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Influence of taxa, trophic level, and location on bioaccumulation of toxic metals in bird's feathers: A preliminary biomonitoring study using multiple bird species from Pakistan

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HIGHLIGHTS

- The first study which screens toxic metals in multiple birds species of Pakistan.
- The study shows metals tendency for various taxonomic and trophic groups of birds.
- This study reports metals concentration snapshot along the stretch of Pakistan.
- It is the first endeavor which unveils the metals associated risks to local avifauna.

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ABSTRACT

Increasing concentrations of heavy metals in the environment and their effects on ecosystems and biota is still an imminent threat, particularly in developing parts of the globe. The aim of the present study was to screen the heavy metal concentrations in multiple bird species across Pakistan and to preliminary evaluate the influence of taxa, trophic level, and geographical location on heavy metal accumulation in various bird species. For this purpose, we measured the concentration of 9 heavy metals (Pb, Cd, Cr, Ni, Co, Cu, Fe, Zn and Mn) in feathers of 48 bird species from different localities in Pakistan. Species exhibited heterogeneous levels of heavy metals in feathers with marked inter and intra specific variations. Mean concentrations of studied metals in feathers followed the trend Fe > Zn > Cu > Pb > Mn > Cr > Ni > Co > Cd. Species belonging to closely related taxa (families) showed comparable metal concentrations in their feathers, inferring potential phylogenetic similarities in metal exposure or accumulation. In general, concentrations of metals were greatest in carnivorous species followed by omnivorous and insectivorous birds, and granivores showing minimal levels ($p < 0.000$). Furthermore, concentrations of metals varied significantly between locations ($p < 0.000$) exhibiting highest concentrations in Punjab province and Baluchistan, probably due to higher industrial and agricultural activity and runoff, respectively. With certain limitation, influence of trophic level, taxonomic affiliation and sampling location of birds on toxic metal accumulation was also statistically corroborated through principal component analysis (PCA). This study highlights that despite restricted emissions, heavy metals persist in the local environment and may pose elevated risks for the studied bird species in Pakistan.

1. Introduction

Over the past few decades, excessive deposition of heavy metals in the environment and their negative impacts on ecosystems and organisms has attracted the attention of ecotoxicologists throughout the globe (Frantz et al., 2012). Heavy metals are persistent elements and ubiquitous in the environment due to both naturally occurring geological cycles and anthropogenic activities. Terrestrial and aquatic ecosystems receive heavy metals for example through accidental discharge, waste dumping and/or atmospheric fallout. Subsequent exposure of biota results in accumulation of

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heavy metals in their tissues and increase of metals accumulation in each succeeding feeding guild (Deng et al., 2007; Naccari et al., 2009). Presence of heavy metals in the environment poses a genuine threat to the quality and sustainability of ecosystems (Burger, 1993; Furness, 1993). A wide range of adverse effect due to heavy metals contamination in organisms, including endocrine and nervous disorders, genotoxicity, and certain physiological and behavioral abnormalities, has been observed in various studies (Burger and Gochfeld, 2000; Martin et al., 2003; Dauwe et al., 2004). Due to increasing public concern regarding heavy metal contamination, it is therefore necessary to assess, monitor, evaluate, manage and remediate ecological damage (Movalli, 2000; Naccari et al., 2009). In a living ecosystem, organisms vary in their level of metal accumulation depending upon their diet, trophic level, age, size, gender and various other internal or external parameters. Assessing the condition of an ecosystem by measuring the concentrations of contaminants in all compartments of the ecosystem is difficult, time consuming and labor intensive. So, for the sake of convenience various indicator (sentinel) species are commonly used which are exposed to the environment and could best reflect the state of that ecosystem in a wider range (Burger and Gochfeld, 2000; Scheifler et al., 2006; Brait and Antoniosi-Filho, 2011; Falq et al., 2011).

Birds are useful sentinels for environmental contamination as they reside at the top of the food chain, are long lived, bioaccumulate a variety of contaminants, are widely distributed in the environment and sensitive to detect environmental change (Furness, 1993; Llabjani et al., 2012). Globally, birds are widely used for biomonitoring. Most of the recent literature has focused on birds of prey (Jager et al., 1996; Movalli, 2000; Battaglia et al., 2005; Burger and Gochfeld, 2009), water fowl and seabirds (Kim and Koo, 2007; Moreno et al., 2011), and small passerine birds (Dauwe et al., 2000; Jaspers et al., 2004; Leonzio et al., 2009). Raptor birds are particularly good bioindicators. These species, being at the top of the food pyramid can yield information over a large area around each sampling site, not only on bioavailability of contaminants but also their possible course of biomagnification in the food web (Battaglia et al., 2005). Some species have biological habits that increase the likelihood of exposure to contaminants and, in that way can produce relevant information that would be missed if only water or soil would be analyzed. Most recently, urbanely-dwelled species like feral pigeon (*Columba livia*) have also been used for the environmental monitoring of urban environment (Brait and Antoniosi-Filho, 2011; Frantz et al., 2012). Measuring the pollutant concentrations directly in the internal tissues of birds is well in practice and proven to be the best indicator for bioaccumulative compounds. But recently, the need for alternative, non-invasive tissues for biomonitoring has arisen for various ethical, practical and conservationist reasons. Instead of sacrificing living birds, different non-invasive matrices such as eggs (Jaspers et al., 2005; Van den Steen et al., 2006; Eens et al., 2013) and feathers (Jaspers et al., 2004; Kim and Koo, 2007; Frantz et al., 2012) are commonly used for biomonitoring. Despite all its pros and cons, feathers offer many advantages as a useful non-destructive biomonitoring material and are often considered to be an excellent tool for monitoring bioaccumulativ compounds (Malik and Zeb, 2009; Garcia-Fernandez et al., 2013).

Among the non-destructive matrices, feathers are most advantageous for bird biomonitoring because they are easy to collect, store and transport. Feathers can repeatedly be sampled from a living bird; moreover, samples can be collected without seriously affecting the fitness of the bird. Reproductive success of birds can also be monitored without interference (Spahn and Sherry, 1999). Furthermore body feathers can be removed from a bird without producing adverse effects on the bird so it is a much valued non-destructive biomonitoring tool for endangered species (Behrooz et al., 2009; Jaspers et al., 2011). During the period of feather growth, heavy metals accumulate in feathers in proportion with the blood concentrations (Eens et al., 1999). Contrary to blood, which reflects short term exposure to metals (Furness, 1993), feathers exhibit a long term exposure because metal accumulation continues throughout feather growth until blood vessels atrophy from it. So feathers serve as an archive for food based bioaccumulative compounds (Burger and Gochfeld, 2000). Because of these specific properties and ease of utility, feathers have been used as a non-destructive biomonitoring tool for metals contamination for decades (Burger, 1993).

Metal accumulation in birds is mostly affected by metal species, its bioavailability and exposure pathways (Burger et al., 2008). Moreover, in literature it is presumed and somehow proven that accumulation of metals in birds is influenced by a variety of parameters such as trophic position, taxonomic group, genetic variability, age, gender, size of bird and feathers types etc. (Burger and Gochfeld, 2000; Dauwe et al., 2002; Burger et al., 2008; Burger and Gochfeld, 2009; Zolfaghari et al., 2009; Lucia et al., 2010; Castro et al., 2011). Many studies revealed that metal accumulation differs in birds with different feeding habits, feeding strategies and trophic levels on the food chain. Birds on the top of the food chain usually accumulate more metals in their tissues than those which are lower on the food chain (Burger and Gochfeld, 2000; Tsipoura et al., 2008). Van Straalen and Ernst (1991) also suggest that levels of metal accumulation in indicator species might increase with the age of the organism and its trophic position. Effects of taxonomic affiliations of birds species on metals have been reported in a limited number of studies (Ochoa-acuna et al., 2002; Zolfaghari et al., 2009). To the best of our knowledge no comprehensive study has investigated the combined effects of trophic level, taxonomic affiliation, and geographic location on metal accumulation in birds. In Pakistan, so far no baseline data for metals contamination in bird is available. It is the first study in which we investigated metal concentrations in 48 selected bird species from different localities in Pakistan and compared toxic metal concentrations among different taxonomic groups, feeding guilds (trophic level) and widely stretched geographical locations in Pakistan. The purpose was to preliminary study the inter and intra-specific variation of heavy metal concentrations in different bird species from Pakistan. We made a first attempt to study the obscure linkages between heavy metal accumulation in different taxonomic groups and trophic levels in birds from Pakistan. In addition, we performed a geographical comparison to compare and evaluate the contamination level at different locations in Pakistan.

2. Materials and methods

2.1. Feathers sampling

Feathers (approximately 0.25 g for each individual; 3–5 birds per species) from a total of 48 species were collected and analyzed from different locations of Pakistan (details on species and sample sizes per location are presented in Table S.I. 2). Whole sampling was carried out from September 2011 to August 2012. No birds were captured for the sole purpose of this particular study; all the samples were taken from birds caught in other studies and some for commercial uses. Fig. 1 demonstrates different sampling sites and number of species collected from different sites. Samples from different individuals (n) of any single species were collected around the same location in the study area. No species was sampled from two or more locations. Sampling sites included remote rural areas, rivers, lakes, dams, cities and two coastal sites. Most of the samples were collected from Punjab province, which is the hub of industrial and agricultural activities. No industrial unit or