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Heavy metal toxicity: A serious health concern

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Abstract

The present study is an attempt to review the toxicity of heavy metals such as Cd, Hg, and Pb and its serious health effects on both man and animals. Chronic cadmium intoxication may give rise to renal tubular dysfunction, anemia, and skeletal damage. Exposure to Cd, Pb, and as can cause mutagenesis, carcinogenesis, teratogenesis, immunosuppression. Therefore, it is important to monitor heavy metal levels in animal tissues which are very important for assessing the potential health risks of metals to humans.

Keywords: carcinogenesis, heavy metals, teratogenesis, toxicity

Introduction

Heavy metals are non-biodegradable pollutants in the environment that enters into the system of man and animals through different routes and gets accumulated in the body (Liu *et al.* 2013) [23]. Heavy metals are generally essential micronutrients but they can be toxic at concentrations higher than the amount normally required (Apostoli, 2002) [2]. Heavy metals such as Cd, Hg, and Pb are toxic even at very low concentrations (Kaewsarn and Yu, 2001; Nies, 1999) [18, 30] which causes serious health risk of both man and animal. Chronic cadmium intoxication may give rise to renal tubular dysfunction, anemia, and skeletal damage. Long-term exposure to lead may cause kidney and liver damage and has an adverse effect on the central and peripheral nervous systems, haemopoietic system, and cardiovascular system (Liu *et al*, 2014) [24]. Therefore, it is important to monitor heavy metal levels, which are very important for assessing the potential health risks of metals to humans.

Agriculture and Industries as a source of heavy metals

In recent years heavy metal poisoning has become a serious health concern of man and animal due to the growing industrial and agricultural sector. Heavy metals from industrial waste contaminate water, air and soil. Food and water are the most common sources of heavy metal exposure for humans. Sources of heavy metals in agriculture include atmospheric deposition, pesticides, fertilizers, livestock manures, irrigations and sewage sludge (Neilson and Rajakaruna, 2014) [31]. Some of the most consistent sources of heavy metals in agricultural systems are phosphate-based fertilizers, including single nutrient fertilizers like superphosphates, binary fertilizers like monoammonium phosphate and diammonium phosphate, and some combined NPK fertilizers. While superphosphate fertilizers contain high levels of Cd, Co, Cu, and Zn, copper and iron sulfate fertilizers often have high levels of Pb and contain Ni (Gimeno-Garcia *et al.* 1996) [12]. Mined across the globe, phosphate rock is naturally high in heavy metals and serves as the base for all phosphate fertilizers. However, the amount of metals in phosphate rocks varies with its origin; heavy metal content of igneous phosphate rocks is generally lower than that of sedimentary phosphate rocks. But even metal content within igneous and sedimentary phosphate rocks varies: for example, sedimentary phosphate rock extracted from areas in Pakistan has lower levels of heavy metals than sedimentary phosphate deposits imported from areas of Egypt, Jordan, and Morocco (Javied *et al.* 2009) [17]. In addition, the extent of heavy metal pollution from fertilizers not only depends on the phosphate rock from which the fertilizer was derived, but also on the amount of fertilizer applied. For economic reasons, phosphate fertilizers may not be sufficiently purified during processing and only a limited fraction of metals is lost, leaving trace heavy metals such as Cd, Co, Cu, Pb, Mn, and Zn in the final product fertilizer. Not only are phosphate-based fertilizers a source of heavy metals in agricultural systems, but the processes of mining and milling phosphate rock are also key sources of heavy metal air and soil pollution (Nziguheba and Smolders, 2008) [32]. In pesticides such as fungicides, herbicides, and insecticides, heavy metals are often active compounds (Gimeno-Garcia *et al.*, 1996) [12]. Heavy metals are also present in many livestock diets at background concentrations, but may also be added to certain feeds as supplementary trace elements to promote health and growth. Cu is often added to pig diets as a potential anti-bacterial agent in the gut. However, most heavy metals consumed by livestock are excreted in urine or feces, which will then be present in manure that is applied to land (Nicholson *et al.*, 2003) [29]. In some parts of India, spreading untreated or partially treated sewage effluents over agricultural land is often practiced because it is economically feasible when compared with costly fertilizers. While restrictions and changes in industrial practices in developed nations have limited discharges of heavy metals into sewage, heavy metals may still arise from domestic sources, such as Cu leaching from Cu pipes and Zn from body care products (McClellan and Halden, 2010) [26]. Moreover, repeated applications of wastewater to agricultural land may also cause heavy metals to build up in soils, with the potential for metals to leach into the soil solution and groundwater (Khan *et al.* 2008) [19]. From these sources, heavy metals may get deposited in soils and then accumulate in vegetables and crops such as wheat, rice, carrots, and lettuce (Javied *et al.* 2009; Zhuang *et al.* 2009) [17, 46].

Bioaccumulation of Heavy metals

Many heavy metals accumulate in one or more of the body organs such as liver, kidney, bone and brain with differing half-lives (King, 1990) [20]. Small animals primarily get exposed to heavy metals through ingestion (Beyer *et al.* 1994) [5], but they also may accumulate them through inhalation, grooming, skin absorption or placental transfer during pregnancy (van den Brink *et al.* 2010) [41]. Metal accumulation in various mammalian tissues like lungs, stomach, kidneys, liver, teeth and hair has been reported (Drouhot *et al.* 2014) [10]. The extent of heavy metal poisoning in animals depends not only on the degree of exposure but also on the species, sex, age, season and diet. Much of the literature has cited heavy metal poisoning in large ruminants such as cattle (Roggeman *et al.* 2013) [38], sheep (Phillips and Tudoreanu 2011) [34] and pig (Reglero *et al.* 2009) [37]. The extent of accumulation in large ruminants like cattle depends on the metal and its concentration in herbage and soil, the age of the animal, and how quickly the metal passes through the gastrointestinal tract (Wilkinson *et al.* 2003) [44]. Large grazers also forage at a larger scale than small herbivores, consuming metals from larger geographic ranges and from a greater range of vegetation types. Thus, plant compositions and variations in diet over a season may also play a major role in large mammal exposure to heavy metals. There are models that can predict risk of metal exposure from environmental factors. However, these predictions are most accurate when animal feeding ranges are localized and diet composition is simple. This may not be the case for large mammals whose feeding ranges are larger and may include fodder and feed from both polluted and non-polluted areas (van den Brink *et al.* 2010) [41]. Several studies show that the diet of large mammals is the primary pathway for metal accumulation, reporting elevated levels of heavy metals in the kidneys, livers, bones, hair, and blood of these mammals (Reglero *et al.* 2009; van der Fels-Klerx *et al.* 2011) [37, 42]. In India, Cattle reared near a thermal energy plant had high levels of Hg in their blood, milk, and urine (Mahajan *et al.* 2012) [25]. A Norwegian study of moose in a metal-polluted natural area showed that grazed plants significantly reduced levels of Cd and Zn in their tissues between spring and mid-summer, potentially posing less metal exposure to moose during that time (Brekken and Steinnes, 2004) [6]. Pokorny and Ribaric-Lasnik (2002) [35] reported that deer kidneys contained significantly higher amounts of Hg and Pb in the late summer and early autumn with a similar, but less pronounced, seasonal pattern for Cd and Zn. The authors suggested that elevated food intake of metal-accumulating mushrooms, may explain the seasonal difference in metal accumulation. Again, seasonal variations in large mammal metal concentrations are species-specific and depend on the availability of food, diet compositions, and metal variability within food sources throughout a particular season (Roggeman *et al.* 2013) [38].

Heavy metal Toxicity

Heavy metals are essential for biological systems and provide beneficial effects to animals, but after they exceeds the permissible limit they produces harmful effects in men and animals (Goyer, 1996) [13]. The toxic heavy metals of greatest concern are Cd, Pb and Hg and the exposure to these heavy metals is a continuous daily process (Mortada *et al*., 2002) [28]. Humans may be exposed to heavy metals through several pathways, including dietary intake, occupational exposure, or from the environment such as inhalation of metal-laden dust. Upon exposure, heavy metals cause a variety of adverse health effects. For example, exposure to Cd may cause kidney damage and acute exposure to Hg may damage lungs and kidneys, as well as cause neurological and psychological problems such as changes in personality, restlessness, anxiety, sleep disturbance, and depression (Amaya *et al.* 2013) [1]. Lead poisoning may result in headaches, irritability, abdominal pain, and nervous system disorders (Jarup, 2003) [16]. Heavy metals affects hormone system and growth of body tissues (Teresa *et al.*, 1997) [40]. Furthermore, these heavy metals apart from acute or chronic poisoning can be transferred to the next generation and have potential toxicity from the viewpoint of a public health (Iyengar and Nair, 2000) [15]. Zook (1978) [47] considered dogs and children to be very similar in their susceptibility to lead and risk do exposure from environmental sources. Owing to the close association and common environment shared with humans, dogs are exposed to similar pollutants and have been suggested as sentinels for biohazards from toxic pollutants (Berny *et al.*, 1995; Swarup *et al.*, 2000) [4, 39].Companion animals like dogs and cats share the same level of toxic exposure of heavy metals as their human counterpart. Also, several heavy metals are added to animal diets for various purposes, resulting in a high concentration of heavy metals in animal waste (Ko *et al*., 2004) [21]. Pets may be even more exposed than their owners to some contaminants, such as soil or house dust. Generally animals have shorter life spans than man so latency periods for the development of some diseases are shorter in animals (Backer *et al.*, 2001) [3]. Attempt have been made to study the content of heavy metals in companion animal (Berny *et al.*, 1995; Kozak *et al.*, 2002) [4, 22]. Exposure to Cd, Pb, and As can cause mutagenesis, carcinogenesis, teratogenesis, immunosuppression. They inhibit growth, lowers fertility and impair reproduction (Horiguchi *et al*., 1994; Mahajan *et al.*, 2012) [14, 25]. The heavy metals are important pollutants for fishes, because these are not eliminated from aquatic systems by natural methods, such as organic pollutants, and are enriched in mineral organic substances. Occurrence of heavy metals differs in fishes, depending on their age, development and other physiological factors. Among animal species, the fishes are inhabitants which can be highly affected by these toxic pollutants (Chan *et al*., 2003) [9].

Heavy metal markers

Metal accumulation in large mammals is tested through hair, milk, blood, liver, kidney, and muscle (Cai *et al.*, 2009; Miranda *et al.*, 2009; Reglero *et al.*, 2009) [8, 27, 37]. Blood metal concentrations generally reflect more recent exposure and are therefore more useful when the exposure period is short (Wittman and Hu, 2002) [45]. Liver and kidney accumulations also reflect short-term exposure, while metals accumulated in bone or hair reflect long term exposure (Pragst and Balikova, 2006) [36]. Hair is an important marker of heavy metal toxicity (Wilhelm *et al*., 1989) [43]. Hair gives a better estimate of the total body intake of certain elements than does blood or urine. Hair analysis is inexpensive and fast; it also detects and measures the content of heavy metals and minerals of the hair. The Global Environmental Monitoring System (GEMS) of the United Nations Environment Program selected human hair as one of the important monitoring materials for worldwide biological monitoring of pollution. Therefore analyses of heavy metals (Cr, Pb, Cd and As) in human scalp hair serves as an assessment for environmental contamination and can be used to sensitise individuals towards maintaining a healthier life style in their environments. Onuwa *et al*., 2012 reported a method for analysis of heavy metals in human hair using Atomic Absorption Spectrometry (AAS). AAS is also used for determination of mercury in the environmental and biological samples (Gao *et al*., 2012) [11]. Inductively Coupled Plasma-Mass Spectrometry (ICPMS) is another analytical technique useful for element analysis in hair due to extremely low instrumental detection limits, wide analytical range, negligible matrix effects and capacity for simultaneous, rapid, accurate and precise determination (Budtz-Jorgensen *et al.,* 2004) [7].

Conclusion

Heavy metals are a unique group of naturally occurring compounds released into the environment by various agricultural and industrial processes. The recent increase in industrial activity, including mining, smelting has led to an exponential increase in the amounts of heavy metals released into air, soil and water. Many countries have regulatory guidelines for heavy metal presence and exposure as well as remediation and treatment options. Screening of soil and water sources is conducted frequently to prevent overconsumption, but many of these programs and technologies are not readily available in developing nations. The net result is that people around the globe are exposed to these poisonous substances. New approaches are required to reduce the adverse consequences of accumulation and toxicity of these metals.

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