Chemosphere 185 (2017) 412–422

Contents lists available at ScienceDirect

Chemosphere

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

Biomarkers of oxidative stress and health risk assessment of heavy metal contaminated aquatic and terrestrial organisms by oil extraction industry in Ogale, Nigeria

Sunny O. Abarikwu [a,*], Eka B. Essien [a], Oreva-Oghene Iyede [a], Kingsley John [b], Chidimma Mgbudom-Okah [a]

[a] Department of Biochemistry, Faculty of Science, University of Port Harcourt, Choba, Nigeria
[b] Department of Soil Science, Faculty of Agriculture, University of Calabar, Calabar, Nigeria

HIGHLIGHTS

- Heavy metals were detected in contaminated food samples in Ogale, Nigeria.
- High concentration of metals were detected in the vegetable, *T. occidentalis*.
- Least concentration of metals were detected in the catfish, *C. gariepinus*.
- Applying dietary intake and health risk calculation is proposed.
- Pb is the only metal through vegetable consumption that posed potential health risk.

ARTICLE INFO

Article history:
Received 12 February 2017
Received in revised form
5 July 2017
Accepted 6 July 2017
Available online 7 July 2017

Handling Editor: Jim Lazorchak

Keywords:
Heavy metals
Oxidative stress
Health risk
Target hazard quotients
Clarias gariepinus
Achatina achatina
Telfairia occidentalis

ABSTRACT

Ogale community in Rivers State, Nigeria is characterized by crude-oil contamination of its land resources. The present study aimed to evaluate the health risk and metal (Cd, Pb, Zn, Cr, and Ni) contamination level of the vegetable (*Telfairia occidentalis*), snail (*Achatina achatina*) and the catfish (*Clarias gariepinus*) collected from Ogale community. Samples collected from Elele Alimini community, a less polluted area was used as control. Oxidative damage was evaluated in tissues of snail and in the liver of catfish. The concentration of most of the tested metals in the food samples collected from the polluted sites were higher than those from the reference sites and in most cases exceeded the acceptable permissible limits. The accumulation of the metals by the food samples followed the order: *T. occidentalis* > *A. achatina* > *C. gariepinus*. The tissues of the snail from the polluted sites showed higher malondialdehyde (MDA) and lower glutathione (GSH) levels, and higher MDA and GSH levels in the fish liver compared to control values. The health risks associated with these metals in terms of dietary intake and target hazard quotients (THQs) showed higher non-carcinogenic effect and carcinogenic risks especially for Pb and Cd from the ingestion of *Telfairia occidentalis and Achatina achatina* from polluted sites. The health hazards due to metal pollution for the highly-exposed consumers of the food samples, especially in Ogale require attention. The oxidative stress response to accumulation status of metals provides a relevant tool for the assessment of metal pollution.

1. Introduction

Heavy metal pollution of terrestrial and aquatic ecosystems has long been recognized as a serious environmental concern especially in developing economies. The contamination of natural waters and adjacent areas by heavy metals negatively affects aquatic biota including fishes as well as several terrestrial life forms such as gastropods, and vegetables (Cajaraville et al., 2000; Ravera, 2001; Otchere, 2003). Environmental pollution by metals, even at low levels pose a serious threat to human and ecological health, owing to their toxicity, persistence, and tendency to accumulate in vegetables, aquatic animals, soil sediments and animals tissues

* Corresponding author.
E-mail addresses: sunny.abarikwu@uniport.edu.ng, abarikwus@gmail.com (S.O. Abarikwu).

http://dx.doi.org/10.1016/j.chemosphere.2017.07.024
0045-6535/

(Sankar et al., 2006; Sharma et al., 2007; Oluyemi et al., 2008; Rahman et al., 2013). Toxicity occurs along the food chain when the organism where the chemicals were bio-concentrated is consumed or eaten by an organism on the higher trophic level (Heng et al., 2004). Aquatic animals e.g. fish occupy the top of the aquatic food chain and are suitable bio-indicators of metal contamination. Thus, the public health issues associated with metal exposure is due to their bioaccumulation and biomagnification in the food chain (Tuzen, 2003; Otitoloju et al., 2009; Sharaf and Shehata, 2015). Therefore, it is important to determine the bioaccumulation capacity for heavy metals by certain organisms in order to determine the extent of the environmental pollution as well as assess potential risk to human health. This can be assessed by monitoring metal concentration in soil sediments and several life forms e.g. fishes, gastropods, vegetables collected around the polluted area of the ecosystems (Ravera, 2001; Zahir et al., 2005; Naser, 2013; Sharaf and Shehata, 2015). Furthermore, metals might be more concentrated within the tissues of organism's e.g. liver and kidney of fishes than in others (Spodniewska and Barski, 2013; Rajkowska and Protasowicki, 2013; Sharaf and Shehata, 2015). It is well known that molluscs e.g. snails accumulate organic and metal pollutants at concentrations several order of magnitude above those observed in the environment and have been considered as useful bio-monitors of certain metals (Kiffney and Clement, 1993; Kesavan et al., 2013; Sharaf and Shehata, 2015).

The assessments of oxidative damage in fish can reflect metal contamination of the aquatic environment (Sevcikova et al., 2011). The changes in antioxidative defence system including GSH-redox systems, superoxide dismutase (SOD), and catalase (CAT) activities in organisms; which are all necessary for protection of tissues and cells against active oxygen metabolites, are important targets and biological endpoints for metal toxicity. They are commonly used for the assessment of stress response to heavy chemicals (Siwela et al., 2010; El-Shenawy et al., 2012; Abarikwu, 2014). Thus, several tissues injured through oxidative stress usually show high concentrations of malondialdehyde (MDA), an end biomarker for lipid peroxidation. Consequently, oxidative stress parameters are now increasingly being used as biomarkers of environmental stress response to metals (Siwela et al., 2010; Sevcikova et al., 2011; El-Shenawy et al., 2012).

Heavy metals from anthropogenic sources constitute a significant part of soil contaminants (Bhagure and Mirgane, 2010). These metals including Cd, Cu, Zn, Cr, Hg, As and Pb might leach to aquatic system, which, at some concentrations, might negatively affects the aquatic biota and consequently leads to health risk on humans who depend on aquatic products as sources of food (Bhagure and Mirgane, 2010; Redriquez-Barroso et al., 2010). Similarly, common garden vegetables grown near polluted sites accumulate heavy metals at concentration high enough to compromise human health (Deepalakshmi et al., 2014; Ojekunle et al., 2014; Xiong, 1998; Sharma et al., 2009). For example, the leaves of spinach (*Spinacia oleracea*), red amaranth (*Amaranthus tricolor*) and amaranth (*Amaranthus oleraseus*) were reported to found to have higher levels of Cd, Co, Pb, Ni, and Cr (Naser et al., 2011). Other edible vegetables e.g. *Vernonia amygdalina*, *Ocimum gratissimum*, *Talinum triangulare*, *and Telfairia occidentalis* from polluted sites were contaminated with Mn and Cu above acceptable international limits (Kalagbor et al., 2014). The roots and leaves of herbaceous plants were found to have higher levels of metals than stems and fruits (Yargholi and Azimi, 2008). The consumption of metal contaminated vegetables by humans represents a potential threat to human health, and can contribute to decrease in life expectancy in affected areas (Lacatusu et al., 1996; Jarup, 2003).

Ogale community, which is located in Eleme Local government Area of Rivers State (Fig. 1), is a heavy industrial base for oil exploitation and crude oil production in Nigeria since 1958, and has an estimated population of over 40, 000. The people of Ogale have traditionally been either crop farmers or have relied on the Ogale Stream, which runs from the farming areas in the north-east of the community land to the west of the community land, its tributaries and waterways as fishing areas. Due to industrial structure and oil spillage due to pipeline vandalism, its regional environmental pollution is severe making it one of the most serious areas of national environmental issues (Luiselli et al., 2006). Most major cities have been concerned with heavy metal monitoring in edible vegetables and aquatic organisms (Ferré-Huguet et al., 2008). Rivers State, one of the most important oil-producing and largest metropolitan regions in Nigeria does not have any monitoring program.

*Telfairia occidentalis (*fluted pumpkin*)* rank among the most widely eaten vegetables at homes and in restaurants across Nigeria and represent a good model for evaluating the health risk effect of leafy vegetables grown in contaminated soils. Snails are easily available for collection in many terrestrial and aquatic ecosystems and exhibit high accumulation of heavy metals (Regoli et al., 2006; Radwan et al., 2010). Thus people who eat snails from coastal areas from oil polluted soils are at risk of metal poisoning (Mahmood et al., 1995). Very little is known of metal levels in the African giant snails as consumed in the southern part of Nigeria. The African catfish (*Clarias gariepinus*) is the most common fresh water fish grown in Nigerian water bodies and the most widely consumed fish by Nigerians (Olaifa et al., 2004). It can therefore be an excellent animal model to study the pollution of Nigerian coastal areas and risk to human health due to consumption of contaminated fish.

The present study was designed to measure the levels of lead (Pb), chromium (Cr), zinc (Zn), cadmium (Cd), and nickel (Ni) in soil samples, edible leafy vegetable *Telfairia occidentalis*, muscle tissues of catfish (*Clarias gariepinus*) and soft tissues of African giant snails (*Achatina achatina*) which were collected from two different sites (industrial site and reference site) in Rivers State, Nigeria. Also the level of oxidative damage was determined in the liver of these fishes and soft tissues of the snails to measure the effect of environmental pollution on these sentinel organisms at the biochemical level. The industrial site (polluted area) is located in Ogale community in Eleme Local Government Area and receives effluents from many industrial sources whereas the second area (reference site) is in Elele Alimini community in Emohua Local Government Area (LGA) where there is limited industrial or anthropogenic activity. Also the human health risk assessment of heavy metals via consumption of the contaminated vegetables, snails, and fish collected from the two different sources was calculated.

2. Materials and methods

2.1. Fish, snails, soil, and vegetable sampling

The sampling was conducted during August–September, 2015. African catfish, *Clarias gariepinus* (15 samples) were collected from each site of the sampling zone in Ogale stream, which runs from the farming areas in the north-east of the community land to the west of the community land, its tributaries and waterways as fishing areas. Ten samples of the widely grown edible vegetable (*Telfairia occidentalis*) in the polluted area were collected from fields beside the stream. Fifteen samples of the African giant snails (*Achatina achatina*) were collected from the polluted sites by hand picking. The same number of C*larias gariepinus*, *Telfairia occidentalis*, *and Achatina achatina* collected from Elele Alimini community, a less