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Review Article

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Hedgehogs and Biomonitoring Heavy Metal(loid)s

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Abstract

Trace elements pollution is a current One Health problem, affecting the health of all living beings (including humans and animals) and the environment itself. Metal(loid)s (as As, Cd, Co, Cu, Hg, Pb, and others) represent hazardous substances with implications in different organs and organic functions, in both acute or chronic exposures. The use of animal species as biomonitoring tools has been pointed out as an essential piece to correctly monitor and evaluate this pollution worldwide. Hedgehogs have been used for this purpose although in very few locations, despite the notable potential they have, due to several biological and ecological characteristics. Their food regiment (mainly insectivorous), distribution, resilience, trophic level and adaptability represent some examples of those positive aspects. This review intends to briefly summarize these hedgehogs' attributes and critically analyse them as positive aspects that turn this species into a suitable bioindicator of exposure and effects of heavy metal(loid) pollution.

KEYWORDS
Metal, Metalloid, Erinaceus spp, Bioindicator, Contamination.

Introduction

Heavy metals and metalloids are inorganic substances with undeniable importance in human, animal and environmental health (One Health) (Hawkes, 1997; Duffus, 2002). One Health is a transdisciplinary subject that relies on the assumption that human health is deeply connected with the health of animals and the environment. Despite the fact that it is not a new concept, One Health principles have been applied to multiple health research projects and strategies, especially in veterinary medicine. The main reasons and recent situations that support this tendency include human population growth, the global movement of people and food, wildlife habitat loss, climate change, and the emergence of new epidemics and pandemics among others (One Health | CDC, 2021).

Heavy metal(loid)s are also frequently named as "trace elements". These substances can be divided into essential elements and non-essential elements. Non-essential elements are those which have no biological function in the body (such as Hg, Cd, Pb, As), whilst essential elements (such as Fe, Cu, Mn, Co, and Zn) take part in several physiological reactions. However, despite the type of element, all of them may cause severe lesions under different amounts, chemical forms, routes or frequencies of exposure (either chronic or acute). For instance, while some are carcinogenic (as As), others are nephrotoxic (as Cd), neurotoxic (Pb), or hepatoxic (Cu or Co) (Khan *et al*., 2015; Ali and Khan, 2019).

Measuring metal(loid)s in the environment is undoubtedly valuable to know which areas should be monitored. However, the use of living beings gives a broader perspective of its consequences on wildlife, domestic animals and humans (D'Havé *et al*., 2007; Shen *et al*., 2019; Jota Baptista *et al*., 2021, 2022; Baptista *et al*., 2022). This is called biomonitoring. From a veterinarian's perspective, biomonitoring allows the quantification of dangerous substances that an animal has been exposed to. Moreover, when allied with histopathology or biochemical analysis, biomonitoring studies allow a prediction and description of the organic lesions that may be associated with exposure to a compound. Ultimately, biomonitoring assessments are crucial to understanding a problem completely and developing mitigation strategies. Not surprisingly, some species are better bioindicators and sentinels of heavy metal(loid)s than others, depending on several biological and ecological factors such as their micro-habitat, trophic chain position or resilience (Alleva *et al*., 2006; Shen *et al*., 2019; Jota Baptista *et al*., 2021, 2022; Baptista *et al*., 2022).

Therefore, this review intends to briefly present the aspects that make hedgehogs suitable bioindicators of heavy metal(loid)s, as well as why and how more hedgehog assessments must be done in the future.

Hedgehogs – biological and ecological aspects

Hedgehogs are mammals from order Eulipotyphla and family Erinaceidae. According to the most recent taxonomy classification, the different hedgehog species are grouped in five genera: Erinaceus (the woodland hedgehogs - *E. europaeus*, *E. concolor*, *E. amurensis* and *E. roumanicus*), *Hemiechinus* (the long-eared

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hedgehogs, *H. auritus* and *H. collaris*), Mesechinus (the steppe hedgehogs – *M. dauuricus* and *M. hughi*), *Paraechinus* (the desert hedgehogs – *P. aethiopicus, P. hypomelas, P. micropus*, and *P. nudiventris*) and Atelerix (the African hedgehogs - *A. albiventris, A. algirus, A. frontalis* and *A. sclateri*). These species have different geographical distributions across Europe, Asia and Africa. There are no native species in America or Australia (Chin and Mans, 2012; Ivey and Carpenter, 2012; Lima, 2013; Amori, 2016; Bexton, 2016; Doss and Carpenter, 2020; Taucher *et al*., 2020).

Currently, their conservation status is classified as Least Concern for all the mentioned species. In general, most hedgehog species are considered stable in most of their geographical locations, with a few exceptions due to the presence of predators or competitors (for instance badgers' influence in *E. europaeus* in the UK). Specifically in Europe, *E. europaeus* has the broadest distribution, being the most commonly found species in western and central Europe, while *E. roumanicus* is present in eastern Europe and Asia. Nevertheless, hybridization has been reported (Zolotareva *et al*., 2021). Under captivity, *A. albiventris* is the most popular hedgehog used as a pet (Juan-Sallés *et al*., 2006).

Hedgehogs are primarily insectivorous, adaptable and very resistant to distinct habitats, from woodlands to rural and urban areas (Vermeulen *et al*., 2009). Although they have a broad geographical distribution, each individual has a small space range (10-30 ha), which allows them to be used as indicators of a health problem in a specific area (D'Havé *et al*., 2006), as chemical pollution. Due to their use as companion exotic pets, *A. albiventris* pathology is better described in literature than the other species, especially regarding neoplastic lesions (Pei-Chi *et al*., 2015). Nevertheless, other biological and clinical information may be obtained for other species, under comparative medicine. On the other hand, wild hedgehogs are becoming more and more common in human gardens and anthropogenic areas, which increases the frequency of human-animal contact, sometimes leading to unfortunate accidents (as car collisions) or human infections by zoonotic agents (as dermatophytosis) (Garcês *et al*., 2020; le Barzic *et al*., 2021; Lukešová *et al*., 2021). In most countries, hedgehogs are one of the most common mammals admitted to rescue centres (Lukešová *et al*., 2021). Therefore, hedgehogs can be considered species of interest to study a variety One Health issues, such as environmental pollution by heavy metal(loid)s (Jota Baptista *et al*., 2021).

Heavy metal(loid)s assessments– a potential tool

In most cases, insectivores (as hedgehogs) and carnivores tend to present higher levels of pollutants, effects and clinical signs than herbivorous animals due to the bioaccumulation phenomena between trophic levels (Alleva *et al*., 2006; Vermeulen *et al*., 2010; Heiker *et al*., 2018).

As an illustration, hedgehogs have shown higher levels of Pb than herbivores or omnivores due to the consumption of insects and earthworms, which bioaccumulate notably high levels of Pb (Reinecke *et al*., 2000). Notwithstanding, some hedgehog species are part of urban fauna, which means they are progressively occupying areas with high levels of urbanisation, where Pb is more frequently present (Alleva *et al*., 2006). On the other hand, in more natural and unpolluted areas, the amount of these compounds (found in hedgehogs' tissues) is usually lower and related to age. The relationship found between the level of metal(loid)s and the hedgehog's age consistently supports the fact that these compounds show a tendency to perpetuate in the environment and bioaccumulate in living beings during their lifespan (in hedgehogs' case 6-8 years) (Rautio *et al*., 2010).

Distinct metal(loid)s' studies have been published, where authors analyse different tissues, namely the blood, liver, kidneys, hair, and spines. While hair and spines can be used as non-invasive samples, internal organs may provide a better insight into the distribution, accumulation, and cellular or molecular damages induced by these substances (Jota Baptista *et al*., 2022). The high hedgehogs' casuistic in recovery centres (Lukešová *et al*., 2021), and the associated mortality contribute to establishing a tissue bank, based on internal organs from necropsies that can be stored frozen for a long time before metal(loid) quantification. On the other hand, spines are transformed hairs that can be easily obtained from captured hedgehogs or hedgehogs under rehabilitation with minimum manipulation. Furthermore, different authors have been studying and reporting correlations for heavy metal(loid) concentrations between spines and internal organs, highlighting the potential of this sample to be used in biomonitoring studies (D'Havé *et al*., 2005, 2006; Vermeulen *et al*., 2009; Dahmardeh *et al*., 2021). This is not possible or feasible for most wildlife species without certain restraint methods or collection equipment.

As mentioned above, wild hedgehogs occupy woodlands, rural areas and, in more recent years, urban habitats. They are progressively invading urban areas and getting into close contact with humans and domestic animals (in urban parks or private gardens), with some people attracting them with pet food to their properties (Taucher *et al*., 2020; App *et al*., 2022). Similarly, African pigmy hedgehogs are exotic pets, sharing the environment with their owners. Even though this may increase the disease spread between species, this also turns the hedgehog into a "true representative" of what are we (and other species) exposed to and what are we absorbing and accumulating in our bodies (including regarding metal(loid)s). Furthermore, hedgehogs are present in all the different continents (except the Antarctic), mostly with stable populations with a suitable abundance of animals.

Due to all the above arguments, the authors of this article clearly believe the potential of hedgehogs must be taken into consideration for future biomonitoring studies. Even though other species may also be considered as suitable for the same or other reasons (Santiago *et al*., 1998; Komarnicki, 2000; Sánchez-Chardi, 2007; Sánchez-Chardi *et al*., 2007; Sánchez-Chardi and López-Fuster, 2009), hedgehogs should definitely be candidates for this purpose.

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conflict of interest

The authors declare that they have no conflict of interest.

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