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Effects of heavy metal residues in livestock feeds and fodders

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Abstract
Heavy metal contamination of animal feeds is a food safety concern that is increasing because it negatively affects the health of animals, the production and human health *via* the food chain. Entry of heavy metals into feed resources from natural and anthropogenic sources such as industrial effluents, wastewater irrigation, agrochemicals and contaminated feed ingredients. While trace elements such as zinc, copper and chromium are necessary for physiological functions but excessive consumption can lead to toxicity. Non-essential metals such as cadmium, lead, mercury and arsenic in particular are particularly dangerous because of their toxicity, bioaccumulation and biomagnification. Chronic exposure depresses the function of organs, mineral balance, immunity and reproduction and residues accumulate primarily in the liver and kidneys. Regulatory enforcement and feed monitoring are essential to provide for animal and public health.

Keywords: Heavy metals, Animal feed contamination, Livestock health, Bioaccumulation, Food safety and Trace minerals

Introduction
Feeds are directly associated with safety of animal-based products (Kamal *et al.*, 2016, 2020) [1, 2]. Food safety risk connected with animal feed can be of three types: biological, chemical or physical (Rahman *et al.*, 2020) [3]. Each hazard is related with specific sources and routes of contamination and exposure. Heavy metals are naturally presenting elements with high atomic weight and a density at least five times greater than that of water (Tchounwou *et al.*, 2012) [4]. Heavy metals such as copper (Cu), cadmium (Cd), chromium (Cr) and lead (Pb) are potential bio-accumulative toxicants that may cause major health problems even at low concentrations (Ali *et al.*, 2013) [5]. While some of the essential heavy metals are included in animal feed to balance the micro minerals (Dai *et al.*, 2016) [6]. Various sources of contaminants such as industrial effluent, sewage water and pesticides are linked to the plant production system and the concentration of contaminants depends on the season and plant type studied. Caggiano *et al.* (2005) [7] studied the concentration of metals along the food chain, namely fodder, milk, milk products and tissues on Italian dairy farms. He found that higher metal concentration in the fodder due to anthropogenic emissions whereas lower metal concentrations occurred in milk and milk products due to the metabolism of the metals in the cow. The highest accumulation of metals was found in the liver and kidneys. Hence, analysis of these tissues can be an indicator or biomarker to characterize the metal concentration towards the end of the food chain. Wastewater holds a range of dissolved and particulate organic matter, soluble organic and inorganic anions which can interact with heavy metals, thereby altering their mobility and subsequent bioavailability (Kunhikrishnan *et al.*, 2012) [8]. They are non-biodegradable substances which can be bio transferred, bioaccumulated and bio magnified in food chains and food webs (Abubakar and Salihu, 2017) [9]. Heavy metals can be classified into two groups: essential (bio metals) and nonessential (or toxic metals). Essential metals (Co, Cr, Cu, Fe, Mn, V and Zn) can also produce toxic effects on organisms at high levels, while toxic metals (Cd, Pb and Al) are toxic to human and animal health and environment even at low concentrations (Russom *et al.*, 2019) [10]. In dairy farming system of Bangladesh, heavy metal contamination was also found due to industrial effluents.

(Kabir *et al.*, 2017) [11]. Bhupal Raj *et al*. (2006) [12] conducted study in Musi river near Hyderabad, India on heavy metal contaminants along the water-soil-plant-animal ecosystem. Ramachandra *et al*. (2018) [13] studied the presence of heavy metals in macrophytes at lake of Bellandur, Bengaluru and found that heavy metals from the lake could be transferred to other organisms such as cattle and humans. If vegetables get contaminated via lake water, fodder grown near lakes might be also carrier of heavy metal. Another study in Mysore, Karnataka suggested that water hyacinth could be a sign of contamination from cobalt and cadmium (Sujatha *et al*., 2001) [14]. Lead and Cd have been considered as chief environmental contaminants as they are easily transferred into the food chain. They relatively produce diverse harmful effects in animals and human on exposure, which may result in undesirable biochemical and physiological alterations. Plasma hormonal changes and abnormal liver function have been observed in cows that were exposed to Pb and Cd in industrial areas (Swarup *et al.*, 2007) [15].

Effects of feed contaminants on animal health

Chemical pollutants with anthropogenic origin can enter into the food chain through water and plant as undesirable contaminants. Those heavy metal show a negative effect on cattle health as well as within the human food chain though at a lower concentration (Dorne and Fink-Gremmels, 2013) [16]. Toxic metals, through various absorption pathways such as direct ingestion, dermal contact and inhalation enter human and animal body (Chandrakar *et al.,* 2018) [17]; such contaminants might not only be harmful for the affected individuals but also have a negative effect on the economy of the affected areas (Bhat *et al.,* 2010) [18].

Table 1: Effect of toxic metals on animal health

Chemical	Toxic effect
Cadmium	Bone diseases (Itai-itai)
Chromium	DNA damage, lung cancer
Lead	Kidney failure, damage of central and peripheral nervous systems and reproductive system
Mercury	Chronic damage to brain, liver damage, damage to the central and peripheral nervous systems, damage to the foetus

Source: Chandrakar *et al.,* 2018 [17]

The presence of Cd (from low level contaminated areas) had a great effect on Cu and Zn homeostasis of cows, increasing the chance for pathogenicity of other metabolic disorders and diseases susceptibility and decrease productivity (Alonso *et al*., 2002) [19]. Miranda *et al.* (2005) [20] reported that the Cd and Pb concentrations in liver and kidney of calves were higher in industrialized than rural zones and these metals might inhibit with the metabolism of trace minerals. According to Ercal *et al.* (2001) [21], oxidative stress in cells can be partly responsible for the toxic effects of heavy metals. Apart from chronic and acute poisoning of the heavy metal contaminated food, heavy metal toxicity can also transfer to the next generation in long term such as adult to offspring or animal to human *via* animal products (Rajaganapathy *et al.,* 2011) [22].

Zinc

Zinc is a crucial element needed by animals in small amounts. Without enough zinc in the diet, there could be loss of appetite, decreased immune function, slow wound healing and skin sores (Gerberding, 2005; Okoye *et al.*, 2011) [23, 24]. Nicholson *et al.* (1999) [25] reported 91 ppm, 29 ppm and 39 ppm Zn in maize gluten, maize silage and rolled barley, respectively and also found 189 ppm Zn in beef cattle feeds. The maximum tolerable concentration of zinc for cattle was set at 500 ppm (NRC, 2005) [26].

Copper

Copper is an essential trace element for formation of many enzymes which is needed for normal growth and development. Li *et al.* (2005) [27] reported the mean Cu concentration in alfalfa hay, haylage, corn silage and corn grain ranges between 3.7 to 6.8 ppm. Nicholson *et al.* (1999) [25] found 10.2, 6.9 and 7.6 ppm Cu in maize gluten, cereals and rolled barley, respectively. They also documented higher concentration of Cu (34.6 ppm) in beef cattle feed. Zhang *et al.* (2012) [28] found the content of Cu ranged from 2.88 to 98.08 ppm in cattle feeds.

Chromium

Chromium is one of the significant components of diet and considered an indispensable trace element. It is involved in the function of insulin and metabolism of lipids in living organisms (Bratakos, 2002) [29]. But, in high concentration can cause renal tubular necrosis, dermatitis, lung cancer and perforation of the nasal system (Idrees *et al.*, 2017) [30]. Sullivan *et al.* (1994) [31] have found that, the Cr content of minerals used for feed ingredients may contain Cr ranging from 60 ppm to 500 ppm. Nicholson *et al.* (1999) [25] reported 1.66 ppm Cr in beef feeds.

Cadmium

Cadmium originates from natural (volcanic activity and weathering of bedrocks) in the aquatic environment or from anthropogenic sources such as mining activities, incineration of waste and agricultural use (Amlund *et al.*, 2012; López-Alonso, 2012; Rajaganapathy *et al.*, 2011) [32, 33, 22]. Nicholson *et al.* (1999) [25] found 0.12, < 0.10 and < 0.10 ppm Cd in maize gluten, cereals and rolled barley, respectively. Again, Hossain *et al.* (2007) [34] found 0.991 to 3.888 ppm cadmium in tannery waste used as feed ingredients. A survey of Cd in cattle feed and cattle manure reported the presence of Cd in cattle feed in farms of different herd sizes, with the mean value between 0.38 to 2.31 ppm in Northeast China (Zhang *et al.,* 2012) [28]. Elliott *et al.* (2017) [35] reported that 21% ruminant feed contain Cd content over the limit of European Union. He found maximum of 68 ppm Cd in ruminant feed.

Lead

Excess natural exposure to Pb in polluted environments alters the endocrine profile and the higher blood Pb level modifies serum biochemical parameters indicative of liver functions (Simsek *et al.*, 2000) [36]. Nicholson *et al.* (1999) [25] reported 2.07, < 1 and 1.16 ppm Pb in maize gluten, cereals and rolled barley, respectively. However, Hossain *et al.* (2007) [34] found higher concentration of lead in tannery waste used as feed ingredients and reported that maximum and minimum concentrations of this element was found 30.114 ppm and 7.577 ppm, respectively. Elliott *et al.* (2017) [35] reported that 16% ruminant feed contain Pb content over the limit of European Union.

Mercury

The origin of mercury in feeds and feed materials can be natural (volcanic activity) as well as from industrial pollution. Fish meal and products containing fish meal such as fish feed should be necessarily monitored, particularly as mercury accumulates in fish tissues. The European Food Safety Authority (EFSA) reported that 8.2% of complete feed for fish (often containing fish) in their study (280 samples between 2003 and 2006) contained mercury levels above the maximum limit of 0.1 mg/kg (EFSA, 2008) [37].

Arsenic

Arsenic in feed and feed material originates from natural geological source, from pollution by industrial activities or specific feed additives (EFSA, 2005) [38]. Arsenic is tended to be accumulated in seaweeds. Especially the brown algae *Sargassum fusiforme* (Harvey) is known for its high concentration of arsenic (Makkar *et al.*, 2016) [39]. Arsenic presents as high-risk impurity in the industrial production of Cupric sulphate (Wang *et al.*, 2014) [40].

Conclusion

Heavy metal contamination of animal feeds represents a food safety challenge of determination with implications for animal health and human consumers. Both essential and non-essential metals enter feed chains through pollution of the environment and contaminated feed ingredients. Chronic exposure to these metals cause disruption of metabolism, decreased productivity which leads to accumulation of residues in animal products. Effective surveillance of feeds, strict compliance to regulatory limit and improved feed and environmental management practices are therefore essential to limit heavy metal transfer along feed-animal-human continuum and to ensure sustainable and safe livestock production.

Conflict of Interest

Not available

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