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Original Article

Bioaccumulation of Heavy Elements in the Organs of Red-Wattled Lapwing in Shadegan Wetland

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Abstract

Background & Aims: Heavy metals are highly stable in wetland and marine environments and can be toxic to organisms. Wetland birds play a vital role in the life cycle and food chain. This study aimed to investigate the bioaccumulation of heavy elements such as lead (Pb), mercury (Hg), nickel (Ni), and copper (Cu) in the organs of red-wattled lapwings in Shadegan wetland in 2019.

Materials and Methods: Pb, Hg, Ni, and Cu were studied in this descriptive-applied study. Ten red-wattled lapwings were randomly prepared in Western Shadegan wetland and with the coordination of the environmental unit of the region through hunting in December 2019. A graphite furnace spectrometer, GBcA made in Australia, was used to determine the amounts of these elements in liver, kidney, and tail feathers. The LOD and relative standard deviation of sampling were also determined, and finally, the results were analyzed using correlation and regression analyses.

Results: Based on the results, the highest cumulative concentration belonged to Cu. Its mean values in the liver, kidney, and tail feathers were 4.16%, 3.95%, and 1.77 mg/kg, respectively. The highest and lowest means of Pb, Hg, Ni, and heavy Cu elements in the kidney tissue were 1.974 and 1.08 mg/kg, respectively. Based on these results, the kidney was the most important tissue accumulating heavy elements in red-wattled lapwing.

Conclusion: Overall, there were significant amounts of heavy elements in various organs of the red-wattled lapwing present in Shadegan wetland. These results indicated the relatively high levels of pollution in Shadegan wetland compared to some other bird habitats in Iran, which is probably attributed to the oil, gas, petrochemical, and sugarcane industries around Shadegan wetland.

Keywords: Heavy metals, Wetland, Red-wattled lapwing, Bioaccumulation

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1. Introduction

Due to the importance of biodiversity and the destructive effects of human activities, pollution is now receiving more attention than in the past [1]. Large amounts of pollutants released into the environment are the result of urbanization and industrial processes [2]. Heavy metals are considered a major environmental threat because of their multiple sources of production and environmental stability [3]. Heavy metal pollution in aquatic and marine environments is a major concern due to its bioaccumulation by organisms such as birds and fish [4]. Due to their toxicity, indestructibility, and accumulation, heavy metals are among the most serious pollutants in the natural environment so that they are accumulated from natural and artificial sources and transferred to the bodies and tissues of organisms, and accumulation in tissues and bodies of living organisms is more dangerous than its toxicity [5]. In recent years, rapid development has introduced large amounts of heavy metals into the natural environment [6]. Owing to the high development capabilities of aquatic ecosystems, they are at great risk of heavy metals. On the other hand, atmospheric inflows and outflows to the sea bring large amounts of heavy metals from terrestrial ecosystems, caused by human or natural activities, to marine ecosystems [7]. Heavy metal pollutants can have destructive effects on the ecological balance of environmental receptors and the biodiversity of aquatic organisms [8]. Heavy metals such as Pb, Hg, and Ni are common pollutants scattered throughout the ecosystems. These elements are naturally present in marine environments, but they are not essential elements that can be toxic to humans if present in the diet [9]. Waterfowls are among the ways through which heavy elements are transmitted to humans [10]. Birds are generally considered to be a useful indicator for measuring heavy metal contamination in the environment [11,12]. The ecology of birds is well known. On the other hand, birds can provide useful information about the intensity and extent of contamination across the food web because they feed at higher trophic levels in ecosystems [13,14]. The use of birds as indicators of heavy metal contamination has an extensive research background. Okati et al [15] studied Pb and cadmium in some birds of the Khuzestan province. Albayrak and Pekgöz [16] also investigated bioaccumulation and the effects of heavy metals on the morphometry of house sparrows in Egypt. Likewise, Nardiello et al [17] evaluated the rate of heavy metals in northern Gannet and Morus feathers on the coast of Spain. The use of birds for the pollution index is more effective in wetlands where living organisms are concentrated

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[18]. Shadegan International Wetland is one of the large wetlands of Iran, located in the southwest of Iran and the south of Shadegan in Khuzestan province. This wetland is the habitat of over 30% of birds (154 species), 25% of mammals (40 species), and 45% of fish (36 species of marsh fish and 45 species of sea fish) in Iran [19]. At the same time, the inflow of sugarcane project effluents into this wetland through the passage of oil pipelines, the inflow of urban and industrial sewage, the dumping of city waste, and the construction of a steel factory next to this wetland are among the most important dangers threatening this place [20]. This wetland is one of the sensitive ecosystems. It is also a host for migratory birds, and due to the siege by the steel and petrochemical industries, it is also in danger of environmental destruction [21]. Therefore, biological monitoring seems necessary to know about the health of its environment. Among the environmental indicators are the organs of birds. Red-wattled lapwing is one of the types of birds living in Shadegan wetland. This species, with the scientific name *Hoplopterus indicus*, is a bird with a red beak and yellow legs that feeds on insects and other invertebrates and is found in pairs [22]. This paper sought to investigate the amount of the bioaccumulation of heavy metals (Pb, Hg, Ni, and Cu) in the tissues of red-wattled lapwings in Shadegan wetlands and to compare its rate of pollution.

2. Materials and Methods

In this descriptive research, data were collected through documentary and field methods. The documentary method includes desk studies and searching for articles related to research theory. Sampling and laboratory measurements of heavy metals in the liver, kidney, and tail feathers of red-wattled lapwing are used in the field method. The studied elements included Pb, Hg, Ni, and Cu. These elements are considered to be the most important indicators of human-made pollution in the natural environment. This species is selected because it is not included in the list of endangered or threatened species, and it is native to Shadegan wetland. Ten birds were randomly hunted for laboratory analysis in December 2019 with the coordination of the environmental unit of the region. It should be noted that this species is on the list of the "least concern" in the International Union for the Conservation of Nature list and is not considered a prohibited hunting species. The location of Shadegan wetland and sampling points are displayed in Figure 1.

The collected samples were dissected, and the organs of the caught birds, including tail feathers, the kidney, and the liver, were removed. It should be noted that the feathers were washed with detergent and distilled water after being transported to the laboratory to remove possible contamination. Then, kidney, liver, and tail feather samples were placed in an oven at 50°C for 48 hours to determine dry weight. The graphite furnace spectrometer (GBcA, Australia) was used to measure heavy elements in different tissues of this bird. To calculate the limit of detection (LOD) of the device for each of the heavy metals, the specified concentration of heavy metals was injected into the device, and its values were obtained after three repetitions. Considering the more favorable precision in the standard increase method than the working chart method, the recovery percentage of the atomic absorption device was performed also based on this method as described in Eq. (1).

$$R = C_{sample} - \frac{C_0}{C_{spiked}} \times 100 \qquad \text{Eq. (1)}$$

where C_{sample} is the concentration of a sample to which a certain amount of heavy metal has been added, and C_0 denotes the initial concentration of the sample. In addition, C_{spiked} represents the concentration equivalent to the amount added to the sample [23]. The final concentration of heavy metals based on the mg/kg wet weight of the sample was calculated by Eq. (2):

$$M = \frac{Cv}{W} \qquad \text{Eq. (2)}$$

where M and C represent the final concentration of the sample based on mg/kg and the concentration estimated

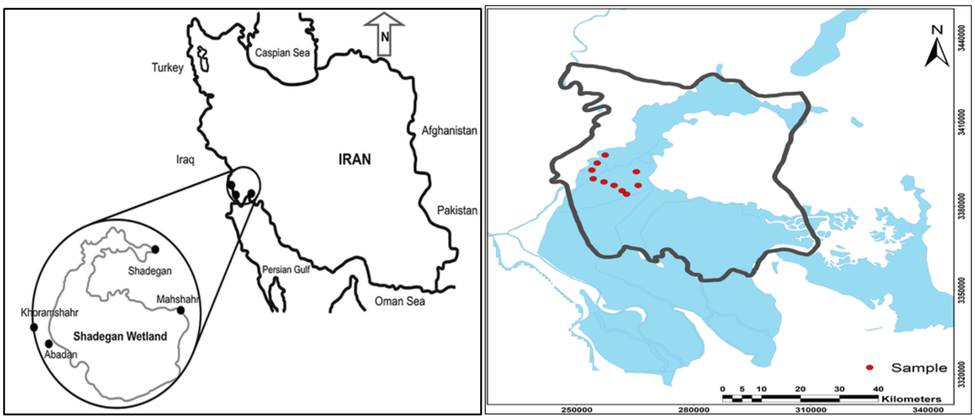

Figure 1. Location of Shadegan wetland and sampling points.

by the device, respectively. Further, *w* and *v* indicate the amount of material used for digestion per g and the final volume of the solution, respectively [24]. Data on LOD and relative standard deviation in this research are provided in Table 1.

To analyze the data, one-way analysis of variance (ANOVA), correlation test, and linear regression were used to determine the relationship between the measured values of heavy elements in different red-wattled lapwing organs by SPSS 19 and OriginPro 2018.

3. Results

The results of the biometry of bird species are presented in Table 2. The mean weight of red-wattled lapwing and the mean length of the hunted birds were 455 g and 34.2 cm, respectively. The length of both ends of the wings was 57 cm.

The results of measuring heavy metals Pb, Ni, Cu, and Hg in the liver, kidney, and tail feathers of red-wattled lapwings are presented in Table 3. Based on the findings, the highest cumulative concentration belonged to Cu, and its mean values in these organs were 4.16, 3.95, and 1.77 mg/kg, respectively. However, the lowest values of the measured elements in red-wattled lapwing's organ were related to Hg; in addition, its mean values in the liver, kidney, and tail feathers were equal to 0.06, 0.12, and 0.04 mg/kg, respectively.

Figures 2 and 3 illustrate the results of measuring heavy elements in red-wattled lapwing organs and samples.

Table 1. LOD and RSD of the Measurement of Heavy Elements

Element	LOD (ugL^{-1})	RSD (%)
Pb	7.9	0.76
Ni	2.3	0.56
Cu	1.4	0.32
Hg	0.25	0.47

Note. LOD: Limit of detection; RSD: Relative standard deviation; Pb: Lead; Ni: Nickel; Cu: Copper; Hg: Mercury.

Table 2. The Results of biometry of red-wattled lapwing

Variable	Mean ± SD
Weight (g)	455 ± 35
Total length (cm	34.2 ± 2.5
Length of two sides of a wing (cm)	57 ± 5

Note. SD: Standard deviation.

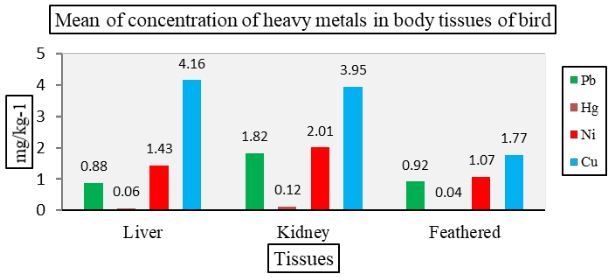

Figure 2. The mean amounts of Pb, Hg, Ni, and Cu in the liver, kidney, and tail feathers of red-wattled lapwing. *Note*. Pb: Lead; Hg: mercury; Ni: Nickel; Cu: Copper.

The highest and lowest means of Pb, Hg, Ni, and Cu were related to the kidney (1.974) and liver tissue (1.08), respectively. Based on these results, the most important tissue accumulating heavy elements in this species was the kidney. The difference in the mean values of heavy elements in different organs of this species was investigated using the one-way ANOVA. Based on the results, there was a significant difference between the amounts of Hg in the liver and tail feather samples in 10 measured samples ($P < 0.05$).

The results of one-way ANOVA between the organs of this species are listed in Tables 4 and 5. A significant difference was found between the amounts of Pb in all organs, Ni in the kidney and liver, Hg between the liver-kidney and kidney-liver, and Cu between the liver-liver and kidney-liver ($P < 0.05$), indicating the difference in the amount of the accumulation of heavy metals in different red-wattled lapwing organs. Accordingly, red-wattled lapwing organs, including the kidney, had a high potential for the accumulation of heavy metals.

4. Discussion

In general, biological monitoring can be a desirable and satisfactory method for measuring the amount of heavy metals and their bioavailability [25]. Burger [26] stated that the identification of the importance and effects of heavy metals in ecosystems has led to the development of biological monitoring plans with the aim of measuring the levels of pollutants in different organisms, in which prominent species are used to estimate the levels of these pollutants in different parts of ecosystems. Bioaccumulation in the food chain is one of the important results of the stability of heavy metals. Water ecosystems

Table 3. The results of measuring lead, mercury, nickel, and copper in the liver, kidney, and tail feathers of red-wattled lapwing

Organs	Lead (mg/kg^{-1})		Mercury (mg/kg^{-1})		Nickle (mg/kg^{-1})		Copper (mg/kg^{-1})	
	Concentration	Uncertainty	Concentration	Uncertainty	Concentration	Uncertainty	Concentration	Uncertainty
Liver	0.883	±0.185	0.068	±0.03	1.43	±0.462	4.16	±2.02
Kidney	1.82	±0.334	0.127	±0.047	2.01	±1.06	3.95	±1.34
Tail feather	0.92	±0.369	0.044	±0.018	1.07	±0.44	1.77	±0.51

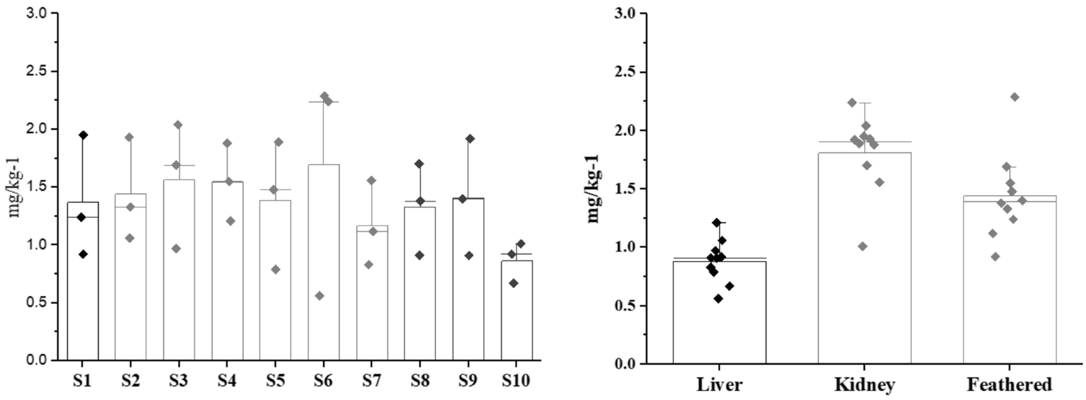

Figure 3. The Mean Amount of Total Heavy Elements in Red-wattled Lapwing Organs (Right) and 10 Measured Samples (Left).

in Iran are highly vast and have significant value. However, in recent years, the destruction of habitats, illegal hunting, the introduction of many environmental pollutants, and other factors have reduced their usefulness for the population of aquatic wildlife, especially aquatic birds. The fact that birds are highly sensitive to environmental pollution is well recognized. In the majority of ecological toxicology studies, birds are used as biological indicators for heavy metals due to their wide geographic distribution, relatively long life span, and appropriate position in the food chain. Shadegan wetland is one of the most important water areas in southwest Iran, which is affected by various environmental pollutions such as oil, steel, and sugarcane industry effluents. Therefore, this research focused on investigating the bioaccumulation of heavy metals (Pb, Hg, Ni, and Cu) in the tissues of red-wattled lapwing in Shadegan wetland in 2019. The results demonstrated that there were significant amounts of heavy elements in various organs of the red-wattled lapwing in Shadegan wetland. The most important accumulating tissue was kidney. In studies by Cui et al [27] and Lin et al [28], the kidney tissue was also the most important organ accumulating heavy elements for domestic pigeon and white stork species. However, in other studies such as those by Kenntner et al [29] and Akan et al [30], the accumulation of heavy elements in the feathers and liver of the white-tailed eagle and urban chicken was more than in the kidney tissue. In the study by Hassanpour et al [7], the mean amount of Pb in the liver and kidney of coots in Gomishan wetland and Gorgan bay was measured as 0.101 and 0.124 mg/kg, respectively, which was lower than the values measured in this study (0.883 and 1.82 mg/kg). In the research by Namroodi et al [31], the mean amount of Hg in the tissues of graylag geese and rural geese was estimated between 0.2 and 0.4 μg/kg, which is lower than the corresponding value reported in the current study. These results confirmed the presence of relatively severe pollution in Shadegan wetland compared to some other bird habitats in Iran.

Table 4. The Results of One-way ANOVA

Heavy metals	*P* value		
	Liver	Kidney	Tail feather
Lead	0.062*	0.257	0.88
Nickle	0.569	0.221	0.746
Copper	0.886	0.529	0.556
Mercury	0.024*	0.171	0.038*

Note. ANOVA: Analysis of variance.
*The mean difference is significant at the 0.05 level.

Table 5. Results of Pearson correlation test for the amounts of heavy elements in bird organs

Heavy metal	*P* value		
	Liver-kidney	Tail feather-liver	Tail feather-kidney
Lead	0.00 **	0.001**	0.03*
Nickle	0.188	0.511	0.018*
Mercury	0.002**	0.205	0.00**
Copper	0.942	0.002**	0.006**

*The mean difference is significant at the 0.05 level.
**The mean difference is significant at the 0.01 level.

5. Conclusion

The results of this study revealed that Cu had the highest level of bioaccumulation in different organs of red-wattled lapwing in Shadegan wetland. Further, the kidney was the most important tissue for accumulating heavy metals in this species. The concentration of heavy metals in different tissues of this species indicated the presence of chemical pollution in the Shadegan wetland. Thus, the results presented in this paper can be used in the environmental management program for the Shadegan wetland. To estimate the effect of factors such as oil facilities, the current study is recommended to be conducted in wider time frames and areas.

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Competing Interests

The authors declared that there was no conflict of interests.

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