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HEAVY METAL-INDUCED ECOTOXICITY IN CHIROPTERA: A REVIEW OF IMPACTS ON BIOLOGICAL TRAITS AND ECOLOGICAL CONSEQUENCES

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Abstract
The most potent environmental pollutants, heavy metals, are released into ecosystems through the effluents of various industries, leading to significant degradation of the environment. Around the world, there is much interest in extreme heavy metal pollution in the environment. These hazardous heavy metals bioaccumulate in many animal tissues, which allows them to enter the food chain. In some areas, bats can assist in biomonitoring of metal exposure. The development, reproduction, and physiology of bats are all adversely impacted by heavy metal toxicity. This review also delivers an overview of the significance of bats, the properties of heavy metals, and the methods by which bats are exposed to heavy metals.

INTRODUCTION

A major risk for bats currently is being exposed to heavy metals. Although several health issues arise due to exposure to heavy metals, pollution from heavy metals continues and is increasing in a number of countries. According to Jan et al. (2015), the eleven heavy metal elements most dangerous for protecting wildlife are lead, tin, manganese, nickel, chromium, copper, mercury, cadmium, cobalt, manganese, and thallium. However, some metals like iron, manganese, and zinc are vital components of life (Wang & Matsushita, 2021). Bats are among the most prevalent animals, with colonies that number in the millions and include some of the highest of organisms on Earth (Hammerson et al., 2017).

Bats are present on every continent except Antarctica. They make up 20% of all mammal species and are the second biggest mammal order, with the greatest diversity occurring in tropical areas (Nowak, 1994). The group is vulnerable to multiple sources of pollutants because of the broad diet of bats, which supports the various environmental services (Jones et al., 2009). Pesticides are typically consumed via fruits (Oliveira et al., 2017) or contaminated insects (Stahlschmidt et al., 2017) by species that feed in agricultural regions. According to Zukal et al. (2015). Through the food chain, trace heavy metals can also bioaccumulate in vegetation, insects, and bats. Bats' higher rates of absorption and food consumption than those of other tiny animals or birds can make them more vulnerable to metal accumulation through nutrition (Zoche et al., 2010).

Bats can serve as regional bio monitors for metal exposure owing to their rewards over other species in terms of ecology and methodology (Ramos et al., 2020).

Biological pest control, distribution of seeds, guano mining, bush meat, medicine, tourism for bat viewing and aesthetics, research, and teaching are some of the economic advantages that bats provide. Bats have little detrimental impacts on the environment and economy. Animals, humans, buildings, crops, and infrastructure are all targets of their destructiveness. Not only that, but they bite people as a kind of self-defense, spread illness, and contaminate the environment (Kasso & Balakrishnan, 2013). The unfavorable belongings of heavy metals on bats' biological characteristics are the primary focus of this review.

Heavy metals

Elements having a specific density of more than 5 g/cm3" are typically used to designate heavy metals (Järup, 2003). Heavy Metals also include metalloids like arsenic (As), which may be hazardous at low exposure levels, assuming that toxicity and heaviness are connected (Bradl, 2002). Chromium (Cr), cadmium (Cd), nickel (Ni), copper (Cu), zinc (Zn), lead (Pb), mercury (Hg), aspartame (As), and many other heavy metals are recognized to be detrimental to the environment and biologically unneeded (He & Yang, 2005). Soils, rocks, sediments, water, and living organisms all contain natural background absorptions of heavy metals in a variety of quantities. The environment naturally contains heavy metals. However, anthropogenic contamination results in greater concentrations of these metals than the usual background values (Dung et al., 2013). These substances can bioaccumulate when retained in the body due to exposure to tainted food, water, or skin (Souza et al., 2020). When they are transferred to other creatures via the trophic chain, a series of events can occur, including hereditary harm. Thus, the possibility that these metals could harm environmental and public health has been the subject of numerous research (Ngo et al., 2021)

Exposure of Bats to heavy metals

Because of their excellent mobility, bats can also be utilized to identify metal exposure across vast areas. Bat exposure to metals from mining operations and air pollution has been documented (Zocche et al., 2010; Hariono et al., 1993). However, nothing is known about the possible dangers of metal in bats until this point (Hernoet, 2013).

Effects on the organs of bats

Recent bat population decreases have been attributed mostly to exposure to heavy metals and pollution (Mickleburgh et al., 2002). The consequences of these contaminants on bat populations and the bioaccumulation of metals in bats, worldwide, are mostly unknown topics (Zukal et al., 2015) numerous investigations documented lead poisoning and possible effects of lead on bat reproduction. Sub-lethal concentrations of Cd, Pb, and other trace elements have also been found in the fur, faeces, and body parts of several species; however, the majority of these studies were from North America and Australia (Walker et al., 2007).

According to Destro et al. (2023), the analysis of heavy metal toxicity in fruit bats revealed variations in organ sensitivity and highlighted the harmful effects of acute exposure, even at low doses.

Effects on kidney and liver

The primary organs in the body that are in charge of detoxification are the liver and kidneys. The liver performs various tasks, including phagocytosis, chemical conversion of harmful compounds, and blood detoxification by excretion in bile (Fox, 1991). The quantity of waste materials that are filtered from the blood and returned to circulation and the extracellular fluid environment of the body is controlled by the kidneys (Fox, 1991). As a result, contaminants that bats ingest, such as the metals found are either retained, broken down, released, or collected in a less harmful form (Baker et al., 2003).

The protein called metallothionein 1 E (MT1E), which is primarily produced in the liver and kidney, protects against metal damage by binding to and detoxifying metal ions (Sakulsak, 2012). Metallothionein has a considerable affinity for some important metals like Zn and Cu as well as non-essential metals like Cd and Hg, according to Waalkes et al. (1984). Over-binding of metal ions to metallothionein can result in physical harm to tissue, including changes in histopathology (Goyer, 1989), as seen in the kidney and liver. (Sánchez-Chardi et al., 2009).

Effects on Muscles

Bats are more vulnerable to the deleterious effects of heavy metal accumulation during hibernation, migration, or breastfeeding when their fat reserves are depleted (Speakman & Thomas, 2003).

But an accumulation of metals in the organs can cause a variety of tissue damage, including inflammation, necrosis, hyperplasia, and hypertrophy. Ma (1989) asserts that altered organ size and impaired organ function can also be consequences of tissue injury. When mercury levels in bat tissues rise, the number of neutrophils a kind of white blood cell that fights fungi and germs decreases (Beldomenico et al., 2008).

Effect on Hormones

Long haul openness to weighty metals can raise glucocorticoid chemical levels connected to long haul stress. As per Becker et al. (2017), this expands the inflammatory reaction in bats, expanding their vulnerability to white-nose disorder.

Effects on brains

Bats might aggregate inorganic and organic pollutants in their tissues in the wake of being presented to contaminations for a lengthy period (Bayat et al., 2014; Hernout et al., 2016). The cerebrum has a pivotal part in controlling hibernation in insectivorous bats (Chen et al., 2008), exploring past hindrances, and catching prey (Schwartz and Smotherman, 2011; Wenstrup and Portfors, 2011). The fitness of bats might be antagonistically impacted by changes in mind pathways brought about by the development of these heavy metals. For example, as indicated by research by Hill et al. (2018), involuntary muscle spasms might be brought about by hindering the synapse acetyl cholinesterase. As indicated Gilgun-Sherki et al. (2001), neurodegeneration, weakened coordination, and sensory impairment could result from expanded oxidative pressure related responsive oxygen species (ROS). Overabundance ROS can attach to glial cells of brains and neurons, delivering neurodegeneration. Investigation into the impacts of foraging on the neurological capability of resident insectivorous bats is, subsequently, critical.

Effects on DNA

Surveying DNA harm is the primary challenging deciding the stress that contamination causes in living things (Klobučar et al., 2003) among the numerous destructive results that genotoxic mixtures might have, including carcinogenesis, teratogenesis, embryo toxicity, and a gathering of related ailments known as genotoxic illness syndrome (Kurelec, 1993). Since most substances have both genotoxic and metabolically poisonous impacts, it is strange for genotoxic mixtures to damage DNA only (Henderson et al., 2000).

The Comet assay's true capacity in ecological biomonitoring strategies has accumulated more interest as it has been utilized to decide whether contaminations could cause DNA harm (Klobučar et al., 2003). Klobučar et al. (2003), Lee and Steinert (2003), and Andrade et al. (2004) have all utilized various species as bioindicators. The extraordinary ways these animals respond to natural changes give data on their physiology, organic chemistry, hereditary qualities, and behavior. Metal exposure is thought to cause more DNA sores, which may be brought about by an increase in the creation of ROS or by obstructing DNA repair mechanisms. Many problems, like malignant growth and premature aging, are supposed to bring about by oxidative DNA harm (Beckman & Ames, 1998).

Effect of Hg on mitochondrial DNA

Mercury's molecular processes, which include the production of free radicals and oxidative pressure, effects on microtubules, repercussions for DNA repair systems, and direct interaction with DNA, may account for its genotoxicity, as suggested by Crespo-Lópeza et al. (2009). Mercury increases the production of reactive oxygen species (ROS) in addition to depleting glutathione (GSH), a crucial antioxidant defense mechanism (Ercal et al., 2001). Base changes and single- and double-strand break in DNA can be brought on by an accumulation of reactive oxygen species (ROS). Mercury affects DNA repair, chromatin structure, and replication by direct complexation, as demonstrated by Castoni and Costa (1983).

Because mitochondrial DNA (mtDNA) is naturally sensitive to genotoxic effects, it is a remarkable tool for determining inherited damage (Santos et al., 2006). Although base excision repair is present in the mitochondria, nuclear DNA and mitochondrial DNA differ in their protective protein architectures and nucleotide excision repair mechanisms. These components are essential for repairing DNA adducts and overt oxidative damage (Cline, 2012). Consequently, mtDNA sustains more damage than nuclear DNA (Cline, 2012). The inner mitochondrial membrane contains mitochondrial DNA (mtDNA), which is already exposed to high concentrations of reactive oxygen species (ROS) due to its proximity to the respiratory chain. Because they promote the formation of distinct DNA adducts and endogenous DNA lesions, environmental contaminants including metals, polycyclic aromatic hydrocarbons (PAHs), and PCBs can exacerbate the illness (Cline, 2012).

Belyaeva et al. (2012) discovered that Hg exposure caused mitochondrial damage in rat cell cultures. Furthermore, exposure to ethyl mercury enhanced the amounts of oxidant-damaged mitochondrial DNA bases and blunt-ended breaks and mitochondrial DNA nicks in human astrocytes by a factor of five. Bats' mitochondrial DNA was more severely damaged.

Bats as Bioindicators

Bioindicatorrefers to a species of narrow amplitude concerning one or more environmental factors and that, when present, indicates a particular environmental condition or set of conditions" (Allaby, 2010).

Bats are effective bioindicators for environmental mercury (Hg) pollution due to their comparatively long lifespan, elevated metabolic rate, and increased food intake, and vast geographical distribution. Bats may be seen consuming water, and insects may contain mercury and other trace metals. This is because these metals have a bio-accumulative property. Insectivorous bats are more likely to acquire hazardous levels of certain trace metals because of their long-life spans (Jones et al., 2009; Lison et al., 2016).

There is a direct correlation between the area's traffic and the concentrations of metal pollution in tiny animals, such as bats. It has been shown that insectivores tend to have more significant amounts of metals in the same habitats than herbivores. Contaminated tissues with heavy metals return to the environment once an organism dies. Research indicates that heavy metal concentrations in many bat species are not decreasing relative to their historical levels. Monitoring ecosystem health is crucial to monitoring heavy metal pollution in bats (Walker et al., 2007).

Conclusion

The effect of heavy metals on bats features a squeezing natural concern that stretches beyond the prompt government assistance of these mammals to the more extensive biological equilibrium and human health. This review addresses the essential natural role bats play, their vulnerability to heavy metal contamination, and their flowing impacts on environments. The findings stress the dire requirement for coordinated endeavors in checking, guidelines, and public attention to relieve heavy metals. Protecting bats from such dangers defends their population and preserves their essential commitments to biodiversity, pest control, and pollination. Eventually, addressing heavy metal contamination is fundamental in keeping up with natural respectability and ensuring their health for the planet.

Recommendation

- To protect bats from the perilous impacts of heavy metals, it is essential to incorporate strict pollution control measures and upgrade ecological observation.
- Activities focus on diminishing heavy metal outflows from urban, industrial, and agricultural sources through better guidelines and cleaner advancements.
- Promoting bats as bioindicators for environmental health can help with the early recognition of the degradation of the environment, directing remediation endeavors.
- Protection techniques should focus on conserving bats' natural habitats, particularly in regions inclined to heavy metal contamination.
- Embracing an exhaustive methodology that joins administrative requirements, community engagement, and research can relieve the effect of heavy metals on bat habitats and save the ecosystem.

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