feathers was measured separately.

A composite sample was used to measure the concentration of heavy metals in the feed consumed by house sparrows. Therefore, we measured the concentration of heavy metals in all types of feed including millet, bread waste, mulberry, millet, and food waste collected and mixed from the sampling stations. Considering that mulberry (white berries) is one of the dominant trees in the parks of Tehran city that are fed by house sparrows, it was included in the nutritional admixture.

2.4.Statistical analysis & GIS

In this study, Arc Map software was applied to create GIS maps.

2.5.Transfer factor (TF) calculation

The transfer factor (TF) index determines how metals transfer between two levels of the food chain [23]. The heavy metals are transferred from soil to plants, as the most important step for elements to enter the food chain. Micronutrient cycles should be followed in a way that does not endanger the health of mankind and the environment [24] . The following hypotheses (Equations 1 and 2) were considered in this research: (a) house sparrows are contaminated with heavy metals mainly through feed, and (b): heavy metals in feathers are increasing due to environmental factors.

$$TF_{\text{body}} = \frac{C\ muscle}{C\ food} \quad (1)$$

$$TF_{\text{feather}} = \frac{C feather}{C\ muscle} \quad (2)$$

3. Results and Discussion

Table 2 shows the mean concentration of lead, cadmium, and nickel in the muscle and feathers of house sparrows. As seen in the table, these metals were present in the tissues of house sparrows.

Table 2. The mean concentration of lead, cadmium, and nickel (mg/kg or ppm) in the muscle and feather samples of house collected from different regions of Tehran (Iran, 2022)

Stations/heavy metals	Pb		Cd		Ni	
	Feather	Muscle	Feather	Muscle	Feather	Muscle
South	2.89	11.95	3.55	5.703	445.09	60.51
East	2.6	1.21	25.99	35.71	255.66	23.822
North	4.77	1.32	0.54	51.54	451.44	6.821
West	0.88	1.21	7.81	40.117	11.59	204.23

Table 3 shows the mean concentration of lead, cadmium, and nickel in the blood and adipose tissue of house sparrows. The nickel concentration in adipose tissue was higher than that in blood, and the nickel concentration in the samples collected from the western areas of Tehran was the highest. The blood nickel concentration was the highest in the southern regions. The cadmium concentration was the highest in the adipose tissue of samples from East Tehran. In the northern regions, the lead concentration in adipose tissue was the highest.

Table3.The mean concentration of lead, cadmium, and nickel (mg/kg or ppm) in the blood and adipose tissue samples of house sparrows collected from different regions of Tehran (Iran, 2022)

Stations/heavy metals	Pb		Cd		Ni	
	Blood	Adipose tissue	Blood	Adipose tissue	Blood	Adipose tissue
South	0.0154	0.046	0.0223	0.86	4.32	5.051
East	0.078	0.052	0.019	3.01	2.98	3.036
North	0.132	0. 29	0.119	0.03	4.04	5.27
West	0.0213	0.001	0.034	0.94	0.56	26.91

The higher concentration of nickel in the adipose tissue compared to the blood indicated that the nickel tends to accumulate in the adipose tissue [25].

The distribution of changes in the concentration of nickel, lead, and cadmium in different regions of study are presented in Figure 1.

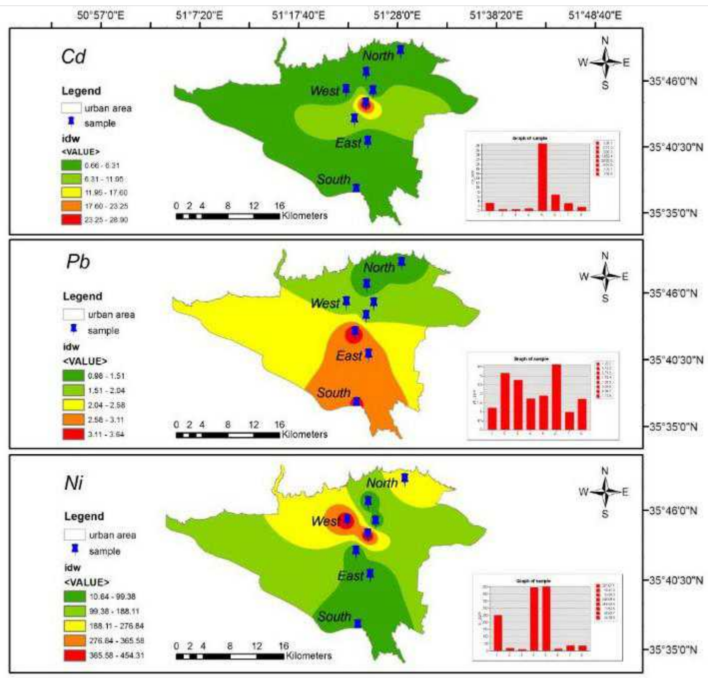

Figure 1. Zoning distribution of changes in the concentration of nickel, lead, and cadmium heavy metals (mg/kg or ppm) in the feather samples of house sparrows collected from different regions of Tehran (Iran, 2022)

The accumulation of studied heavy metals in the feather samples of house sparrows collected from different regions of Tehran was illustrated by the GIS maps, where the difference is obvious. There were differences in the concentration of nickel, cadmium, and lead in different areas of Tehran. It could be said that land use in different regions played an important role in the environmental distribution of heavy metals. In the northern and western parts of the city, there was a large amount of nickel, so they reached a critical level. On the other hand, nickel was at a lower level in the south and east of Tehran. It was justified that the behavior of metals, the density of vegetation, and the distance from the main roads were the main factors of the high concentration of heavy metals in different parts of Tehran. The main reason for the presence of heavy metals in the environment could be attributed to the air pollution of this city, so being away from high-traffic areas could have an effect on the concentration of soil metals.

The results showed that the concentration of heavy metals in unwashed feathers was higher than that in washed ones (Table 4). Since the feathers are in direct contact with the environment, dust-containing pollutants settle on them.

Table 4. Comparison of heavy metal concentration (mg/kg or ppm) between washed and unwashed feather samples of house sparrows collected from different regions of Tehran (Iran, 2022)

heavy metals	Pb	Pb	Ni	Ni	Cd	Cd
Stations/Factor	Washed	Unwashed	Washed	Unwashed	Washed	Unwashed
South	2.89	3.67	3.55	4.12	445.09	449.23
East	2.6	3.31	25.99	29.76	255.66	261.31
North	4.77	5.11	0.54	2.86	451.44	456.75
West	0.88	1.12	7.81	9.86	11.59	12.76
Mean	2.78	3.30	9.61	11.65	291	295

The concentration of heavy metals in washed and unwashed feathers has been compared in order to assess the environmental impact. The results showed that the average lead concentration was 2.78 mg/kg in the samples of washed feathers and 3.30 mg/kg in unwashed feathers. In addition, the average nickel concentration was 9.61 mg/kg in washed feather samples and 11.65 mg/kg in unwashed feathers. The average concentration of cadmium was 295 mg/kg in unwashed feather samples and 291 mg/kg in washed feather samples. These findings indicate the atmospheric deposition of pollutants in the form of dust on house sparrow feathers and therefore the high levels of heavy metals measured in unwashed feathers. In a research, it was found that external contamination played a major role in the uptake of heavy metals into feathers [26] . In our study, the order of contamination with heavy metals was determined by comparing washed and unwashed feathers: Cd > Ni > Pb.

The results of measuring heavy metals in the feed samples of the house sparrows(Table 5) indicated that the highest concentration of nickel was in bread scraps (41.62 mg/kg) and the lowest level was in berries (0.14 mg/kg). The highest concentration of lead was found in mulberry (0.69 mg/kg) and the lowest level was in millet (0.14 mg/kg). Regarding cadmium, the highest concentration (1.05 mg/kg) was related to food waste and the lowest level was mulberry (0.04 mg/kg).

Table 5. Concentration of heavy metals (mg/kg or ppm) in the possible diet of house sparrows collected from different regions of Tehran (Iran, 2022)

	Ni	Pb	Cd
Millet	26.09	0.14	0.16
Bread scrap	29.06	0.18	0.21
Mulberry	0.14	0.69	0.04
Food waste	41.62	0.26	1.05

At the time of this study, the highest concentration of heavy metals in feed was related to nickel. Volcanic dust particles and weathering in rocks and earth are natural sources of atmospheric nickel [27] .In our study, the order of feed contamination with heavy metals was determined to be food waste > bread scrap> millet > mulberry for nickel, mulberry > food waste > bread scrap> millet for lead, and food waste > bread scrap> millet >mulberryfor cadmium. The human source of cadmium in Tehran has previously contributed to tire wear [28] .

Regarding the transfer of metals, cadmium is transferred from soil to plants, lead is transferred to soil by airborne dust, and nickel is transferred to soil from atmospheric sediments. Heavy metals can be transferred from one trophic level to another and may reach a final link in the food chain[29] . Cadmium is of soil, lead of air, and nickel of soil and air. It seems that the white mulberry is exposed to air pollution and the pollutants from traffic are more concentrated on it. In trophic levels, the amount of elements increases or decreases [30] . The transfer coefficient of heavy metals from feed to feathers, muscle, adipose tissue, and blood of house sparrows collected from different regions of Tehran is shown in Table 6. As it turns out, the amount of heavy metal TF from mulberry to muscle has been higher than other nutrients.

Table 6. Index of transfer factor from feed to feathers, muscle, adipose tissue, and blood of house sparrows collected from different regions of Tehran (Iran, 2022)

TF	Ni	Pb	Cd
Body muscle/Millet	2.31	85.35	35.643
Body muscle/ Bread scrap	2.08	66.38	35.64
Body muscle/Mulberry	432.21	17.31	142.05
Body muscle/Food waste	1.453	45.96	5.431
Blood/Feather	0.0022	0.000532	0.00628
Blood/Adipose tissue	0.8552	0.334	0.199
Feather/Body muscle	7.355	0.241	0.622

As it is clear in Table 6, regarding nickel and cadmium elements, the highest value of TF index was related to Body muscle/Mulberry with values of 432.21 and 142.05, respectively, and the lowest value was related to feather with a value of 0.0022. The highest TF coefficient for lead element (85.35) was related to Body muscle/Millet and the lowest values were related to Blood/Feather with the values of 0.000532 and 0.00628, respectively. Regarding cadmium, the highest TF coefficient was calculated for Body muscle/Mulberry and the lowest value was calculated for Blood/Feather as 0.000532.

The results showed that the lead content in the muscles of house sparrows in the southern and western regions of Tehran was the greatest. The cadmium values were also the highest in the muscle in the north and west of Tehran. The concentration of nickel was greatest in the sampling stations of western regions in the muscles than that in the feathers. The results reported by Tayebi and Jahangiri [31] on Mousa Creecks Island (southern Iran) were completely opposite to the results of this study, which could be due to the cleanliness of the area. This can indicate the effect of air pollution on the increase of heavy metals in the feathers of house sparrows in Tehran compared to other parts of it.

4. Conclusions

The current research was performed to determine the variations in the environmental concentration of selected heavy metals at different sampling points of Tehran through house sparrow as a bioindicator. When using birds as biological monitoring, the ability to fly should be taken into account, because the bird uses more feeding sites due to increased flight power. Therefore, since the house sparrow's flight power is limited and it feeds on food sources close to the nest, it was used as a biological indicator in this research.

The results of measuring the concentration of heavy metals .including nickel, cadmium, and lead in the feather samples of house sparrows showed that the accumulation of nickel was the highest in the eastern and western regions. The concentration of cadmium was the highest in the parks of the southern and northern regions. The concentration of lead in most areas had relatively similar values, but it was also the highest in the northern and southern regions. The comparison of our results reveals the correlation between the concentration of heavy metals studied in different tissues of house sparrows and the distribution of polluting sources in Tehran in terms of traffic load, the establishment of gas stations, and industrial pollution transfer routes. To conclude, house sparrow can be used as a suitable biological indicator in determining the distribution of changes in the concentration of some heavy metals. It is suggested to investigate the effect of different age groups and gender on the accumulation of heavy metals on the house sparrow tissues in future studies.

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6. Data availability statement

The authors confirm that the data supporting the findings of this study are available in the article and its supplementary materials as a PhD Thesis at Islamic Azad University of Damavand Branch, Iran.

7. Conflict of Interest

The authors have declared no conflict of interest.

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