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Heavy metals in swine meat and manure

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Abstract. The entrance of heavy metals into the food chain poses health risks to humans and animals. In swine, exposure to copper (Cu) and zinc (Zn) is related to antimicrobial resistance, whereas cadmium (Cd) and lead (Pb) are possibly linked to kidney toxicity. Heavy metals detection and bioaccumulation in animal meat and offal motivates continuous monitoring of Pb, mercury (Hg), nickel (Ni), arsenic (As), Cu, Zn and Cd concentrations in pork and wild boar and estimates of human intake. The liquid fraction of swine manure contributes to heavy metals leakage into wastewaters and agricultural soils, with eco-toxicological relevance. Efficient swine waste management systems are developed.
Key Words: Health risks, kidney toxicity, bioaccumulation, offal, eco-toxicology.

Introduction. Heavy metals are ubiquitous in soil, water and air, and their deleterious effects on human and animal health are extensively described (Petrescu-Mag et al 2009; Petrescu-Mag & Petrescu-Mag 2010; Georgescu et al 2011a). The entrance of heavy metals into the food chain entails significant risks to humans. Among metals linked to various threats to human health, the most important are mercury (Hg), lead (Pb), nickel (Ni), arsenic (As), copper (Cu), cobalt (Co), zinc (Zn), cadmium (Cd), selenium (Se), iron (Fe), chromium (Cr) and manganese (Mn), exhibiting either toxic or metabolic effects. In humans, legislative exposure limits are set for some of these heavy metals (Adal & Wiener 2014) but for others, for example Cr or Mn, a clear reference standard is lacking.

Human contamination with heavy metals can be acute (for instance, associated to occupational exposure, or intentional or accidental ingestion) but is, more frequently, chronic. The most important sources of contamination are represented by air, water and food, either through direct industrial pollution of air and water (Petrescu-Mag et al 2009), mining, leakage from various food containers (*e.g.* beverages), or propagation through the trophic chain. Toxicity related to heavy metals is associated with adverse effects on the nervous and hematopoietic system, the liver and lung, and increased risk of neoplasms. More recently, endocrine-disrupting effects of heavy metals were acknowledged, achieved by interactions with the activity of endogenous hormones/hormone receptors.

Table 1

Endocrine-mediated effects and toxicity of heavy metals (Georgescu et al 2011a)

Element	*Endocrine effects*
Lead	Reproductive disruption, infertility, interferes with haematopoiesis, hepatotoxic, neurotoxic
Cadmium	Sex differentiation disorders and reproductive effects, endocrine-related cancer (breast)
Arsen	Diabetes, cancer (bladder, lung, skin), reproductive effects
Mercury	Pituitary insufficiency, reproductive effects, neurotoxic, mutagenic
Zinc	Xenoestrogen
Nickel	Goitrogenic, inhibits prolactin and growth hormone secretion, teratogenic

Particularly, As, Hg, Ni, Pb and Zn are known as endocrine-disrupting heavy metals (Georgescu et al 2011a) and their endocrine-mediated effects are summarized in Table 1.

Heavy metals in swine products and byproducts. Pork meat represents one of the most valuable protein sources for humans. Therefore, the concentration of non-essential elements, including heavy metals, in pork meat is important with respect to human nutrition. Apart from that, Cr and manganese, for instance, are intentionally used to decrease fat and improve carcass characteristics and meat quality.

In a Brazilian study, As, Cd, Pb, Hg, and antimony (Sb) levels were below toxicological reference values in pork meat but increased caesium (Cs) concentration was obtained, mainly in beef samples (Batista et al 2012). Samples from pigs collected at slaughter in North-west Spain showed that mean concentrations for Cd, Pb, Hg, and As in muscles, liver and kidney were low and that the maximum admissible concentrations established by the EU were not exceeded in any sample (Lopez-Alonzo et al 2007). To be emphasized, Pb content in pork liver pastes is higher than would be expected from the liver content alone, the container being an additional important Pb source in this case.

Atomic absorption spectrometry of swine kidney samples from Serbia revealed the presence of Hg in 33.3% of samples, while Cd was detected in only 27.7% of samples but in higher quantities (Milicevic et al 2009). It is notable that histopathological examination of kidneys showed alterations compatible with tubulopathies (haemorrhage, oedema, necrosis etc.), however, these changes were less associated to the presence of heavy metals suggesting synergism among toxic elements and other nephrotoxic compounds.

Cadmium and Pb content was also determined in wild boar meat and liver from various areas such as Viterbo Province (Italy), Mecklenburg-Western Pomerania (Germany) and Poland (Rudy 2010; Danielli et al 2012; Dannenberger et al 2013). Isolated samples contained these metals at levels higher than the EU limits set for domestic animals. Particularly liver samples may contribute to significant Cd and Pb human exposure, especially in children (Danielli et al 2012). Between 2003-2006, estimated average Pb intake resulting from wild boar meat consumption in Southern Spain indicated large variations, ranging from 0.3-38 μg/kg/week, with over 200% above the WHO-recommended provisional tolerable weekly intake observed in hunter populations consuming wild boar (Morales et al 2011; JECFA 2000, 2001). Thus, it is increasingly suggested that the legislation regarding Pb and Cd levels in human food should also cover large game meat.

Pig manure is used as a fertilizer. Applying swine manure compost results not only in addition of nutrients but also in heavy metals (and, possibly, pharmaceuticals) accumulation in the soil, leading to increased heavy metals mobility (Hammer & Clemens 2007). In pork, heavy metals are demonstrated in the liquid fraction of the anaerobically digested swine manure and therefore also found in wastewaters. Atom spectroscopic measurements of heavy metals in 305 pig manure samples confirmed presence of various concentrations of Cd, Cr, Cu, Pb, Hg, Ni and Zn (Hölzel et al 2012). Soil pollution with heavy metals originating from pig manures under intensive farming may result in Cu, Zn and Cd contamination of agricultural cultures. In a Chinese study, 44 and 60%, respectively, of brown rice soil samples exceeded the Chinese Soil Cu and Cd Environmental Quality Standards, although the concentration of Cu, Zn and Cd did not exceed the Chinese Food Hygiene Standard (Shi et al 2011). A strict correlation was noticed between heavy metals concentrations in soil and application rates of pig manure under these circumstances. On the other hand, it is shown that addition of pig manure to mine soils may diminish the water-extractable metal content in soils and may improve the pH and conditions for plant growth (Faz et al 2008).

Besides environmental soil and water pollution, heavy metals such as Cu or Zn act as determinants of antimicrobial resistance in the porcine micro-flora, a phenomenon connected to high resistance rates of *Escherichia coli* against beta-lactams or aminoglycosides in swine (Hölzel et al 2012). A key biological indicator of exposure to heavy metals is *Eisenia foetida* (Georgescu et al 2011b); bioaccumulation of Cu, Zn, Pb and Cd in the earthworm fed on pig manure has been demonstrated (Li et al 2010).

Development of an efficient swine waste management system is crucial. Several methods have been suggested; these systems should feature high efficiency, removing up to 99% heavy metals, odours, solids etc. (Vanotti et al 2009), simple, and allowing on-farm implementation. Moreover, they should bear a reasonable cost. In addition, waste management systems should benefit livestock productivity.

In order to remove heavy metals from pig manure, bioleaching using iron- and sulphur-oxidizing bacteria allowing transformation of heavy metals by formation of secondary iron minerals was successfully tested. In the experiments of Zhou et al (2012), the removal efficiencies of Zn, Cu, and Mn from pig manure were 95.1%, 80.9%, and 87.5%, respectively. Anammox bacteria allowing anaerobic ammonium oxidation have been used to treat wastewaters containing antibiotics, Cu and Zn (Lotti et al 2012). Manure bio-chairs produced obtained by pyrolysis (350-700°C) are thought to represent heavy metal stabilizers in agricultural soils however this process appears to be manure-dependent; whereas poultry and turkey litter may exhibit important heavy metal retention, swine manure, exhibiting an high ash and P content appeared to be a least effective stabilizer (Uchimiya et al 2012).

Conclusions. Lead, Cd, Cu and Zn are identified in swine meat at low levels. In contrast, wild boar may occasionally represent a source of food contamination with heavy metals, especially in hunter populations. While the muscle content in heavy meals is rather low, internal organs such as the kidney and the liver accumulate higher amounts. Agricultural practices such as use of manure compost as fertilizer may increase heavy metals mobility and leaching. Therefore, simple, cost-effective and highly efficient waste management systems are needed.

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