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Research Article

An evaluation of heavy metals in the edible muscle tissues of two commercial fish species (*Oreochromis niloticus* and *Hoplosternum littorale*) and human health risk assessments

Halley Grayson Orville, Surendra Winjajellum, Rajeshkumar Sivakumar
Department of Agriculture, Faculty of Agriculture & Forestry, University of Guyana, Tain Campus, Berbice, Guyana, South America.

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Abstract: This study provided new information on the concentration of heavy metals in two edible commercial fish species harvested from freshwater bodies along Guyana's coastal regions and compared them with internationally accepted standards for heavy metals in fish destined for human consumption. Empirical data from the present study showed that the levels of Lead (Pb) in local commercial fish species (*Oreochromis niloticus and Hoplosternum littorale*) soled at Guyana's municipal markets are above the maximum standards recommend for human consumption. Furthermore, in both geographical regions (region 5 and region 6) and in both tested fish species (*Oreochromis niloticus* and *Hoplosternum littorale*) Pb have been found to be approximately 103 - 152 times above the maximum limit recommended for fish destined for human consumption. Additionally, the present study also proved that fish soled at Guyana's municipal markets contain high levels of Cadmium (Cd) and Manganese (Mn). While at the same time, it assessed the health risks of heavy metals toxicity to human beings. It is very important to identify the relationship between the presence of these heavy metals (Pb and Cd) in foods and the prevalence of certain disease conditions within the Guyanese population. Since the symptomatology resulting from many of the disorders caused by these metals are similar to other illnesses commonly diagnosed in our hospitals. Especially, common behavior and learning problems (such as hyperactivity), memory and concentration problems commonly observed in children, high blood pressure, hearing problems, headaches, slowed growth, reproductive problems in men and women, digestive problems, urinary problems, cancers, muscle and joint pain. The findings from the present study can be useful to guide planning of public health activities, future policies and stimulate further research into this life-threatening phenomenon known as heavy metal toxicity. Furthermore, the Guyanese environmental regulations do not have standards regulating maximum levels for heavy metals in aquatic products and waters, while high levels of metals have been continuously reported. Moreover, urgent nationwide heavy metal testing and monitoring of fish, human beings and waterbodies needs to be implemented and reviewed regularly. With the view of obtaining base data on metal impacts and establishment of needed regulations for heavy metal pollutants.

Keywords: Pollution; Heavy metals; Bioaccumulation; Health risks; *Oreochromis niloticus*; *Hoplosternum littorale*

Introduction

Guyana is bounded by Venezuela on the west, Brazil on the west and south, and Suriname on the east, with a 459-kilometre Atlantic coastline on the northeast. It has a coastal plain, which occupies about 5 percent of the country's 214,969 square kilometers area, which is home to more than 90 percent of the country's inhabitants. The coast ranges from 26 to 77 kilometers wide and extends from the Correntyne river in the east to the Venezuelan border in the northwest. The coast is made up largely of alluvial mud swept out to sea by the Amazon river, carried north by ocean currents, and deposited on the Guyanese shores. This mud overlays the white sands and clays formed from the erosion of the interior bedrocks and carried seaward by the rivers of Guyana. While, a line of swamps forms a barrier between the white sandy hills of the interior and the coast. These swamps, formed when water was prevented from flowing onto coastal croplands by a series of dams, serve as reservoirs during periods of drought. Also, at high tide and during the rainy seasons much of the coastal areas floods resulting in heavy water pollution from sewage, agricultural and industrial chemicals from human activities. In other words, the floodwaters server as collector and reservoir for all materials spread by human industrial and agricultural activities in Guyana. These pollutants are known to cause undesirable changes in the physicochemical or biological factors of ecosystem, which in turn directly or indirectly affect the ecological balance of the environment, and may ultimately affect human beings. Among the list of chemical contaminants that may possibly be

***Corresponding Author**:
Dr. Grayson Orville Halley,
Lecturer, Department of Agriculture,
Faculty of Agriculture & Forestry,
University of Guyana, Tain Campus,
Berbice, Guyana, South America.
E-mail: ace0779@yahoo.com

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released into the coastal environment includes aliphatic and aromatic compounds, phthalate esters, radio nucleotides and heavy metals. The heavy metal group of water contaminants is attracting the focus of Aquaculturist, environmentalist and fisher folks alike, since they not only affect aquatic organisms but also have the potential to ultimately affect human beings. Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds bioaccumulates in fish anytime they are taken up and stored faster than they are broken down (metabolized) or excreted. Pb and Cd are two of the most commonly occurring and commonly studied heavy metal contaminants because of their toxicity to humans. However, metals such as Zn, Cu, Fe, Mn, and Co are essential for the growth and development of human beings. In view of avoiding undesirable health hazards consequent of "excessive" intake of toxicants (including toxic metals), international and national scientific organisms such as FAO/WHO, FDA, European Union, etc. have used the safety factor approach for establishing acceptable or tolerable intakes of substances that exhibit threshold toxicity. The acceptable daily intake (ADI) or tolerable daily intake (TDI) or provisional tolerable weekly intakes (PTWI) are used to describe "safe" levels of intake for several toxicants including toxic metals. For chemicals that give rise to such toxic effects, a tolerable daily intake (TDI), i.e. an estimate of the amount of a substance in food, expressed on a body weight basis (mg.kg-1 or mg.kg-1 of body weight) that can be ingested over a lifetime without appreciable health risk. Exposure exceeding the TDI value for short periods should not have deleterious effects upon health. However, acute effects may occur if the TDI is substantially exceeded even for short periods of time. Besides, contaminants possessing very long half-lives can be accumulated in the body and chronic effects are most often observed when critical concentrations are reached in target tissues. The accumulation of heavy metals in the human body by ingestion can be responsible for a wide range of health effects such as cancer, neurotoxicity, immune-toxicity and cardio-toxicity leading to increased morbidity, mortality in populations (Dockery et al., 1993; Pope et.al., 1995). Therefore, to maintain the quality of food it is important to regularly monitor and evaluate these pollutants levels in fishes.

Tilapia (*Oreochromis niloticus*) and Hassar (*Hoplosternum littorale*) are two fish species of socioeconomic importance to the Guyanese populace. Tilapia (*Oreochromis niloticus*) is an omnivorous grazer that feeds on phytoplankton, periphyton, aquatic plants, small invertebrates, benthic fauna, detritus and bacterial films associated with detritus. Tilapia can filter feed by entrapping suspended particles, including phytoplankton and bacteria, on mucous in the buccal cavity, although its main source of nutrition is obtained by surface grazing on periphyton mats (FAO, 2015). On the other hand, Hassar (*Hoplosternum littorale)* is a Callichthyid armored catfish of wide distribution in South America. Its preferential biotopes are swamps and marshes. And it is an air breather which tends to inhabit oxygen deficient biotopes; a special adaptation of large intestine epithelia enables it to use atmospheric oxygen (Singh, 1978; Machado-Allison, 1987). *Hoplosternum littorale* is an opportunistic omnivore/scavenging generalist that consumes a variety of benthic invertebrates, algae and detrital material. Individuals exhibit an ontogenetic shift from a microphagus larval and juvenile diet of rotifers, copepods, cladocerans, etc., to an adult diet consisting of larger crustaceans, insects and insect larvae, detritus and algae (Winemiller 1987 and Mol 1995). These fish species are commonly found in the swamps, rivers, canals and reservoirs along Guyana's coastal regions. Their feeding habits and preferred habitat makes them ideal candidates for assessing bioaccumulation of heavy metals and risk assessment of human exposure to these poisonous metals. Furthermore, these fishes are consumed and sold commercially by the villagers. Unlike most other studies which assesses bioaccumulation in the entire fish the present research will maintain its focus only on edible muscle tissues since it is the main fish part that is consumed by human beings. The objectives of the present study were to evaluate the level of heavy metals (Cu, Zn, Mn, Cd, Pb and Cr) in two commonly available fish species Tilapia (*Oreochromis niloticus*) and Hassar (*Hoplosternum littorale*) which appear to have great economic and ecological importance to the coastal regions of Guyana and to assess the threats to human health.

Background and Justifications

Because of the geographical layout of Guyana's coastal plain coupled with the large plantation type agricultural activity (such as Rice and Sugar canes cultivations) of the zone, it is possible that the fishes harvested and consumed by the Guyanese populace are exposed to agrochemicals and sewage from household activities containing heavy metals and may lead to the bioaccumulation of these metals in key commercial fish species. Additionally, the meteorological activity of the coastal region is characterized by two distinct seasonal weather patterns (namely: Rainy and Dry seasons). During the rainy season the coastal region floods merging irrigation and drainage networks, resulting in large quantities of pollutants entering water ecosystems. Additionally, it is well known that some household items such as: ceramics, televisions, paints, costume jewelry, lipstick, batteries and other electrical devices contain heavy metals. While, large number of agrochemicals, industrial and mining wastes are known to contain heavy metals which often findings their way into the environment. This study provided new information on the levels of heavy metals in two edible commercial fish species harvested from freshwater bodies along Guyana's coastal regions. This paper reviewed certain heavy metals and their impact and biotoxic effects on man, to bring about awareness in a country in which environmental pollution as a result of heavy metals does not form part of public discussions. The findings can be useful to guide planning of public health activities, future policies and stimulate further research into this life-threatening phenomenon.

Materials and methods

Study locations

There were four sampling sites for this study. The sites include four municipal fish markets located within regions No.5 and No.6, along Guyana's coast (i.e. Region No.5: Rosignol Market and Bath Settlement Market; Region No.6: New Amsterdam Market and Port Mourant Market).

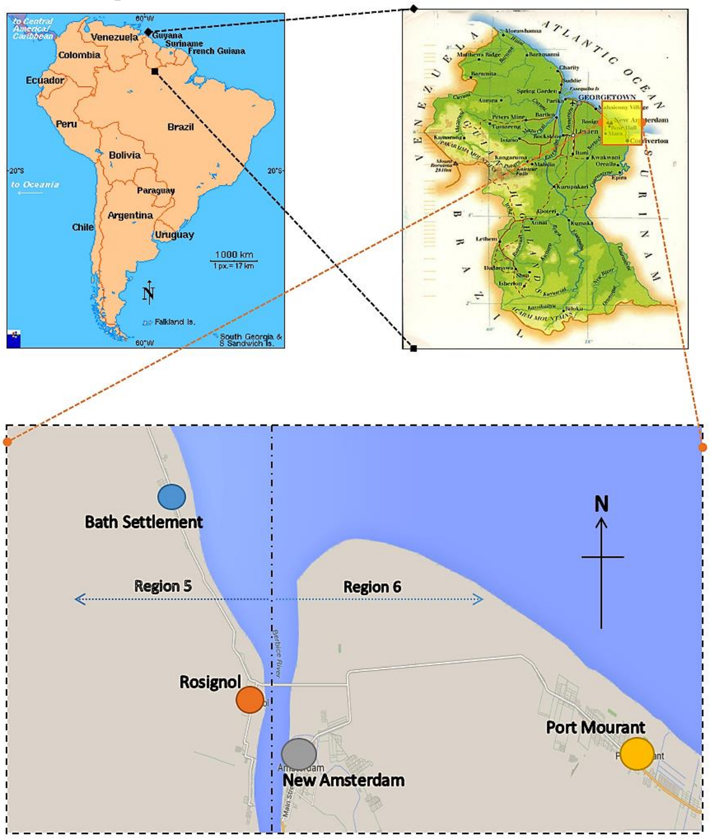

Figure 1. Study Location (map of the study sites)

Sampling

Three specimens of each study species (*Oreochromis niloticus* and *Hoplosternum littorale*) were collected from 3 random fish vendors within each municipal Markets. Giving a total of 3 fish of each species per market (3 *niloticus* and 3 *littorale).* The muscle tissues of the specimens were immediately removed, weighed and packed into sterile polyethylene bags, placed in ice cooler until their arrival at the laboratory; samples were subsequently stored at -20 ^{o}C for 24 hours.

Figure 2a. Tilapia (*Oreochromis niloticus)*

Figure 2b. Hassar (*Hoplosternum littorale*)

Metal analysis

The muscle tissues were oven dried, crushed and homogenized using mortar and pestle. Approximately 2 grams of the dried powdered tissues from each tested species were then weighed and transferred to two separate 25 mL conical flasks, to which 10 mL of a 4:1 (v/v) nitric acid to chloric acid mixture was added to each flask. Each comical flask was then covered with a watch glass and allowed to react overnight at room temperature. The samples were digested then left to evaporate some of its liquid at 65^{o}C on a hot plate then cooled to room temperature. Subsequently, the digested samples were then filtered through Whatman No.1 filter paper and collected in 25 mL beakers. Content of the beakers were quantitatively transferred to 10 mL volumetric flasks and brought to volume with ultrapure water; which was then used in the analysis for heavy metal elements. Element (Cu, Zn, Mn, Cd, Pb and Cr) contents in the samples were determined by atomic Absorption spectrometer (Perkin-Elmer, AA 800) and are expressed as μg g-1 dry weight of tissue (Kingston and Jassie, 1988).

Statistical Analysis

All data were recorded in Microsoft excel. The concentration mean of heavy metals and Standard Error of the mean were calculated in Microsoft excel. Least Significant Difference (LSD) (Statistix 10) was used to highlight specific differences between markets for both fish species. Finally, Microsoft Excel was used to generate tables.

Results

Results from the present study showed presence of all tested heavy metals (Cu, Pb, MN, Zn, Cd and Cr) in both fish species (*Oreochromis niloticus and Hoplosternum littorale*) respectively. However, Cu, Zn and Cr were well below the standard recommended maximum limits for these metals in fish destined for human consumption. While, Pb and Cd registered concentrations above the recommended standards for fish meat. Furthermore, the empirical data showed that mean Pb concentrations for *Oreochromis niloticus* was 141.2 times above the standard recommended maximum level while that of *Hoplosternum littorale* was 112 times above the standard maximum limit. Additionally, mean Mn concentration in *Oreochromis niloticus* was also above the maximum standard recommended limit for fish meat. The mean metals concentrations in muscle tissues of *Oreochromis niloticus* ranked in the following order: Pb>Zn>Mn>Cd>Cu>Cr. On the other hand, mean metal concentrations in *Hoplosternum littorale* ranked in the following order: Pb>Zn>Cu>Cd>Mn>Cr. Nonetheless, when the two species were compared no significant differences were observed between the heavy metals Cu, Zn, Cd nor Cr concentrations in muscle tissues. However, empirical data from this study showed that *Oreochromis niloticus* had significantly higher Pb, Mn and Cd concentration when compared with levels found in *Hoplosternum littorale*, which are shown in **Table 1**.

Additionally, when the data was organized by regions the following order of tissue metals was obtained: Pb>Zn>Mn>Cd>Cu>Cr, for *Oreochromis niloticus* acquired from within both region 5 and region 6 respectively. On the other hand, metals concentrations in *Hoplosternum littorale* acquired from municipal markets within region 5 revealed similar order Pb>Zn>Cu>Cd>Mn>Cr as that of *Oreochromis niloticus*, while region 6 *Hoplosternum littorale* metals concentrations showed a change in the ranking of the metals as follows Pb>Zn>Cu>Cd>Mn>Cr, shown in **Table 2**.

Metal mean concentrations in *Oreochromis niloticus* for all markets ranked in the following : **Cu**- Bath Settlement > Rosignol > Port Mourant > New Amsterdam; **Pb**- Rosignol > Port Mourant > Bath Settlement > New Amsterdam; **Mn**- Bath Settlement > Rosignol > New Amsterdam > Port Mordant; **Zn**- New Amsterdam > Bath Settlement > Port Mourant > Rosignol; **Cd**- Rosignol > New Amsterdam > Bath Settlement > Port Mourant and **Cr**- New Amsterdam > Rosignol > Bath Settlement > Port Mordant, respectively **(**see **Table 3)**.

Metal mean concentrations in *Hoplosternum littorale* for all markets ranked in the following order: **Cu-** Port Mourant > Bath Settlement > New Amsterdam > Rosignol; **Pb**- New Amsterdam> Bath Settlement > Port Mourant > Rosignol, **Mn-** Bath Settlement > New Amsterdam > Rosignol > Port Mordant; **Zn**- Bath Settlement > New Amsterdam > Rosignol > Port Mourant; **Cd**- Bath Settlement > New Amsterdam > Port Mourant > Rosignol and **Cr**- Rosignol > Bath Settlement > New Amsterdam > Port Mordant, respectively **(**see **Table 4)**.

Table 1. Mean metal concentrations for both fish species compared with standards for fish for human consumption (mg/kg)

Heavy Metals:	*Oreochromis niloticus*	*Hoplosternum littorale*	*Standards FAO/WHO (1989); FEPA (2003)*
Cu	0.65[a]	0.74[a]	30.0
Pb	7.06[b]	5.60[c]	0.05
Mn	1.20[a]	0.60[d]	1.0
Zn	4.62[a]	4.73[a]	40.0
Cd	0.79[a]	0.60[a]	0.5
Cr	0.25[a]	0.17[a]	1.0

Note: Data are expressed as mean ± standard error (m± SE). Different lower-case letters indicate significant differences and with $P < 0.05$ being considered significant.

Table 2. Mean metal concentrations for both fish species by Regions compared with standards for fish for human consumption (mg/kg)

Heavy Metals:	Region No. 5 *Oreochromis niloticus*	Region No. 6 *Oreochromis niloticus*	Region No. 5 *Hoplosternum littorale*	Region No. 6 *Hoplosternum littorale*	Standards FAO/WHO (1989); FEPA (2003)
Cu	0.71[a]	0.65[a]	0.59[d]	0.90[c]	30.0
Pb	7.60[a]	7.06[a]	5.19[a]	6.00[a]	0.05
Mn	1.54[a]	1.20[c]	0.74[b]	0.47[d]	1.0
Zn	4.39[a]	4.62[a]	4.89[a]	4.56[a]	40.0
Cd	0.87[a]	0.79[a]	0.63[a]	0.57[a]	0.5
Cr	0.31[a]	0.25[a]	0.28[c]	0.05[d]	1.0

Note: Data are expressed as mean ± standard error (m± SE). Different lower-case letters indicate significant difference and with $P < 0.05$ being considered significant.

Table 3. Metal concentrations in *Oreochromis niloticus* muscle tissues from each municipal market compared with standards for fish for human consumption (mg/kg)

Heavy Metals:	Bath Settlement	Rosignol	New Amsterdam	Port Mourant	Standards FAO/WHO (1989); FEPA (2003)
Cu	0.7[a]	0.7[a]	0.5[a]	0.6[a]	30.0
Pb	6.9[a]	8.2[c]	6.0[d]	6.9[a]	0.05
Mn	1.7[a]	1.3[a]	1.2[a]	0.4[b]	1.0
Zn	5.2[a]	3.5[b]	5.4[a]	4.2[b]	40.0
Cd	0.5[a]	1.1[c]	0.9[c]	0.5[a]	0.5
Cr	0.3[a]	0.3[a]	0.3[a]	ND	1.0

Note: Data are expressed as mean ± standard error (m± SE). Different lower-case letters indicate significant difference and with $P < 0.05$ being considered significant.

Table 4. Metal concentrations in *Hoplosternum littorale* from each municipal market compared with standards for fish for human consumption (mg/kg)

Heavy Metals:	Bath Settlement	Rosignol	New Amsterdam	Port Mourant	Standards FAO/WHO (1989); FEPA (2003)
Cu	0.74[a]	0.44[b]	0.67[a]	1.13[c]	30.0
Pb	6.24[a]	4.14[b]	6.68[ac]	5.32[ad]	0.05
Mn	1.02a	0.46a	0.68a	0.26[a]	1.0
Zn	5.08[a]	4.70[a]	4.73[a]	4.40[a]	40.0
Cd	0.79[a]	0.47[b]	0.57[b]	0.57[b]	0.5
Cr	0.18[a]	0.37[b]	0.11[a]	ND	1.0

Note: Data are expressed as mean ± standard error (m± SE). Different lower-case letters indicate significant difference and with $P < 0.05$ being considered significant.

Discussion

Health risk of Pb exposure

The present study showed that the levels of Pb in local commercial fish species soled at Guyana's municipal markets are above the standard recommended limit for human consumption. Furthermore, in both geographical regions (region 5 and region 6) and in both tested fish species (*Oreochromis niloticus* and *Hoplosternum littorale*) Pb have been found to be approximately 103 - 152 times above the maximum limit recommended for fish destined for human consumption. Although it is probable that human exposures to Pb from combustion of leaded gasoline and leaded water pipes have decreased considerably, this study proved that human exposure to Pb is still of great concern in Guyana. Although Pb in petrol has dramatically decreased over the last decades it seems to have persisted in the environment; and its physical and chemical properties are currently still applied in the manufacturing, construction and chemical industries which ultimately ends up into the environment and the food chain. The present study proved that the general population is exposed to Pb from food.

Once free in the body system, Pb may cause nephrotoxicity, neurotoxicity, and hypertension. Furthermore, human exposure to Pb can result in a wide range of biological effects depending on the level and duration of exposure. Various effects occur over a broad range of doses, with the developing fetus and infant being more sensitive than the adult. High levels of exposure may result in toxic biochemical effects in humans which in turn cause problems in the synthesis of hemoglobin, effects on the kidneys, gastrointestinal tract, joints and reproductive system, and acute or chronic damage to the nervous system. Children are particularly susceptible to lead exposure due to high gastrointestinal uptake and the permeable blood-brain barrier. The proportion of Pb absorbed from the gastrointestinal tract is about 10% in adults, whereas levels of 40-50 % have been reported for infants. Children under 6 years are especially susceptible to the adverse effects of Pb, as the blood-brain barrier is not yet fully developed in young children and hematological and neurological adverse effects of Pb occur at lower threshold levels than in adults (Tandon S.K, Chatterjee M, *et al*., 2001 and Lindbohm ML, Sallmen M, *et al*., 1991) (Jennings*, et. al*., 1996). Blood levels in children should be reduced below the levels so far considered acceptable, since recent data indicated that there may be neurotoxic effects of Pb at lower levels of exposure than previously anticipated. Hence, there is a need for proper understanding of mechanism involved, such as the concentrations and oxidation states, which make Pb and other metals such as Cd harmful. While, it is also important to know their sources, leaching processes, chemical conversions and their modes of deposition in polluting the environment, which essentially supports life. Not only does Pb poisoning stunt a child's growth, damage the nervous system, and cause learning disabilities, but also it is now linked to crime and anti-social behaviors in children (US.G.A.O, General Accounting Office report, 2000).

Recent studies have also looked at possible links between workplace exposures to Pb and cancers, including cancers of the brain, kidney, bladder, colon, and rectum. The results of these studies have been mixed. Some studies have found links, while others have not. The link between Pb exposure and cancer is clearly a concern, and more research is needed to better define the possible link between Pb exposure and many cancers. Literature sources also point to the fact that these metals when ingested, they form stable biotoxic compounds, thereby mutilating their structures and hindering bioreactions of their functions. Resulting in nervous system, hematopoietic system, renal system damages and in encephalopathy, peripheral neuropathy central nervous disorders, anemia, (Manju Mahurpawar, 2015). Over the past two decades these disorders are increasingly being diagnosed in the Guyanese population. The author is of the belief that many of these disorders may have direct link to heavy metals toxicity.

Health risk of Cd exposure

The present study proved that fish soled at Guyana's municipal markets for human consumption contains high levels of Cd. The metals Cd is known to pose great threat to human health. Thus, its effects are regularly reviewed by international bodies such as the WHO. Cd is a toxic metal occurring in the environment naturally but currently, Cd is being used in numerous rechargeable batteries and agrochemicals. With the proliferation of mobile and portable rechargeable devices Cd pollution has regained popularity among researchers. Another reason being, that products containing Cd are rarely re-cycled, but often dumped together with household wastes. Additionally, cigarette smoking is a major source of Cd exposure; while, in non-smokers, food is the most important source of Cd exposure. Cd is also present as an impurity in several products, including phosphate fertilizers, detergents and refined petroleum products. The cultivation of rice and sugarcane have been practiced alone Guyana's coast regions for hundreds of years on the same lands, thereby exhausting soil nutrients leading to the present situation whereby these crops have become heavily dependent on application of fertilizers. Sugarcane plantations on Guyana's coastal regions have been in existence for over 300 years and in recent decades hundreds of tons of fertilizers are applied to the soil annually. A study carried out by Ansari AA and Bacchus BW (2009), reported that the levels of heavy metals in soil and waterbodies in cultivated areas along Guyana's coast were very high: Pb 23.453 ± 6.029, Cd 23 ± 0.0128, Mn 52.715 ± 6.475 in soil. Ansari *et al.,* opined that the high levels of Pb, Cd and Mn in soils has direct correlations with the use of fertilizers and other agrochemicals, especially in large scale monocropping such as rice and sugarcane cultivations. Cd is an accumulative toxicant and carcinogenic that affects kidneys, generates various toxic effects in the body, disturbs bone metabolism and deforms reproductive tract as well as endocrine system. Exposure to Cd increases calcium excretion thereby causes skeletal demineralization, probably leading to increases in bone fragility and risk of fractures. Cadmium and its compounds are currently classified by IARC as a Group 1 carcinogen for humans. Occupational human exposure has been correlated with lung cancer. Cd exposure during pregnancy, leads to reduced birth weights and premature birth (Henson MC, Chedrese PJ, 2004). Cd derives its toxicological properties from its chemical similarity to Zinc (Zn) an essential micronutrient for plants, animals and humans. Cd is efficiently retained in the kidney (half-time 10-30 years) and the concentration is proportional to that in urine (U-Cd). Recent data indicated that adverse health effects of Cd exposure may occur at lower exposure levels than previously anticipated, primarily in the form of kidney damage, bone effects and fractures. Studies suggested that Cd is associated with several clinical complications and renal tubular damage was shown to develop at levels of exposure much lower than previously thought. Cd-induced tubular proteinuria is irreversible, and continued exposure may lead to glomerular damage with decreased glomerular filtration rate (Järup L, 2002, European Dialysis and Transplant Association - European Renal Association). Elliott P, Arnold R, *et al.,* (2000), studied the risk of mortality, cancer incidence, and stroke in a population potentially exposed to Cd, their findings revealed that although there was no clear evidence of health effects from possible exposure to Cd despite the extremely high concentrations of Cd in the soil, there was evidence of increase in cancer incidence, an increase in genitourinary cancers, increase mortality from hypertension, cerebrovascular disease, nephritis and nephrosis, of borderline significance. As techniques are perfected for detecting smaller amounts of trace elements in various tissues in the body, investigators are finding that the threshold for toxicity from trace elements is much lower than expected. Further research on Cd is necessary to reveal the mechanisms of toxicity and true environmental and occupational exposure limits. It can be anticipated that a considerable proportion of the non-smoking adult population has urinary Cd concentrations of 0.5 microg/g creatinine or higher while, for smokers this proportion is considerably higher. This implies no margin of safety between sources of exposure in the general population (Järup L, Akesson A, 2009). Therefore, measures should be put in place to reduce exposure to a minimum from all sources and the tolerably daily intake should be set in accordance with recent findings. Furthermore, the Guyanese environmental regulations do not have standards regulating maximum levels for heavy metals in aquatic products and waters, while high levels of metals have been continuously reported. Moreover, urgent nationwide heavy metal testing and monitoring of fish, human beings and waterbodies needs to be implemented and reviewed regularly. With the view of obtaining base data on metal impacts and establishment of needed regulations for maximum limits for heavy metals.

Conclusion

This research proved that the average resident of Guyana is being subjected to severe chronic Pb, Cd and Mn insult through dietary exposure. The data also suggested that the amount of Pb and Cd introduced into Guyana's relatively small rural coastal environments is alarmingly high. For the maintenance of a healthy population Guyana needs to urgently implement a great deal of preventative measures to avoid ingestion of these particularly toxic metals. The monitoring of endogenous levels of metal ions requires implementation of strong comprehensive regulations and significant resources to avoid metal intake by the general population. The advances of toxicological studies have improved our knowledge about human exposure to toxic metals and metalloids, and their health effects. On the other hand, future studies should be focused on identifying relationships between the presence of these heavy metals in foods and drinking waters and the prevalence of these disorders within the Guyanese population and worldwide. Since the symptomatology resulting from many of the disorders caused by metals are similar, to illnesses commonly diagnosed in our hospitals. Especially, common behavior and learning problems (such as hyperactivity), memory and concentration problems in children, high blood pressure, hearing problems, headaches, slowed growth, reproductive problems in men and women, digestive problems, urinary problems, muscle and joint pain. Thus, this ongoing research work shed light onto the issue of metals pollution which plague the residence of developing rural communities and often goes undiagnosed in countries such as Guyana. And hilighted the linkages between agriculture activities (especially plantation type cropping systems such as sugarcane and rice) and the release of hazardous toxic metals into the water ecosystems, thereby, led to the contamination of fishes in these regions.

References

1. Ansari AA, Bacchus BW. Effect of Agricultural Chemicals on Aquatic Ecosystem in Guyana. Global Journal of Environmental Research, 2009, 3(1): 22-25.

2. Agah H, Leermakers M, *et al.,* Accumulation of trace metals in the muscles and liver tissues of five fish species from the Persian Gulf. Environmental Monitoring Assessment. 2009, 157: 499-514.

3. Al-Kahtani MA. Accumulation of heavy metals in tilapia fish (*Oreochromis niloticus*) from Al-Khadoud Spring, Al-Hassa, Saudi Arabia, American Journal of Applied Science. 2009, 6(12): 2024-2029.

4. Amaraneni SR. Distribution of pesticides, PAHs and heavy metals in prawn ponds near Kolleru Lake wetland, India. Environmental international. 2006, 32: 294–302.

5. Blasco J, Arias AM, *et al.,* Heavy metals in organisms of the River Guadalquivir estuary: possible incidents of the Aznalcollar disaster. The Science of the Total Environment. 1999, 242-249.

6. Boujard T, Keith P, *et al.,* Diel cycle in *Hoplosternum littorale* (teleostei): evidence for synchronization of locomotor, air breathing activity by circadian alternation of light and dark. Journal of Fish Biology. 1990, 36: 133-140.

7. Castro-Gonzeza MI, Me´ndez-Armentab M. Heavy metals: implications associated to fish consumption. Environmental Toxicology Pharmacology. 2008, 26: 263–271.

8. Chandrasekar K, Chary NS, *et al.,* Fractionation studies and bioaccumulation of sediment-bound heavy metals in Kolleru lake by edible fish. Environmental International. 2003, 29, 1001–1008.

9. Cook JA, Andrew SM, *et al.,* Lead, zinc, cadmium and fluoride in small mammals from contaminated grass-land established on fluorspar tailings. Water, Air, and Soil Pollution. 1990, 51, 43–54.

10. Deb SC, Santra SC. Bioaccumulation of Heavy Metals in fishes. An In-Vivo Experimental study of Sewage Fed Ecosystem. The Environmentalist. 1997, 17: 21-32.

11. Elliott P, Arnold R, *et al.,* Risk of mortality, cancer incidence, and stroke in a population potentially exposed to cadmium. Occup Environ Med. 2000. https://www.ncbi.nlm.nih.gov/pubmed/10711276#

12. Ellis JK, Athersuch TJ, *et al.,* Metabolic profiling detects early effects of environmental and lifestyle exposure to cadmium in a human population. BMC Med. 2012. https://www.ncbi.nlm.nih.gov/pubmed/22713677#

13. FAO: Compilation of legal limits for hazardous substances in fish and fishery products. FAO Fishery Circular, No. 464. 1983, pp: 5-100.

14. FAO: Cultured Aquatic Species Information Programme; *Oreochromis niloticus (Linnaeus, 1758).* 2015.

15. Farag AM, May T, *et al.,* The effect of chronic Chromium exposure on the health of Chinook salmon (*Onchorhynchus tshawytscha*) Aquatic Toxicology. 2006, 76: 246–257.

16. Farombi EO, Adelowo OA, *et al.,* International Journal Environmental Research and Public Health. 2007, 4(2): 158-165.

17. FEPA: Guideline and Standards for Environmental Pollution and Control in Nigeria. Federal Environmental Protection Agency, Nigeria. 2003.

18. Fiala J, Hrubá D, *et al.,* Is environmental cadmium a serious hazard to Czech population? Int J Occup Med Environ Health. 2001, 14: 185–188.

19. GESAMP: Protecting the oceans from land based activities: Land based sources and activities affecting the quality and use of the marine, coastal and associated freshwater environments. 2001, pp. 162.

20. Goyer RA, Clarsksom WT. Toxic effects of metals. In: C.D. Klaassen (Ed.), Casarett and Doull's Toxicology. The Basic Science of Poisons, McGraw-Hill, NY. 2001, pp. 811–867.

21. Henson MC, Chedrese JP. Endocrine Disruption by Cadmium, a Common Environmental Toxicant with Paradoxical Effects on Reproduction. 2004, 229 (5): 383-392. https://doi.org/10.1177/153537020422900506

22. Henry F, Amara R, *et al.,* Heavy metals in four fish species from the French coast of the eastern English Channel and southern bight of the North Sea. Environment International. 2004, 30: 675–683.

23. Järup L, Akesson A. Current status of cadmium as an environmental health problem. Toxicology and Applied Pharmacology. 2009. https://www.ncbi.nlm.nih.gov/pubmed/19409405#

24. Järup L. Hazards of heavy metal contamination. British Medical Bulletin. 2003, 68: 167-82. https://www.ncbi.nlm.nih.gov/pubmed/14757716#

25. Järup L. Cadmium overload and toxicity. European Dialysis and Transplant Association - European Renal Association. 2002, 2, 35-9. https://www.ncbi.nlm.nih.gov/pubmed/11904357#

26. Jarup L, Berglund M, *et al.,* Health effects of cadmium exposure—a review of the literature and risk estimate. Scand J Work Environ Health. 1998, 24(Suppl 1):1–52.

27. Jennings GD, Sneed RE, *et al.,* Metals in drinking water. North Carolina Cooperative Extension Service Publication no.:AG-473-1. 1996.

28. Kalay M, Canil M. Elimination of essential (Cu, Zn) and non-essential (Cd, Pb) metals from tissue of a freshwater fish *Tilapia zilli*. Turkish Journal of Zoology. 2000, 24: 429–436.

29. Licata P, Trombett D, *et al.,* Organochloride compounds and heavy metals in the soft tissue of the mussel *Mytilus galloprovincialis* collected from Lake Faro (Sicily, Italy). Environment International. 2004, 30: 805–810.

30. Lindbohm ML, Sallmen M. Paternal occupational lead exposure and spontaneous abortion.

Scandinavian Journal of Work, Environment and Health. 1991, 17(2): 95-103.

31. Machado-Allison, A.J., 1987. Los peces de los llanos de Venezuela. Un ensayo sobre su Historia Natural. Universidad Central de Venezuela, Caracas, 144 p.
32. Macklin MG, Brewer PA, *et al.,* A geomorphological approach to the management of rivers contaminated by metal mining. Geomorphology. 2006, 79: 423–447.
33. Manju M. Effects of heavy metals on human health. International Journal of Research – GRANTHAALAYAH. 2015, 530: 2394-3629.
34. Mansour SA, Sidky MM. Ecotoxi-cological studies. 3: Heavy metals contaminating water and fish from Fayoum Governorate, Egypt. Food Chemistry. 2002, 78: 15-22.
35. Martin CW. Heavy metal trends in floodplain sediments and valley fill, River Lahn, Germany. Catena. 2000, 39: 53-68.
36. Mendil D, Uluozlu OD. Determination of trace metals in sediment and five fish species from lakes in Tokat, Turkey. Food Chemistry. 2007, 101: 739-745.
37. NAS: Medical and biological effects of environmental pollutants: manganese. Washington, DC, National Academy of Sciences, National Academy Press. 1973.
38. Nouri J, Mahvi AH, *et al.,* Regional distribution pattern of groundwater heavy metals resulting from agricultural activities. Environmental Geology. 2008, 55: 1337–1343.
39. Passow H, Rothstein A, *et al.,* The general pharmacology of the heavy metals. Pharmacological Reviews. 1961, 13: 185-224.
40. Salomon W, Forstner U. Metals in hydrocycle Berlin: Springer. 1984.
41. Sankar TV, Zynudheen AA, *et al.,* Distribution of organochloride pesticides and heavy metal residues in fish and shellfish from Calicut region, Kerala, India. Chemosphere. 2006, 65: 583–590.
42. Sing TB. The biology of the Cascadura, *Hoplosternum littorale* with reference to its reproductive biology and population dynamics. Ph. D. Thesis. University of West Indies, St.-Augustine, Trinidad. 1977, 298 p.
43. Terra BF, Araújo FG, *et al.,* Heavy metal in tissues of three fish species from different trophic levels in a tropical Brazilian river, Water, Air and Soil Pollution. 2008, 187: 275–284.
44. UNEP: Regional overview of land based sources of pollution in the wider Caribbean region, Vol. 33 UNEP/CEP Kingston. 1994, pp. 89.
45. US Department of the Interior: Mineral industry surveys. Manganese. Washington, DC, Bureau of Mines and the US Geological Survey. 1998.
46. US EPA: Health assessment document for manganese. Final draft. Cincinnati, OH, US Environmental Protection Agency, Office of Research and Development (EPA-600/8-83-013F). 1984.
47. USGAO: Health Effect of lead in drinking water. U.S. General Accounting Office reports, 2000.
48. Venkatramreddy V, Vutukuru SS, *et al.,* Ecotoxicology of Hexavalent Chromium in Freshwater Fish: A Critical Review. Reviews on Environmental Health. 2009, 24: 129–145.
49. Vutukuru SS. International Journal of Environmental Research and Public Health. 2005, 2: 456-462.
50. Webb M. The geochemistry, Biochemistry and Biology of Cadmium". Elsevier/Noyth Holland Biomedical Press, Amsterdam. 1979.

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