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## The role of *Ascaridia columbae* in bioremediation of heavy metal accumulation in *Columba livia* tissues

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### Abstract

Pigeons are susceptible to various pollutants. The purpose of this study was to determine the role of nematode parasites in the bioremediation of metal accumulation in domestic pigeon *Columba livia*. A total of 26 domestic pigeons from poultry farm in Riyadh, Saudi Arabia; were collected randomly. The concentration of elements in infected and non-infected pigeons was measured using inductively coupled plasma mass spectrometer. The levels of the metal varied that depending on different tissues. During this study, zinc was measured as the dominant metal. Overall, the results showed that all heavy metals concentrations in liver samples were significantly higher than in other pigeon tissues. Nematodes have been collected and described in the intestinal tract of pigeons. The results showed that intestinal nematode parasites in the tissues of infected pigeons caused a significant decrease in metal concentrations compared to non-infected ones. Bioaccumulation factors have shown that nematode parasites have a higher concentration potential than pigeon tissues. Adult nematode infection in domestic pigeons is considered a biomarker of heavy metal contamination, and its presence reduced the biosynthesis of heavy metals in pigeon tissues.

**Keywords:** *Columba livia*; *Ascaridia* species; Biological indicators

### 1. Introduction

Birds are good subjects for pollution studies because they have high trophic levels, are well studied, easy to detect, and are indicators of environmental health [1,2]. Due to anthropogenic activities, heavy metals are often mobilized faster than normal in birds and environments [3]. Prolonged exposure to contaminants over time can result in physiological, behavioral, and biochemical changes in hosts, which may ultimately influence the spread and severity of parasitic diseases [4, 5, 6].

The ability to bioaccumulate by the parasites arising from the competition for chemical elements, including heavy metals which is a valuable tool for evaluating the functions of the parasite-host system [7]. Previous studies describe a higher concentration of different heavy metals in different parasites than host tissue and the possibility of bioaccumulation of parasites to reduce heavy metals concentration in their hosts [8]. With regard to urban ecosystems, data on the use of parasites as potential bio-indicators for heavy metal pollution are still very scarce and apply exclusively to cestode/mammal models [9,10]. While, models have been proposed for water birds [11] or raptors [12], but no data on urban birds are available.

In Saudi Arabia, the nematode *Ascaridia columbae* is one of the most common helminthes for pigeons. Since, nematode/pigeon systems were never evaluated, the main objective of this study was to evaluate the accumulation of trace elements in *A. columbae* and in *Columba livia* tissues in Riyadh, Saudi Arabia, and therefore to evaluate the *A. columbae*/*C. livia* model as another promising bioindicator system.

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## 2. Material and methods

A total of 26 of the domestic pigeon, *Columba livia*, were accidentally picked from a poultry farm in Riyadh, Saudi Arabia. The pigeons were taken to the laboratory and then dissected and examined for the presence of endoparasites under a dissecting microscope. Helminthes were collected from infected organs using a pipette and washed several times to remove residues and mucus in saline petri dishes. Based on taxonomic keys, parasites were identified based on their morphological properties. Based on the protocol mentioned in UNEP/FAO/IOC/IAEA [13], both parasite and pigeon tissues were removed and analyzed separately to detect heavy metals. The samples were digested with concentrated nitric acid and perchloric acid (2:1 v/v) for 3 days at 60°C. After complete digestion, the samples were diluted with bidistilled H<sub>2</sub>O and then analyzed for trace elements in an inductively coupled plasma mass spectrometer (Varian Model-Liberty Series II, Analytical West, Inc., Corona, California, USA). The values of all observed heavy metals are given in mg/g wet-weight in comparison to the values determined by FAO/WHO [14].

Absorption wavelengths and detection limits for heavy metals using an Elbert mount diffraction grating monochromator (Horbia Scientific, NJ, USA) were 188.980 nm and 0.16 ppm for As, 214.439 nm and 0.04 ppm for Cd, 267.716 nm and 0.04 ppm for Cr, 327.395 nm and 0.05 ppm for Cu, 257.610 nm and 0.05 ppm for Mn, 220.353 nm and 0.13 ppm for Pb, 196.026 nm and 0.09 ppm for Se, 213.857 nm and 0.04 ppm for Zn, 231.604 nm and 0.001 ppm for Ni, 238.204 nm and 0.01 ppm for Fe, 279.553 nm and 0.01 ppm for Mg, 396.152 nm and 0.12 ppm for Al, 455.403 nm and 0.16 ppm for Ba, 238.892 nm and 0.02 ppm for Co, 202.032 nm and 0.05 ppm for Mo, 407.771 nm and 0.13 ppm for Sr.

In addition, the bioaccumulation factor (BAF) was determined to quantify the bioaccumulation of heavy metals in pigeon tissues, according to Sures et al. [7]. All data from the experiment were presented as means ± SE and underwent a one-way analysis of variance test (ANOVA) in which significant relationships between heavy metal accumulation in parasite and pigeon tissues were identified. All statistical procedures were performed using SPSS statistics 16.0 software (SPSS Inc., Chicago, IL, USA) and Duncan's multiple range tests. When p-values were <0.01 and <0.05, variations were considered significant.

## 3. Results

Based on the taxonomic keys, nematodes are identified according to their morphological characteristics as *Ascaridia columbae*. The distribution of elements in the host-parasite system presented in Table (1). Pigeons infected with intestinal nematodes have a significant decrease in the elements compared to non-infected ones. The concentration of metals in the tissues of the infected pigeon was Zn > Al > Mg > Cu > Sr > Ni > Ba > Cd > Fe > Se > Mn > Mo > Co > Cr > Pb > As. The ability of tissues of infected pigeon for the collection of different metals were found in the following order: ovary > pancreas > kidney > feather > liver > lung > muscle > heart > testes.

In all the elevated host tissues, Zn was the dominant element. Liver accumulates in large quantities compared to other tissues. The heart was the main place for accumulation of Mg. In comparison to other tissues, the highest mean concentrations of As and Al were found in the kidney. In addition, in the kidney and feather, Mn was prominent. Fe and Co increased significantly in the lungs. In contrast to other pigeon tissues, the ovary contains Cr, Cu, Pb, Ni, Fe, Mg, Al, Ba, Co, Mo, and Sr that accumulated significantly in large quantities. On the other hand, it is observed that other metals of As, Cd, Cr, Se, Ni, Co and Mo accumulate in feather. The remaining elements (Cd, Cu, Pb, Se, Ba, and Sr) increased significantly in the pancreas have. Muscles and testes are the lower organs for the accumulation of metals. The heavy metal concentrations found in the parasites were significantly higher than in the tissues of the host pigeons, and were ordered as follows: Sr > Mn > Zn > Mg > Al > Mo > Se > Ni > Cd > Ba > Cr > As > Cu > Pb > Co > Fe. The concentrations of these metals are generally at dangerous levels which exceeded the acceptable limits prescribed by the US Environmental Protective Agency.

The differences found among the majority of the heavy metal density in various tissues and parasites of pigeons are significant (Table 2). This showed that in parasitic nematodes, the capacity to accumulate heavy metals was significantly higher than the apparent difference in the tissues of its host. As a result, the ratio (C[nematode parasite]/C[pigeon tissue]) for the most essential elements was higher than 0.5, with the following order Mn > Se > Cd > Mo > Ba > Cr > As > Sr > Co > Ni > Zn > Pb > Cu > Mg > Al > Fe. In addition, Mn (BAF=7948.6) yielded the highest bioaccumulation factor, which gave higher accumulation ratio between parasite and pigeon tissues higher than other elements.

**Table 1** Effect of parasitic infestation on trace element concentrations ( $\mu\text{g/g}$  wet weight) in infected pigeon organs as well as in parasitic nematode *A. columbae*

Trace element	Different host tissues									<i>A. columbae</i>
	Liver	Kidney	Heart	Lung	Muscles	Pancreas	Ovary	Testes	Feather	
As	0.66±0.07 <sup>c</sup>	2.93±0.3 <sup>bc</sup>	0.17±0.13 <sup>c</sup>	0.54±0.04 <sup>c</sup>	1.27±0.04 <sup>c</sup>	0.63±0.04 <sup>c</sup>	0.71±0.08 <sup>c</sup>	1.26±0.05 <sup>c</sup>	7.54±3.58 <sup>b</sup>	83.59±4.17 <sup>a</sup>
Cd	0.26±0.03 <sup>c</sup>	0.22±0.07 <sup>c</sup>	0.29±0.08 <sup>c</sup>	0.95±0.34 <sup>c</sup>	1.47±0.49 <sup>c</sup>	3.63±1.13 <sup>c</sup>	2.69±1.05 <sup>c</sup>	0.64±0.17 <sup>c</sup>	38.15±6.29 <sup>b</sup>	132.61±11.64 <sup>a</sup>
Cr	1.37±1.13 <sup>b</sup>	1.69±0.49 <sup>b</sup>	0.32±0.73 <sup>b</sup>	0.51±0.08 <sup>b</sup>	0.53±0.19 <sup>b</sup>	2.72±1.01 <sup>b</sup>	3.62±1.13 <sup>b</sup>	0.41±0.09 <sup>b</sup>	8.01±2.06 <sup>b</sup>	100.47±10.80 <sup>a</sup>
Cu	12.7±1.2 <sup>cd</sup>	9.44±0.8 <sup>de</sup>	4.62±0.59 <sup>ef</sup>	4.62±0.55 <sup>ef</sup>	13.01±2.1 <sup>cd</sup>	23.27±3.68 <sup>b</sup>	18.64±3.26 <sup>bc</sup>	3.33±0.01 <sup>ef</sup>	0.15±0.03 <sup>f</sup>	62.65±4.58 <sup>a</sup>
Mn	3.78±1.15 <sup>b</sup>	8.77±1.43 <sup>b</sup>	0.06±0.01 <sup>b</sup>	2.66±1.82 <sup>b</sup>	0.15±0.03 <sup>b</sup>	2.52±1.03 <sup>b</sup>	0.02±0.002 <sup>b</sup>	0.40±0.13 <sup>b</sup>	9.43±1.51 <sup>b</sup>	729.86±29.66 <sup>a</sup>
Pb	1.79±0.82 <sup>b</sup>	1.14±0.21 <sup>b</sup>	1.04±0.14 <sup>b</sup>	0.86±0.13 <sup>b</sup>	1.55±0.51 <sup>b</sup>	4.86±1.47 <sup>b</sup>	7.12±1.32 <sup>b</sup>	0.18±0.08 <sup>b</sup>	0.46±0.10 <sup>b</sup>	57.65±6.49 <sup>a</sup>
Se	1.97±0.50 <sup>b</sup>	0.90±0.32 <sup>b</sup>	0.04±0.02 <sup>b</sup>	3.72±1.15 <sup>b</sup>	2.28±0.51 <sup>b</sup>	9.13±2.60 <sup>b</sup>	7.06±1.79 <sup>b</sup>	0.16±0.06 <sup>b</sup>	7.15±1.37 <sup>b</sup>	183.97±8.90 <sup>a</sup>
Zn	86.98±7.3 <sup>b</sup>	48.8±6.2 <sup>cd</sup>	16.11±1.3 <sup>e</sup>	25.81±3.2 <sup>de</sup>	25.72±2.6 <sup>de</sup>	54.96±7.24 <sup>c</sup>	101.23±10.6 <sup>b</sup>	15.86±2.01 <sup>e</sup>	0.58±0.21 <sup>f</sup>	394.50±22.57 <sup>a</sup>
Ni	1.01±0.13 <sup>c</sup>	3.47±0.71 <sup>c</sup>	0.77±0.08 <sup>c</sup>	1.31±0.12 <sup>c</sup>	2.79±0.22 <sup>c</sup>	4.71±0.519 <sup>c</sup>	5.60±0.19 <sup>c</sup>	1.11±0.14 <sup>c</sup>	33.70±7.92 <sup>b</sup>	173.83±12.21 <sup>a</sup>
Fe	4.14±1.44 <sup>d</sup>	4.85±0.9 <sup>cd</sup>	4.15±0.97 <sup>d</sup>	9.42±1.79 <sup>c</sup>	1.53±0.58 <sup>d</sup>	2.58±0.95 <sup>d</sup>	15.10±3.36 <sup>b</sup>	0.98±0.30 <sup>d</sup>	3.63±1.16 <sup>d</sup>	22.34±2.05 <sup>a</sup>
Mg	6.49±1.44 <sup>c</sup>	12.27±2.6 <sup>c</sup>	22.96±2.04 <sup>c</sup>	6.73±1.66 <sup>c</sup>	10.04±1.5 <sup>c</sup>	21.39±3.82 <sup>c</sup>	53.91±8.12 <sup>b</sup>	8.70±1.89 <sup>c</sup>	16.87±2.11 <sup>c</sup>	337.12±26.11 <sup>a</sup>
Al	19.67±4.6 <sup>d</sup>	76.99±8.7 <sup>b</sup>	18.24±3.6 <sup>d</sup>	63.55±9.6 <sup>b</sup>	30.93±7.2 <sup>cd</sup>	60.32±6.1 <sup>cb</sup>	65.57±8.89 <sup>b</sup>	19.47±4.23 <sup>d</sup>	5.52±1.74 <sup>d</sup>	245.44±138.6 <sup>a</sup>
Ba	2.18±0.82 <sup>b</sup>	5.44±1.76 <sup>b</sup>	2.13±0.99 <sup>b</sup>	4.84±2.01 <sup>b</sup>	7.96±2.45 <sup>b</sup>	12.21±4.08 <sup>b</sup>	14.41±5.28 <sup>b</sup>	3.36±1.24 <sup>b</sup>	0.07±0.01 <sup>b</sup>	128.92±20.44 <sup>a</sup>
Co	0.22±0.09 <sup>c</sup>	0.67±0.15 <sup>c</sup>	0.21±0.14 <sup>c</sup>	4.28±3.85 <sup>bc</sup>	1.58±0.59 <sup>bc</sup>	1.29±0.77 <sup>bc</sup>	2.21±0.87 <sup>bc</sup>	0.45±0.22 <sup>c</sup>	13.09±7.58 <sup>b</sup>	35.83±8.03 <sup>a</sup>
Mo	1.98±0.84 <sup>b</sup>	2.41±1.18 <sup>b</sup>	0.31±0.09 <sup>b</sup>	1.10±0.59 <sup>b</sup>	0.37±0.17 <sup>b</sup>	3.33±1.38 <sup>b</sup>	4.64±1.178 <sup>b</sup>	0.94±0.31 <sup>b</sup>	10.57±1.69 <sup>b</sup>	214.72±23.93 <sup>a</sup>
Sr	2.70±0.99 <sup>b</sup>	4.75±2.26 <sup>b</sup>	1.71±0.55 <sup>b</sup>	4.53±1.41 <sup>b</sup>	6.83±1.66 <sup>b</sup>	12.36±2.82 <sup>b</sup>	12.77±3.57 <sup>b</sup>	2.76±1.13 <sup>b</sup>	8.22±5.54 <sup>b</sup>	969.00±35.08 <sup>a</sup>

\* Mean values within the same row with different superscripts (a, b, c, d, e, f) differ significantly at  $p \leq 0.05$ .

**Table 2** Mean and range of accumulation factors  $[C]_{\text{parasite}}/[C]_{\text{pigeon tissue}}$  for trace elements detected in *A. columbae* in relation to *C. livia* tissues

Trace element	Accumulation factors $[C]_{\text{parasite}}/[C]_{\text{host tissue}}$								
	Liver	Kidney	Heart	Lung	Muscles	Pancreas	Ovary	Testes	Feather
As	132.59**	29.378	521.08	164.39*	62.457**	126.73	124.93*	66.967	9.2780**
Cd	518.61	714.79	462.77*	248.52	112.56	41.824*	56.573**	239.56*	3.4970
Cr	350.11*	67.809**	281.57	204.82*	190.56*	37.861*	30.604**	242.06	12.833*
Cu	4.8520	6.4044	14.333**	13.986	4.9534	2.6802	3.5640	18.548*	410.83**
Mn	211.96*	90.656**	1210.4	2124.7*	4608.1*	377.01*	7948.6*	1899.1	73.698*
Pb	46.791	38.427	51.004**	64.544*	45.116	13.942	8.1730*	169.10*	134.34**
Se	114.69*	280.96**	1660.9	54.610	88.295*	20.931**	25.677**	1468.2*	26.009*
Zn	4.6634	8.6093	26.479**	15.963*	15.994*	7.2553	3.2345	26.826	719.29
Ni	174.83**	51.406*	228.82	133.41**	60.806	37.218**	31.727*	155.62*	5.5769*
Fe	6.3571	4.6153	5.8746**	2.6680*	18.033**	9.0316	1.5977	26.713	6.6989*
Mg	53.672*	26.460**	14.532	47.282	34.621	16.454*	5.9691	36.733*	15.411
Al	12.680	3.1049	14.385**	3.7257*	8.2375**	4.0253	3.6711	12.626*	44.130**
Ba	74.311**	28.070	94.238	33.0733*	20.874*	12.383*	12.693*	58.563	1773.5*
Co	188.74	49.847*	530.05**	45.140	22.782	47.044	18.515	60.386*	7.2763
Mo	155.73*	101.98	835.05	225.99**	571.82**	62.283**	48.708**	244.04	20.225*
Sr	241.06*	100.58**	319.90*	98.046*	69.566	44.972	44.069**	195.47**	48.004*

\* Accumulation is significant at the 0.05 level \*\* Accumulation is significant at the 0.01 level

#### 4. Discussion

The metal concentrations of intestinal parasites is compared to that of its host organs, indicating that it accumulates heavy metals in concentration, which have higher orders than its pigeon hosts. Such results were agreed with Sures [15] and later by Eissa et al. [16] whom reported that parasites accumulate large amounts of toxic metals in their bodies, thus acting as metal sinks for their hosts and helping them survive in the presence of toxins. Moreover, Azmat et al. [17] reported high levels of toxic metals in *Echinocephalus* sp. and *Ascaris* sp. in its host suggested that these parasitic nematodes can be used as environmentally sensitive indicators for heavy metals. In addition, Madanire-Moyo and Barson [18] reported that parasites are excellent indicators of environmental conditions.

This research showed that the ovary was a major target organ, which received the largest amount of heavy metals from the pigeon body. A possible explanation for this is the existence of high amounts of Pb, consistent with Forstner and Wittmann [19], who demonstrated that Pb has an effect on the permeability of the membrane of host organs, where it inhibits the biosynthesis of heme and induces functional disruption or degradation of these tissues. The increased concentration of elements in host muscles during infection can be caused by the host's compensatory response [20].

With respect to the essential elements, higher concentrations of Zn are frequently detected without any toxic effect on the health of the organism. In addition, Zn can reduce its toxicity in contact with specific toxic elements such as Cd and Pb [21]. In the present investigation, the distribution of Zn in different organs of infected pigeons was in agreement with Pourang [22] who studied the accumulation of several heavy metals in *Esox lucius* and *Carassius auratus* from Anzali wetland. On the other hand, higher concentrations of Cu are usually toxic [23]. As, Bireš et al. [24] have shown that Zn prevents the accumulation of Cu in animal tissues and, therefore, provides some protection against the toxic effects of Cu. The most affected element here was Fe, Cu, Zn, Mn, and Co, which are lower in the host muscles. This indicated that the essential pathogenic effect of parasitic infection on the quality and usable biomass of the host, this agreed with Baruš et al. [25]. In the present study, the mean concentrations of Cu, Ni, Cd, Se, Mo, Co, Cr, and As were found to be higher in

pigeon feathers compared to soft tissues. This was accepted with Ek et al. [26] stated that the concentration of the metals in the feather is usually due to external contamination and the internal metabolism of trace elements.

In non-infected pigeons, the bioaccumulation of different metals in different organs was higher than in infected ones. Several studies have documented a reduction in the levels of some elements in parasitized host, including Fe [27], Ca, Na, and Mg [25], Zn [28], Cu [29], and Pb [30] these are similar to the results described here, in that intestinal nematode parasites have a higher metal bioaccumulation efficiency compared to pigeon tissues.

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## 5. Conclusion

Particular pigeon nematode parasites from the terrestrial environment may accumulate toxic metals. Therefore, the application of certain parasites as sentinel organisms could provide a new promise of environmental science for future research.

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## Compliance with ethical standards

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### *Disclosure of conflict of interest*

The authors declare that they have no conflict of interest regarding the content of this article.

### *Statement of ethical approval*

The present research work does not contain any studies performed on animal subjects by any of the authors.

### *Statement of informed consent*

Informed consent was signed to all respondents before the data collection.

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