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Exploring the Toxicological Landscape: Heavy Metals and Their Impact on Animal Health and Productivity

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Abstract

The ecosystem, wildlife and people are at risk when heavy metals are released back into the environment as a result of anthropogenic activity. It is well recognized that several contaminants, including lead, cadmium, arsenic and mercury, are dangerous. Conversely, some elements are required for biological functions, such as zinc, copper, cobalt, iron, magnesium, manganese, selenium and cysteine. Overconsumption of certain metals over tolerance limits can expose animals to tainted feed along with water and put them at risk for health problems. Animal exposure to heavy metals and environmental contamination are results of anthropogenic activities that lead to the redistribution of heavy metals. While hazardous heavy metals can endanger an animal's health when they are above a threshold, essential heavy metals are partially responsible for measuring the functioning of the body. Exposure can occur through tainted food, water, or naturally high levels of heavy metals. Prolonged exposure causes degradation that impacts productivity and general health. Heavy metals are persistent in the body and have an impact on an animal's quality of life, reproduction and health. Public health is at risk when heavy metal concentrations in animal products exceed permissible limits. Overexposure to heavy metals causes acute or chronic toxicity in animals, which has an impact on reproductive processes, general health and product quality. In this review examining the field of toxicology and assessing the animal's welfare and productivity. Prolonged exposure results in decreased efficiency and a decline in general health. Animal products pose a risk to public health when they contain heavy metals over essential limits. Effective management techniques, targeted drugs and early diagnosis are crucial for reducing the harmful effects of heavy metal poisoning on the health and productivity of cattle.

Keywords: Toxicity Landscape, Animal’s Health, Productivity, Arsenic, Lead, Mercury, Cadmium

INTRODUCTION

A vital component of animal civilization and the contemporary global economy, animal husbandry produces resources, including meat, milk, leather and wool. Concerns about animal care, sustainability and environmental effects are present in modern livestock farming. Heavy metals have a dual role in the intricate network of ecological systems as organic components (1) and artificial pollutants (2). Essential trace elements like zinc and copper (3) are necessary for animal physiological processes, as shown in Figure (1). An excess of these and other heavy metals can harm an animal's health and productivity. There are concerns over the potential effects of heavy metals on terrestrial and marine ecosystems (4) due to their widespread distribution in the environment and their genesis from industrial processes, naturally occurring sources and agricultural operations.

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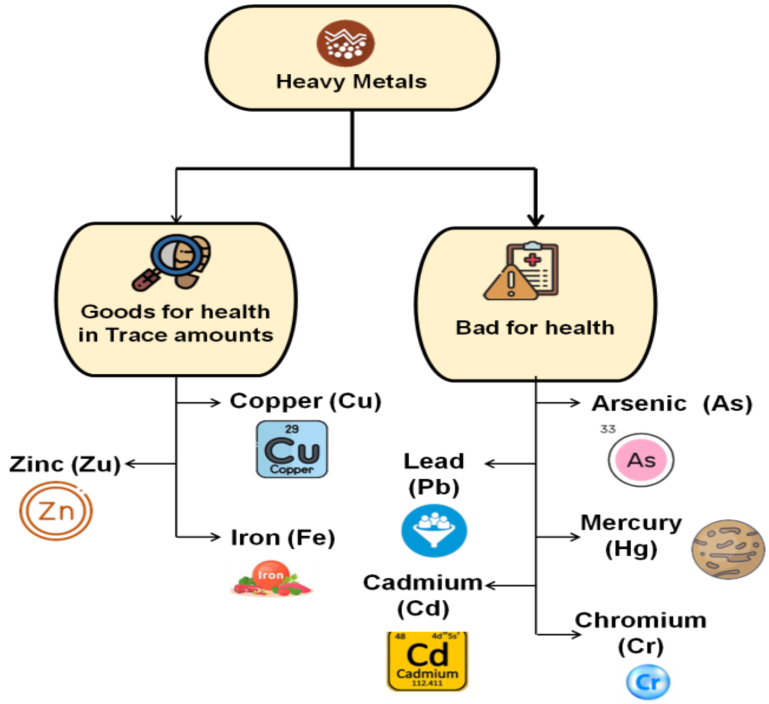

Figure (1). Positive and Negative Effects of Heavy Metals on Animal Health (Source: Author)

Heavy metal pollution of soil, mostly from industrial and agricultural sources, is a global health concern since it can be ingested through food items and it is made worse by fertilizer use, home waste and industrial effluents (5). Among the essential services provided by agricultural systems, which comprise grasslands and farming businesses, are food and raw materials. Fertility depends on soil microbes, especially bacteria, but soil quality is threatened by animal activity and soil finiteness (6). In 1984, a devastating industrial accident occurred at the Union Carbide India Limited (UCIL) pesticide plant in Bhopal, Madhya Pradesh. The toxic gas leak exposed 5,000 residents and led to thousands of deaths (7). The facility, which has been abandoned, is highly contaminated with persistent organic and inorganic pollutants. UCIL produced the different insecticides: Carbaryl (Sevin) is a mixture of Aldicarb (Demic), Cevitol, Carbaryl and γ-HCH (Gamma-hexachlorocyclohexane) and Methyl Iso-Cyanate (MIC), these components are not heavy metal, but it is a reactive component, that component reacted with water to form a toxic heavy metals like lead (Pb), mercury (Hg), cadmium (Cd) and chromium (Cr) (8). There can be different isomers of HCH because of how the other isomers are processed, used and removed. More stable substances called chlorinated benzene compounds were developed as byproducts of HCH (Hexachlorocyclohexane) or HCB (Hexachlorobenzene) breakdown or used as surfactants (9). The overuse of benzene hexachloride (BHC), which has been connected to a number of toxicological consequences, including neurological and reproductive abnormalities, has resulted in severe pollution in Bhopal. Five isomers α, β, γ, δ and ε makes the technical grade of HCH. Known by another name, γ HCH, lindane possesses insecticidal qualities, but in lab animals, it has been linked to liver and renal damage (10). Being a highly carcinogenic compound, alpha HCH is categorized as a potential animal carcinogen. Recognized as a possible animal carcinogen, beta HCH is the most stable isomer and builds up in tissues. Because it dissolves well in fat and it is poorly soluble in water, chlorinated benzene is not hazardous in the short term but is toxic over the long time (11). As cooling solutions and sealants, heavy metals such as mercury and chromium were used; this caused high pollution and raised persistent problems for the health of the surroundings and animals, as well as animal health (12).

This study looks at the role that heavy metals play in a toxicological environment like Bhopal and how they interact with animal life, highlighting the significance of comprehending how these interactions impact animal health, animal consumption and agricultural sustainability. It examines the physiological response and potential health impacts of consuming contaminated animal products.

The Vital Role of Heavy Metals in the Natural Environment

High in atomic weight and density, heavy metals have both advantageous and detrimental effects on animals and animal surroundings. These are elements that are found naturally and they are necessary for many physiological processes, including the control of enzymes, oxygen transport and antioxidant defense. Iron, zinc and copper are examples of essential metals that are vital to good health (13); deficits in these elements can result in the toxicity that nonessential heavy metals produce. Heavy metals can be divided into four categories: high toxicity, low toxicity, unnecessary and essential (14). Needed elements promote vital processes in the body, but very toxic, unwanted metallic elements like As, Pb, Hg and Cd are hazardous at modest doses while offering not known biological advantage. These harmful heavy metals can build up in biological tissues, interfere with cellular processes and resemble essential elements. Metals' fundamental characteristics impact both their bio-transformation and toxicity (Figure (2)).

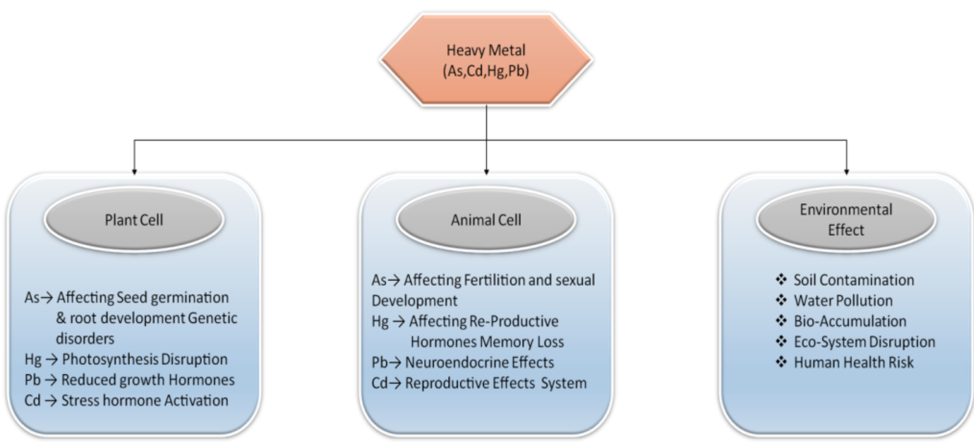

Figure (2). Vital Role of Heavy Metals in Environment (Source: Author)

The non-destructive nature of heavy metals poses difficulties for detoxification processes, in contrast to organic substances, which can be broken down into less hazardous components. The persistence of heavy metals in the environment and their accumulation in living things add to their toxicity. The persistent and bioaccumulative character of heavy metal pollution is highlighted by their inability to be broken down into less harmful byproducts (15). The possibility of heavy metal toxicity, particularly with highly toxic heavy metals, is a significant reason for concern when it comes to animal and animal exposures. To control the hazards related to heavy metal pollution, put preventative measures into place and create plans for cleaning up impacted areas, it's critical to comprehend the distinctions between necessary and unnecessary heavy metals. Various anthropogenic sources cause heavy metals, which are unaffected by animal activity, to be concentrated and redistributed in the environment (16). The burning of fossil fuels, mining, metallurgy, foundries and vehicle emissions are a few of them. The toxicity of heavy metals is a result of natural processes such as soil erosion, volcanic activity, metal evaporation, corrosion, sediment re-suspension and geological weathering. The average quantities of lead, cadmium, mercury and Arsenic in various environmental media are shown in Table (1). Crystalline minerals contain Arsenic, although different amounts can

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be found in soil, groundwater and surface water. These concentrations are essential for evaluating the state of the ecosystem and any possible hazards related to these heavy metals.

Table (1). Natural Level of Heavy Metals in Environment (Source: Author)

Various Environment	Arsenic	Mercury	Lead	Cadmium
Crystalline	Avg 2ppm	-	-	-
Soil	1-40 ppm	200-300 ppm	15-40 mg/kg	0.3mg/kg
Groundwater	0.01-800ppb	$2\mu g/l$	-	$1\mu g/l$
Surface water	2.38-65 ppb	$0.001 mg/l$	$0.05\mu g/l$ - $2.00\mu g/l$	$0.05\mu g/l$ -$1.0\mu g/l$

Metals are being more widely distributed, which raises questions regarding their ecotoxicological impacts and potential dangers to household animals. Biological enlargement and biological increase in plants and animals are two examples of biological cycles that lead to the absorption of heavy metals into food cycles. Through industrial and agricultural processes, heavy metal pollutants find their way into the food chain, impacting environmental factors, dairy quality and animal welfare. When domestic animals eat polluted plants, feed, water, or soil, they come into contact with heavy metals.

The hazardous impact of heavy metals on the wellness and farming of animals

Animals are not the source of heavy metals or its removers; rather, anthropogenic activities like mining, metallurgy as well as burning fossil fuels cause heavy metals to be redistributed and accumulated in the environment. Natural exposure sources include things like volcanic activity, metal evaporation, erosion, soil erosion, re-suspension of sediment and geologic degradation. The increasing availability of metals raises concerns about their toxicological impact on the natural world, especially with regard to poisoning in domestic animals. Environmental conditions have a direct impact on animal welfare, milk quality and heavy metal pollutants find their way into the food chain through agriculture as well as industry (17). Animals exposed to toxic substances can serve as indicators of how heavy metals hazardous waste impacts the well- being of livestock populations. The use of arsenicals in veterinary medicine, feed additives, growth promoters, drugs for selenium poisoning, grazing pollution from herbicides, pesticides containing arsenic, as well as from lead and copper furnaces, including the prevention along with treatment of animal diarrhoea are among the many sources of arsenic exposure that pose a serious risk to domestic animals in India (18). Animals naturally come into contact with arsenic through metal ores and metal-tainted groundwater. During a thorough 28-year field study project in India, high levels of arsenic were found in over 170,500 tubes well water and soil samples from India. Nearly 10% of the 100,500 people assessed had been exposed to arsenic on a regular basis. Many animals in areas impacted by arsenic exposure eat grasses, feed items, vegetables and rice plants that are polluted with Arsenic in addition to drinking water that has been tainted, which might potentially expose them to As. Arsenic has a complicated toxicity profile; Ten times as dangerous as pentavalent chemical arsenic compounds are trivalent chemical arsenic compounds, known as arsenates. Even in arsenic-affected areas, higher amounts of Arsenic have been found in livestock's milk, blood and hair. Medical cases of arsenic poisoning in animals are uncommon in India (19).

Arsenic Poisonousness

Coal smelting and burning are the primary sources of Arsenic, the third most hazardous heavy metal found in coal ash. Its effects on health are dependent on its chemical form; several forms can be found in the oxidizing chimney

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gas environment that arises from burning coal. Low temperatures release both AsO and As2O3 into the atmosphere, whereas high temperatures release As2O3 (20). Weakness, vomiting, nausea, diarrhea and profuse diarrhea are some of the symptoms of acute arsenic poisoning from contaminated food (Figure (3)).

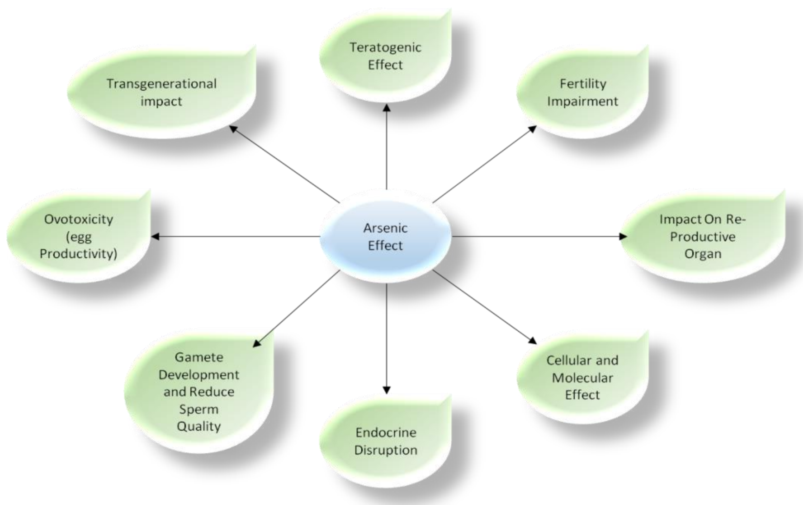

Figure (3). Arsenic Effects (Source: Author)

Heart failure, cardiac arrhythmia, myocardial infarction, asthma and respiratory disorders can result from prolonged exposure, details in Figure (4).

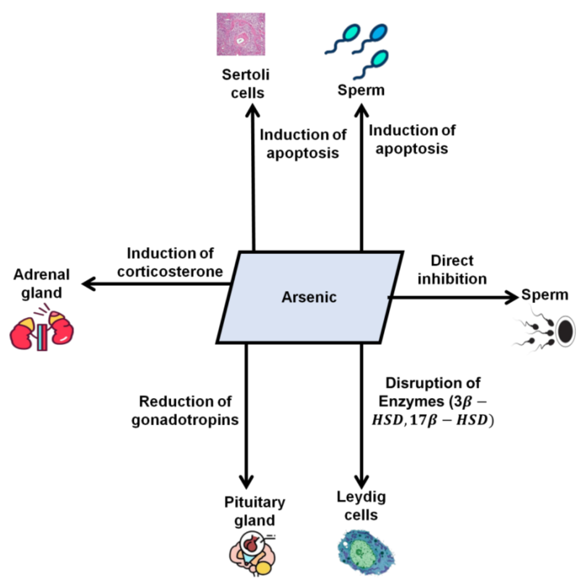

Figure (4). Effects of Arsenic on Male Animal Health (Source: https://www.mdpi.com/2305-6304/10/12/744#)

To reduce hazards to the environment along with animal health and to create preventative measures, it is critical to comprehend the complex toxicity of Arsenic. The leading cause of infertility, a worldwide public health issue, is oxidative stress brought by an abundance of reactive oxygen species (ROS) or reactive nitrogen species (RNS).

Infertility results from this injury, which impacts both the female and male reproductive systems (21). Environmental variables, including heavy metals like arsenic, can cause issues with reproduction by decreasing sex hormone levels, disrupting sperm generation. Ogenesis as well as causing issues in the testicular and ovarian. The imbalance caused by the higher reactive oxygen and nitrogen species throws off the delicate equilibrium required for normal reproduction processes, leading to infertility. Understanding and addressing these factors of the environment is the first step towards solving the global problem of infertility. Because of its elevated levels of contamination of groundwater, arsenic, a naturally occurring pollutant in India's food, water and soil, poses a serious concern to the natural world and public health. Economic and social variables such as poverty and malnutrition increase the incidence of arsenic-related illnesses, which affect about 100 million people globally (22). The therapy with As_2O_3 markedly elevated autophagy, dysfunctional mitochondria and oxidative stress in female mice. This imbalance in the oxidant-antioxidant system exacerbated the damage caused by oxidative stress produced by As2O3. "Reactive oxygen species" (ROS) production surged interfering with energy production and leading to various cellular dysfunctions. It has been established that oxidative stress and mitochondrial dysfunction, which affect ovarian failure, are influenced by autophagy processes (23).

Lead Poisonousness

Lead can have a number of harmful consequences, such as disruption of hemoglobin biosynthesis, increase in blood pressure, damage to the kidneys (24), miscarriages and brain damage. It can have an impact on kids' behavior and capacity for learning. Through the placenta of the mother, lead can enter the fetus and seriously harm the brain and nervous system. Memory loss, depression, nausea, stomach discomfort, coordination problems, exhaustion, sleep difficulties, migraines and anemia can result from prolonged exposure (25). Exposure to lead can have a harmful effect on the female reproductive system, interfere with sperm production and upset hormonal balance. Lead and cadmium's combined effects can make reproductive toxicity much more severe, which helps to explain their impact on reproduction in detail as shown in Figure (5).

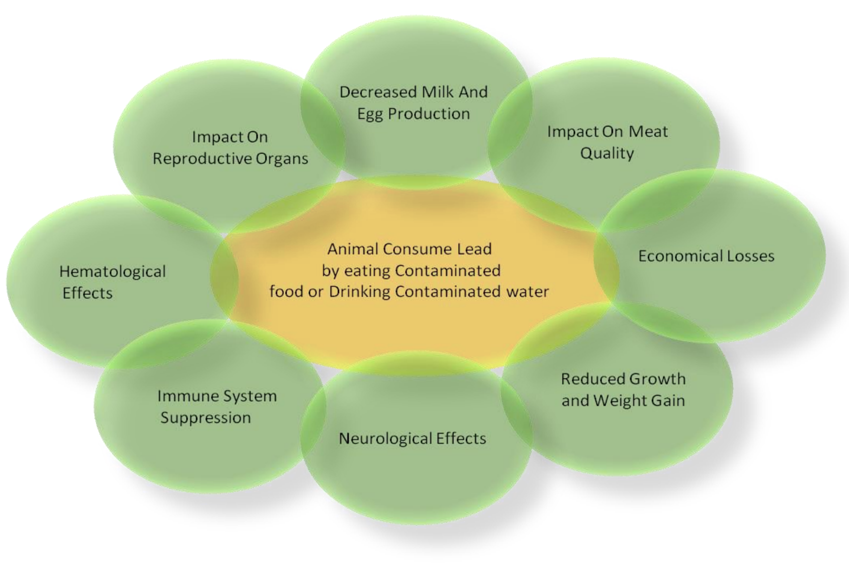

Figure (5). The Impact of Lead on the Welfare of Animals (Source: Author)

Diseases including cancer, reproductive issues, central nervous system dysfunction along with respiratory and cardiovascular disorders are brought by heavy metal exposure. There is a severe risk to human health from these

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pollutants, which include PM, ozone, nitrogen oxide, sulfur dioxide, volatile organic compounds (VOCs), dioxins and PAHs. They can cause immediate poisoning or chronic intoxication (26). The molecular mechanisms of heavy metal poisoning emphasize how these metals attach to proteins and enzymes to cause harm, neurotoxicity, the production of free radicals, reproductive health and oxidative stress (27). In aquatic food webs, piscivorous birds are very susceptible to mercury exposure, which can negatively impact their ability to reproduce. According to Everglades' research, there was little or no association between plasma mercury and albumin mercury coupled with sexual end goals. All post-hatching endpoints showed a negative correlation with feather mercury, which accounted for 8.3% of the variation in the likelihood of laying an egg and a chick (28).

Mercury Poisonousness

It is the only metal that, at average temperature, can exist in both liquid and vapor states (Figure (6)). Mercury is very poisonous and serves no biological purpose.

Figure (6). Mercury State (Source: https://th.bing.com/th/id/OIP.uIbvmv8mG84Nit8NUMCPTAHaEK?rs=1&pid=ImgDetMain)

The body is unable to eliminate mercury once it has entered a biological system. As a result, the metal gets increasingly bio-enriched throughout the food chain (Figure (7)). Long-term mercury exposure harms the neural system, resulting in deep sadness and personality changes, as well as increased excitability, sleepiness, hallucinations, tremors, seizures and memory loss (29).

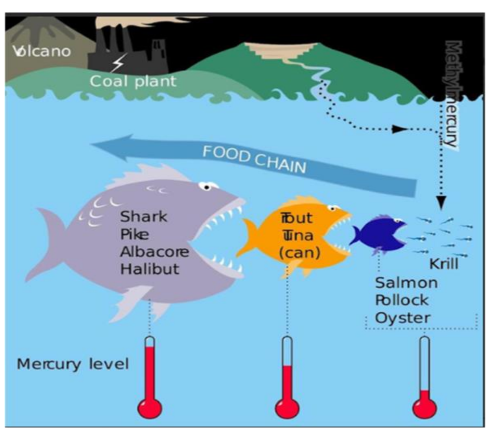

Figure (7). Mercury Level Increase via the Food Chain (Source: https://bluefinfilm.weebly.com/uploads/1/0/8/1/108197151/67788583-727879174312263-8283355913696313344-n_orig.jpg)

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Employees with ongoing exposure have displayed indications of renal impairment. Hazardous mercury can cross the blood-brain barrier that leads to neurological and renal problems. The gastrointestinal tract absorbs 95% of mercury that is consumed; to enter red blood cells and the brain, it attaches to glutathione and cysteine protein groups. Mercury entering the circulatory system can affect the kidneys, central nervous system and red blood cells (30). It is men who are exposed to employment who first see the main neurological effects. Mercury can cause problems with the sensory system, such as hearing, touch, vision, retinopathy and optic neuropathy. Adult animals exposed to mercury can have ataxia, tremor, neuropathy, loss of consciousness and possibly pass away. Thirty percent of pesticide use occurs in the central-western region of Brazil, where higher exposure to pesticides has been linked to higher infant mortality from central nervous system abnormalities. The levels of mercury in adults were associated with total Hg and methyl Hg in those without a history of liver disease (31).

Cadmium Poisonousness

Cadmium is a toxic heavy metal that poses significant health risks to animals due to its absorption and transit through the digestive system. It enters the bloodstream through the liver and accumulates in the kidneys, causing damage to the kidneys and a decrease in their function (Figure (8)).

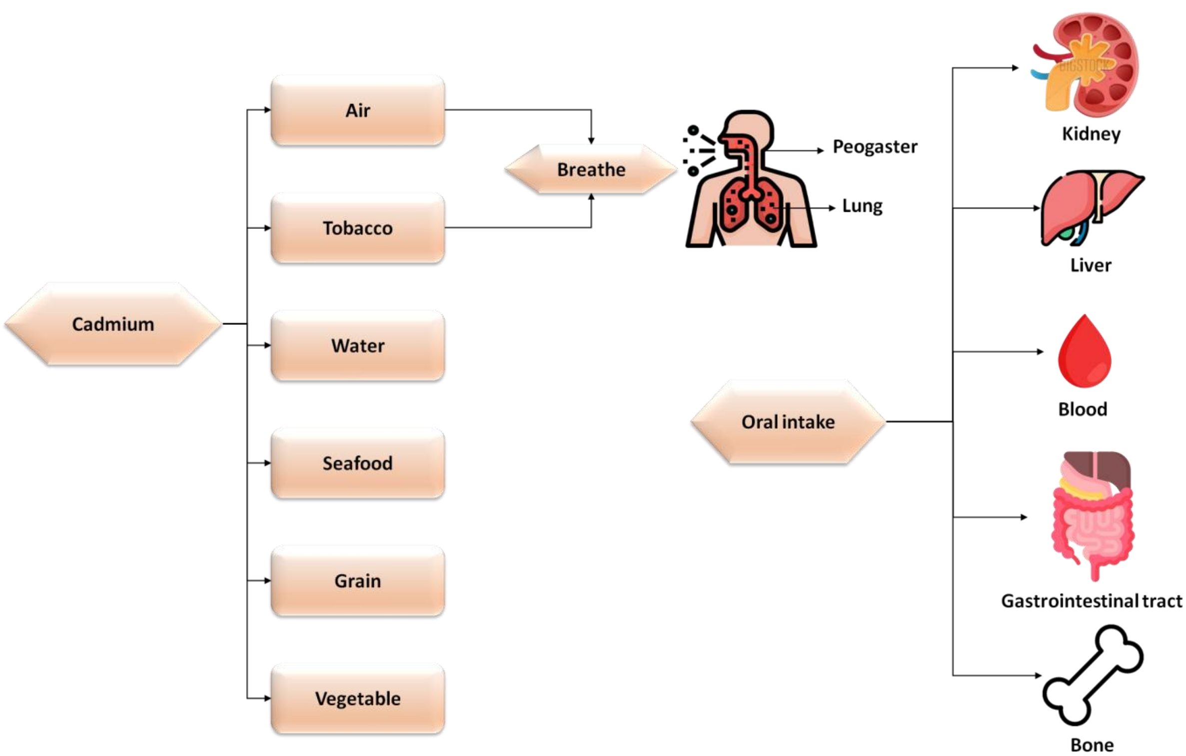

Figure (8). Cadmium Poisonousness for Animal's Health (Source: https://doi.org/10.3389/fimmu.2021.695484)

The kidneys eliminate essential proteins and carbs, which can cause imbalances and long-term accumulation that, exacerbates chronic health conditions. Cadmium can cause gastrointestinal problems, bone fractures, infertility, immune system and neurological damage, psychological issues, DNA damage detailed in Figure (9) and possibly the start of cancer (32).

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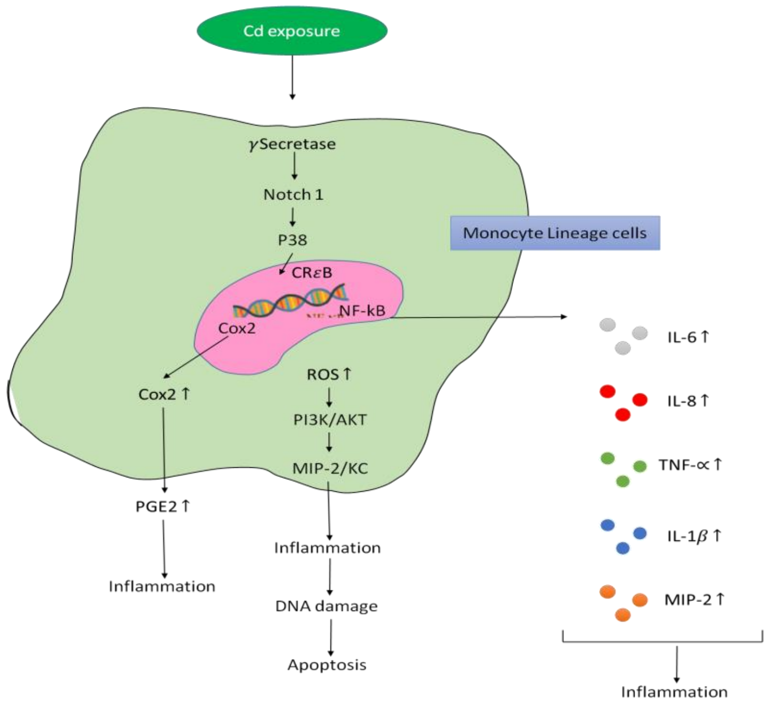

Figure (9). DNA Response (Source: https://doi.org/10.1080/08923973.2019.1697284)

Careful monitoring and management of cadmium levels in food and the environment are necessary to lower the risk of cadmium-related health problems. Thus, to decrease the risk of cadmium-related health issues, preventative actions, including monitoring and controlling cadmium levels, are required. Reduced cadmium exposure can be achieved with the use of proper waste management practices and public awareness. Exposure to cadmium can have detrimental consequences on the skin, heart, bones and reproductive systems (33). It can result in bone distortion, which raises the risk of osteoporosis, discomfort and a lower standard of living. There have been two theories put out regarding bone lesions associated with everyday sickness, the most severe kind of chronic cadmium poisoning (34). Although it can build up in other tissues, including the placenta and bone, cadmium poisoning mainly affects the kidney and liver. Nephrotoxicity from acute cadmium poisoning can lead to cellular damage and an increase in proteins in the urine (35). In mammalian species, cadmium can have an impact on ovarian function that reduces sperm density, size and quantity, impairing development. In addition to giving the gastrointestinal tract water, avoiding cadmium salts and performing gastric waste if excretion is not possible, therapy for cadmium poisoning involves prompt attention. The cadmium removal Japanese technique is given in Figure (10).

Figure (10). Cd Removal Technique (Source: http://www.filtsep.com/view/45906/japanese-firm-develops-cadmium-removal-system-for-wastewater/)

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The potential for removing cadmium from contaminated soil and water has been investigated in relation to Indian mustard and river red gum. Cadmium has been extracted from soil and wastewater using nanoparticles of titanium dioxide and aluminum oxide. Another technology under investigation to remove cadmium from food is microbial fermentation. Updated information on the consequences of cadmium exposure on animal health is included in this review, with a particular emphasis on molecular and intracellular alterations. According to these results, cadmium can be eliminated from food, water and soil by using these plants along with their nanoparticles, which would eventually benefit animal's health (36). Studies conducted on Indian Koels shown that a solitary injection into the subcutaneous tissue of 1.5 mg of *cadmium chloride (CdCl)* per 100g increased ovaries epithelial layer circulation and hemorrhaged as a function of body mass index, ultimately leading to cellular death. Additionally, the magnum's plica membrane showed significant degradation, suggesting that the connective tissues surrounding the site of ovulation is deterioration (37).

CONCLUSION

Due to problems with heavy metals effects in animal's life and environment, animals exposed to heavy metal poisoning are at grave risk for health issues. A comprehensive strategy is required to mitigate the substantial threats that heavy metals pose to animals and the ecosystem. Preventive methods like the phytoremediation and inter cropping can lower the concentrations of heavy metals in the natural world, whereas entree-absorbers and botanical medicines can increase toxicity. Animals are given antioxidants to improve their resilience and general health by preventing the harmful effects of oxidative stress brought by exposure to heavy metals. For certain metallic substances, further research is required on the molecular targets, cytosolic interactions and disastrous the field of epidemiology. Developments in toxicology shed light on how resistant animals are to exposure to heavy metals, which aids in the creation of practical mitigation techniques. Protecting the health and reproductive capacities of animals, ensuring the safety of animal products for human consumption, addressing the problems posed by heavy metal poisoning in animals as well as improving the general environment and public wellness require a comprehensive approach that includes prevention, natural rehabilitation, medical treatments and current research.

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