Ecotoxicology and Environmental Safety 151 (2018) 98–108

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

journal homepage: www.elsevier.com/locate/ecoenv

Accumulation patterns and risk assessment of metals and metalloid in muscle and offal of free-range chickens, cattle and goat in Benin City, Nigeria

Emmanuel Temiotan Ogbomida[a], Shouta M.M. Nakayama[b], Nesta Bortey-Sam[b], Balazs Oroszlany[b], Isioma Tongo[c], Alex Ajeh Enuneku[c], Ogbeide Ozekeke[c], Martins Oshioriamhe Ainerua[c], Iriagbonse Priscillia Fasipe[a], Lawrence Ikechukwu Ezemonye[c], Hazuki Mizukawa[b], Yoshinori Ikenaka[b,d], Mayumi Ishizuka[b,*]

[a] Ecotoxicology and Environmental Forensic Unit, National Centre for Energy and Environment, Energy Commission of Nigeria, University of Benin, P.M.B 1154, Benin City, Nigeria
[b] Laboratory of Toxicology, Department of Environmental Veterinary Sciences, Graduate School of Veterinary Medicine, Hokkaido University, Kita 18, Nishi 9, Kita ku, Sapporo 0600818, Japan
[c] Department of Animal and Environmental Biology (AEB), University of Benin, P.M.B 1154, Benin City, Nigeria
[d] Water Research Group, Unit for Environmental Sciences and Management, North-West University, Potchefstroom, South Africa

ARTICLE INFO

Keywords:
Heavy metals
Offal
Muscles
Hazard Quotient
Hazard Index

ABSTRACT

The use of free range animals for monitoring environmental health offers opportunities to detect exposure and assess the toxicological effects of pollutants in terrestrial ecosystems. Potential human health risk of dietary intake of metals and metalloid via consumption of offal and muscle of free range chicken, cattle and goats by the urban population in Benin City was evaluated. Muscle, gizzard, liver and kidney samples were analyzed for Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Cd, and Pb concentrations using inductively coupled plasma mass spectrometer (ICP-MS) while Hg was determined using Hg analyzer. Mean concentrations of metals (mg/kg ww) varied significantly depending upon the tissues and animal species. Human health risk estimations for children and adults showed estimated daily intake (EDI) values of tissues below oral reference dose (RfD) threshold for non essential metals Cd, As, Pb and Hg thus strongly indicating no possible health risk via consumption of animal based food. Calculated Hazard quotient (THQ) was less than 1 (< 1) for all the metals analyzed for both adult and children. However, Cd and As had the highest value of THQ suggestive of possible health risk associated with continuous consumption of Cd and As contaminated animal based foods. Hazard Index (HI) for additive effect of metals was higher in chicken liver and gizzard for children and chicken liver for adults. Thus, HI indicated that chicken liver and gizzard may contribute significantly to adult and children dietary exposure to heavy metals. Principal component analysis (PCA) showed a clear species difference in metal accumulation between chickens and the ruminants. This study provides baseline data for future studies and also valuable evidence of anthropogenic impacts necessary to initiate national and international policies for control of heavy metal and metalloid content in food items.

1. Introduction

Heavy metals and metalloids are pollutants that pose a great potential threat to the environment and human health on a global scale. They are intrinsic, natural constituents of the environment (Simone et al., 2012) and humans may promote their pollution through anthropogenic activities (Gall et al., 2015) such as extensive application of fertilizers or sewage sludge and pesticides in agriculture, waste disposal, atmospheric deposition, burning of fossil fuels, smelting, mining operations, electroplating, and discharge of wastewater from manufacturing industries including textile industry (Gall et al., 2015).

Heavy metals are widespread and highly persistent in the ecosystems due to their stability and non-degradable properties (Ali et al., 2013). They can enter the food chain via anthropogenic or natural

* Correspondence to: Laboratory of Toxicology, Department of Environmental Veterinary Sciences, Graduate School of Veterinary Medicine, Hokkaido University, N18, W9, Kita–ku, Sapporo 060–0818, Japan.
E-mail address: ishizum@vetmed.hokudai.ac.jp (M. Ishizuka).

https://doi.org/10.1016/j.ecoenv.2017.12.069
Received 3 February 2017; Received in revised form 28 December 2017; Accepted 30 December 2017

contaminations of air, water or soil and accumulate in animals at the top of the food chain through bio-magnification effects to pose chronic toxicity and serious health risk to man. Heavy metal toxicity in man can diminish mental and central nervous system function, elicit damage to blood composition, as well as the kidneys, lungs, and liver, and reduces energy levels (Amirah et al., 2013). Long-term exposure may result in slow progressive physical, muscular and neurological degeneration that mimics Alzheimer's disease, Parkinson's disease, muscular dystrophy and multiple sclerosis (Amirah et al., 2013).

In recent years, human exposures to heavy metals in Africa have risen as a result of an exponential increase in industrialization, urbanization, municipal solid waste generation and agricultural processes. Also uncontrolled illegal mining activities have added to the enormous amount of heavy metal contamination. The impact of these heavy metals on the environment can be a serious threats to the stability of the ecosystem and human health especially the African children as vulnerable group. In Sub-Sahara Africa environmental pollution by heavy metals has become a serious problem due to non-compliance and enforcement of existing environmental laws and regulations, inadequate monitoring capabilities, weak institutional structures and poor legal framework. In March 2010 large scale of lead poisoning due to artisanal/illegal gold mining activities occurred in Anka and Bukkuyum local government area of Zamfara state North-Western Nigeria leading to 163 deaths of which 111 were children under 5 years of age (Médecins Sans Frontières (MSF), 2010). Similarly, in May 2015, 28 children also died in Angwan Maijero and Angwan Karo, Madaka district of Rafi local government area of Niger State, Nigeria as a result of lead poisoning (Ministry of Mines and Steel Development MMSD, 2015).

Contamination of the environment and dietary intake of contaminated meat and meat products from food chain has been the most common and principal pathways of human exposure to heavy metals. Animals at the top of food chain may generally accumulate a large amount of heavy metals in their tissue, according to their age, size and feeding habits (Mahmood et al., 2012). In Nigeria, traditional rural animal production systems are mainly based on free-range (FMAWR, 2008). These animals could potentially pick heavy metals through grazing pesticide treated vegetation land, scavenging in open waste dumps for fodder, drinking polluted water from drains and streams and exposure to atmospheric depositions especially from automobile fumes and open burning of solid waste. These heavy metals can accumulate in organs and other fatty tissues, thus providing a major route for human exposure upon consumption. A recent study conducted by Bortey-Sam et al. (2015) evaluated human health risks from metals and metalloid via consumption of food animals in Tarkwa municipality in the western region of Ghana, an area predominantly known for artisanal gold mining activities. They indicated accumulation and distribution of heavy metals and metalloid in offal and muscles of chicken, goat and sheep with sufficient emphasis on species sensitivity and public health risk through consumption of these animal based foods. The study shows evidence of metal transfer from artisanal gold mining sites to free range animals thus, leading to accumulation of different metals in offal and muscles (Cd, Cr, Cu, Ni, Pb and Zn). They observed that metal accumulation was more pronounced in the liver and kidney of chicken than in muscles. This signifies sensitivity of chicken to heavy metals accumulation and the unique role of animal based food play in metals and metalloid transfer to man with possible health risks. While Bortey-Sam et al. (2015) succinctly compare health risks of metals and metalloid via intake of offal and muscles of free range animals from Tarkwa artisanal gold mining sites, recent studies in Nigeria focused mainly on human health risk assessment of some selected heavy metals via drinking water (Maigari et al., 2016), consumption of fishes (Orosun et al., 2016), cow meat (Ihedioha and Okoye, 2013), and illegal gold mining site (Olujimi et al., 2015). However, potential health impacts of municipal solid waste (MSW) in urban areas with specific reference to free range animals reared in proximity to dumpsites have not been fully evaluated. Causal linkages between exposure to waste and health outcomes for some particular types waste are well established, but the impacts of MSW on free range animals still remain unclear or not prioritized as public health issues. MSW is a growing major challenge to many rapidly urbanizing Africa countries. Furthermore, the full extent of the burden of ill health attributable to exposure of free range animals and the consumption of their muscles and offal has not also be elucidated.

The present study address health risks of metals and metalloid of offal and muscles of free range animals from municipal solid waste sites in Benin City Nigeria, a major environmental problem of urbanization, population growth and economic development. Free range animals are important in heavy metal studies as bio-indicators of the general environmental pollution status (Roggeman et al., 2013). Therefore, comprehensive study of heavy metal levels in tissues and offal of free range animals are needed to document the safety of meat and meat products in Nigeria. Although heavy metal contamination have been documented in literatures, information concerning human health risk via consumption of meat and meat products contaminated with heavy metal in Benin City, Edo State still remain very scarce. Therefore, this study describes and compares accumulation, distribution and species sensitivity to heavy metals under different land use pattern. The accumulation of metals and metalloid in free range animals from different locations and ecological regions present a clear picture of environmental pollution status. The distribution pattern of metals in different organs using principal component analysis (PCA) showed species sensitivity to metal and possible human exposure through dietary intake. The outcome of this study will aid in the development of sustainable environmental management options of municipal solid wastes and health intervention policies for affected areas and many other developing countries.

2. Materials and methods

2.1. Study area

The study was conducted in Benin City, Edo State around markets, abattoirs and dumpsite areas (Fig. 1). Benin City is located 6.3176°N, 5.6145°E and is the capital and largest City of Edo State in Southern Nigeria. The city has a total area of 1225 km^2 with an estimated human population of 1147,188 (National Population Commission (NPC), 2006). The city is a commercial centre strategically positioned as the gateway to the northern, eastern and western states of Nigeria. The notable economic activities include breweries, wood carving, traditional brass and bronze casting, wood and timber processing, printing and publishing. Major markets located within the city are Oba, New Benin, Oliha, Uselu, Agbado and Edaiken markets. Domestic and industrial wastes are often generated and discharged into the environment causing public health nuisances. Heaps of solid wastes are often seen littering the streets and market places. The disposal sites are capable of releasing large amounts of harmful chemicals such as heavy metals into the soil which easily found their ways into the food chain.

2.2. Sample collection

This study was carried out between August 2013 to March 2014 in Benin City, Edo State of Nigeria. Samples were collected from six locations in the three Local Government Areas which includes Ovia North-East Local Government Area (Oluku abattoir), Egor Local Government Area (Benin Technical College Road abattoir, Uselu market, University of Benin residential quarters, Ekiuwa market) and Oredo Local Government Area (Oliha market) of Edo State (Fig. 1). Fresh samples of kidney, liver and muscle of free-range goats (*Capra hircus*) and cattle (*Bos taurus*) were collected from the abattoirs while kidney, liver and muscle of free-range chickens (*Gallus gallus domesticus*) were collected from live adult chickens after exsanguination and dissection in the laboratory. Samples were kept frozen in labelled