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Levels of Cr, Cu and Zn in Food Stuffs from a Wastewater Treatment Wetland, Phnom Penh: A Preliminary Assessment of Health Risks

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Abstract: The naturally occurring wastewater treatment wetlands of Phnom Penh, Cambodia, also are home to a peri-urban community that actively harvests various food stuffs (vegetables, snails, fish) from the wetlands. Concern has been expressed about the potential health implications of eating food stuffs taken from the wetlands. Therefore, the objectives of this study were to identify the uses (e.g. fishing, shellfish cultivation, and aquatic plant harvesting) of wetlands through direct survey of users; analyze food stuffs to assess metals (Zn, Cu and Cr) levels; and develop simple contaminant exposure estimates for the survey participants. Sample collection and social surveys were conducted to fulfill the objectives of this research. It was found that the metals concentrations in vegatables were low compared to fishes and snails. The contaminant exposure estimates (risk assessment) of Morning glory (*Ipomoea aquatica*), the predominant vegetable in the study area, and fish, showed that Zn, Cu and Cr originating from consumption of these food stuffs still do not pose any serious health risk to the community (with the exception of Cr for children eating fish at one sample site). A higher risk was identified for children consuming snails, specifically with respect to Cr.

Key words: Exposure pathway, Morning glory, fish, snails, heavy metals, risk assessment, wetland.

Introduction

There is some concern that there may be a significant increase of pollution due to the decreasing area of sewage treatment wetlands (from planned drainage) and increasing industrialization around Phnom Penh. The city relies on the wetlands to treat its waste before it reaches the Mekong/Bassac/Tonle Sap river system. Most wastewater discharged from the industries does not receive pretreatment, which may lead to a decline in the quality of the water around the wetland area. Not only does the wetland serve a wastewater purification role, but it also is a natural and economic resource for the peri-urban community around this area. Moeng (2004) stated that people living around the Boeng Trabek area earned $27.5/day from vegetable plantation in 2002. There were 294 farmers who harvested up to 26 tons/day of vegetables on the 123 ha land area around Boeng Trabek, Boeng Cheung Ek and Boeng Tumpun wetlands. Those vegetables were then sold to markets and also used as daily food. Unfortunately, even without proof through direct analysis, the food stuff has potential for heavy metal contamination from the wetland as the concentrations and mass loadings of Cr and Cu are observed to decline

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through the wetland before reaching its outlet (Visoth et al., 2010). Eating contaminated food stuff may result in a negative impact to the consumers' health. Little et al. (2003) reported that there may be a risk to the people's health that are living and eating the available food stuff around the wetland area in Phnom Penh. However, there has been minimal quantification of the metal levels in food stuff, with the exception of Marcussen et al. (2009). Therefore, the objectives of this study were to: identify the uses (e.g. fishing, shellfish cultivation and aquatic plant harvesting) of wetlands through direct survey of users; analyze food stuffs to assess metal (Zn, Cu, and Cr) levels; and develop simple contaminant exposure estimates for the survey participants.

Materials and Methods

Sample Collection and Preparation

Food stuff sampling was conducted in both the dry (12 May 2007) and wet (21 September 2007) seasons. This collection was done at three different sites on the Boeng Cheung Ek wetland namely Trabek Downstream (Site 1), Middle (Site 2) and Boeng Cheung Ek Outlet (Site 3) to compare the level of contaminants. These sites were similar to the sample sites described by Visoth et al. (2010). The map of the study area is given in Figure 1. All the food stuff was collected by hand, then put into plastic bags marked with the relevant site and brought back to the laboratory facilities at Royal University of Phnom Penh (RUPP). Fish and snail samples were obtained from local fishermen as near the vegetable sites as possible. The fish were placed in an ice box and transported to the RUPP laboratory.

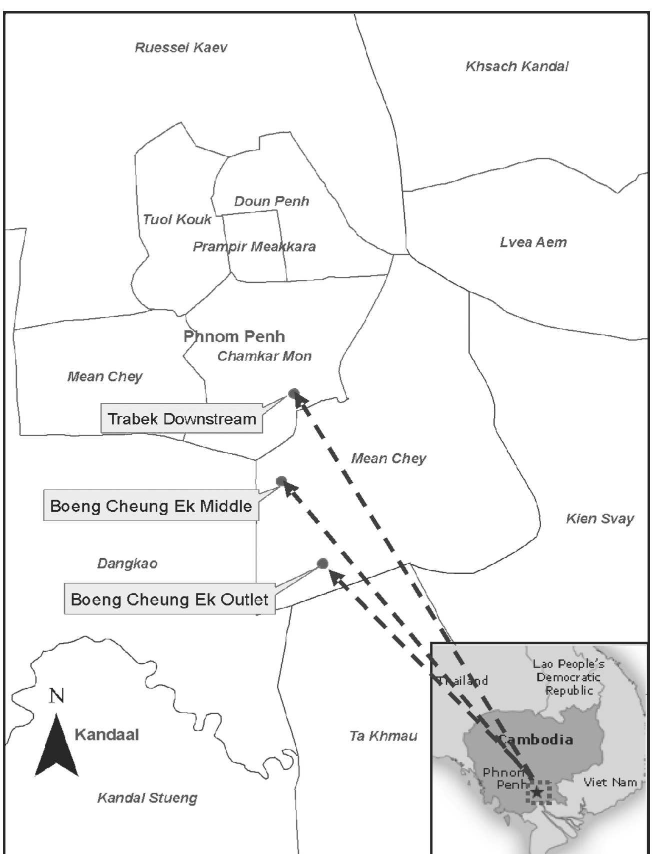

Figure 1: Location of Boeng Cheung Ek wetland and sample sites.

Sample Analysis

Vegetables, fish and snails were separated and identified following the method of Campbell and Plank (1998), to determine the concentration of the selected heavy metals namely Cu, Cr, and Zn. The samples were digested by concentrated nitric acid and filtered before the analysis by Atomic Absorption Spectrophotometer (AAS). Analytical instrumentation was a Perkin-Elmer, AAS housed in the Chemistry Department at RUPP. It is important to emphasize that only the edible parts of the food stuffs were used for the analysis. All the glassware to be used were cleaned with 10% HNO_3 to avoid contamination.

Social Survey

A social survey was conducted at the end of June 2008. Details of the survey questions can be obtained from the senior author and are not provided here in consideration of space. Briefly, however, the households were asked questions regarding socioeconomic characteristics, food stuff production, and food consumption. The total number of people surveyed was 67 for each site (total of 201 people).

Risk Assessment

Risk Assessment with regard to exposure to metal-contaminated food stuff by ingestion was carried out to estimate the non-cancer toxic (chronic) risk of local poor communities who derive their income mainly from the wetland resource. Estimation of risk was calculated based on equation details in USEPA's Exposure Factors Handbook (cited in Leung et al., 2008). The Average Daily Dose (ADD) (mg/kg/day.BW (body weight)) was determined by the equation:

$$\text{ADD} = \frac{C \times IngR \times EF \times ED}{BW \times AT}$$

where C is the average concentration of heavy metal (mg/kg.WW (wet weight)) in the food stuff, and Ingestion rates, $IngR$ (mg/day), of the food stuff. An average body weight, BW of 60 kg for adults and 15 kg for children was assumed. Based on the survey in this study exposure frequency, *EF* = 76 days/year for Site 2 and 52 for Site 3; exposure duration, *ED* = 10 and 5 years for adults and children (Site 2) and 7 and 5 years for adults and children (Site 3); the averaging time, *AT* = 3650 and 1825 days for adults and children (Site 2) and 2555 and 1825 days for adults and children (Site 3). Non-cancer toxic risk was determined by calculating the hazard quotient, HQ where HQ = ADD/RfD and RfD (mg/kg/day.BW) is an estimation of the daily exposure to the human population that is likely to be without appreciable risk of deleterious effect during a lifetime. Therefore, HQ<1 suggests unlikely adverse health effects. An HQ>1 suggests the probability of adverse health effects (Watts, 1998). RfD for Zn, Cu and Cr used in this study were 0.3, 0.05 and 0.003 mg/kg/day respectively (Health Canada, 1995; Baars et al., 2001; Environment Agency, 2002).

The calculation of Risk Assessment was done based on the availability of food stuff at each site. However, because of the broad range of fish and snail species that are eaten, an average concentration for fish and snails was used in the Risk Assessment calculations.

Results and Discussion

Heavy Metal Concentrations

Samples were collected only by hand due to the ecology at the sites. There are many different kinds of vegetables and fishes found in each site, especially at Site 3 (Outlet area). Additionally, the variety of species varied according to the seasons. However, Morning glory (also known as water spinach) and Snakehead fish were the predominant vegetable and fish species, respectively, at all three sites and in both seasons. Figures 2, 3, and 4 show the concentrations of selected heavy metals in food stuff at the different sites, by season. No fish species were available at Site 1. Four kinds of vegetables were found at common sites, namely Saladesong, Morning glory, Vietnamese herb, and Kachet (also known as water mimosa). It is noted that Saladesong has the highest value of Zn in the dry season (4.039 mg/kg WW) at Site 1. Snail generally had a higher concentration of the three heavy metals. Only Morning glory and Kachet were available at Site 2, in addition to many kinds of fishes such as Catfish, Krach fish, Eel, and Snakehead fish.

A greater variety of vegetable and fish species were found at Site 3 compared to the other two areas. This may be due to the quality of soil and water near the outlet which could make suitable conditions for both vegetables and fishes to thrive. In addition, Site 2 is an area of the wetland that focusses heavily on Morning glory and water mimosa production, essentially to the exclusion of other vegetables. Snails were found at all three sites, although these were not sorted by species. The concentration of heavy metals in food stuff generally was lower in the rainy season. The pollutant concentrations appear to be diluted during this wet season, resulting in lower contamination of the wetland area. The dilution may be the result of a freshwater pulse entering the wetland from the Bassac River during the rainy season (see Visoth et al., 2010). In essence, the wetland acts like a mini-Tonle Sap Lake system. This freshwater pulse also could bring fish to the wetland from outside areas. Generally, lower concentrations of metals were noted in the vegetables as compared to fish and snails at the study areas.

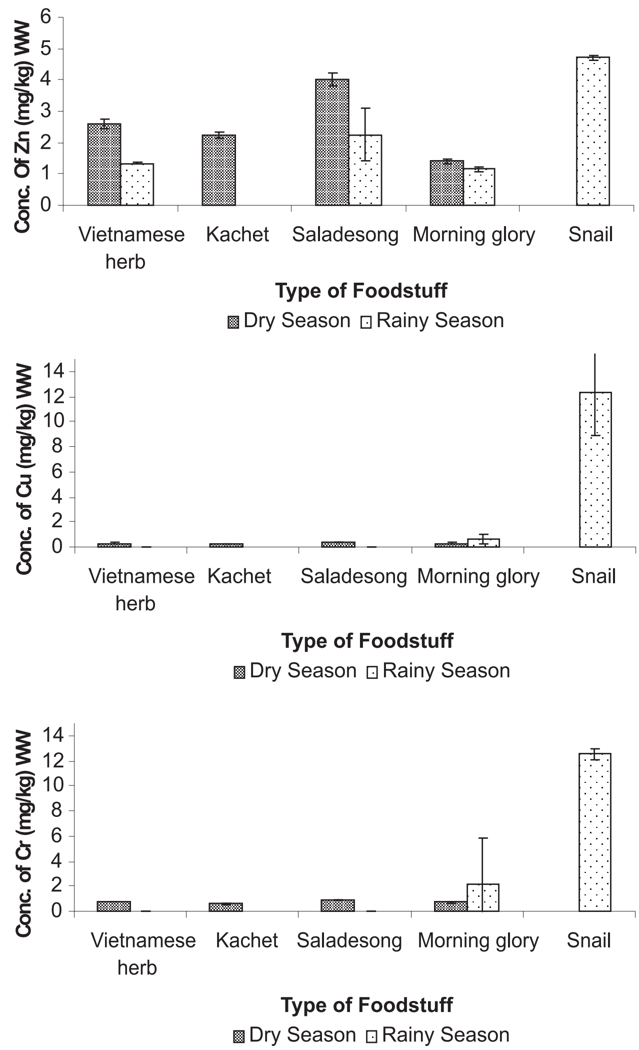

Figure 2: Selected heavy metals concentrations at Site 1.

Figure 3 shows the Cu concentrations were high in Snakehead fish in the rainy season at Sites 2 and 3 respectively. Higher concentrations of Zn and Cr in fish species was indicated for both rainy and dry season in Sites 2 and 3 (Figures 3 and 4).

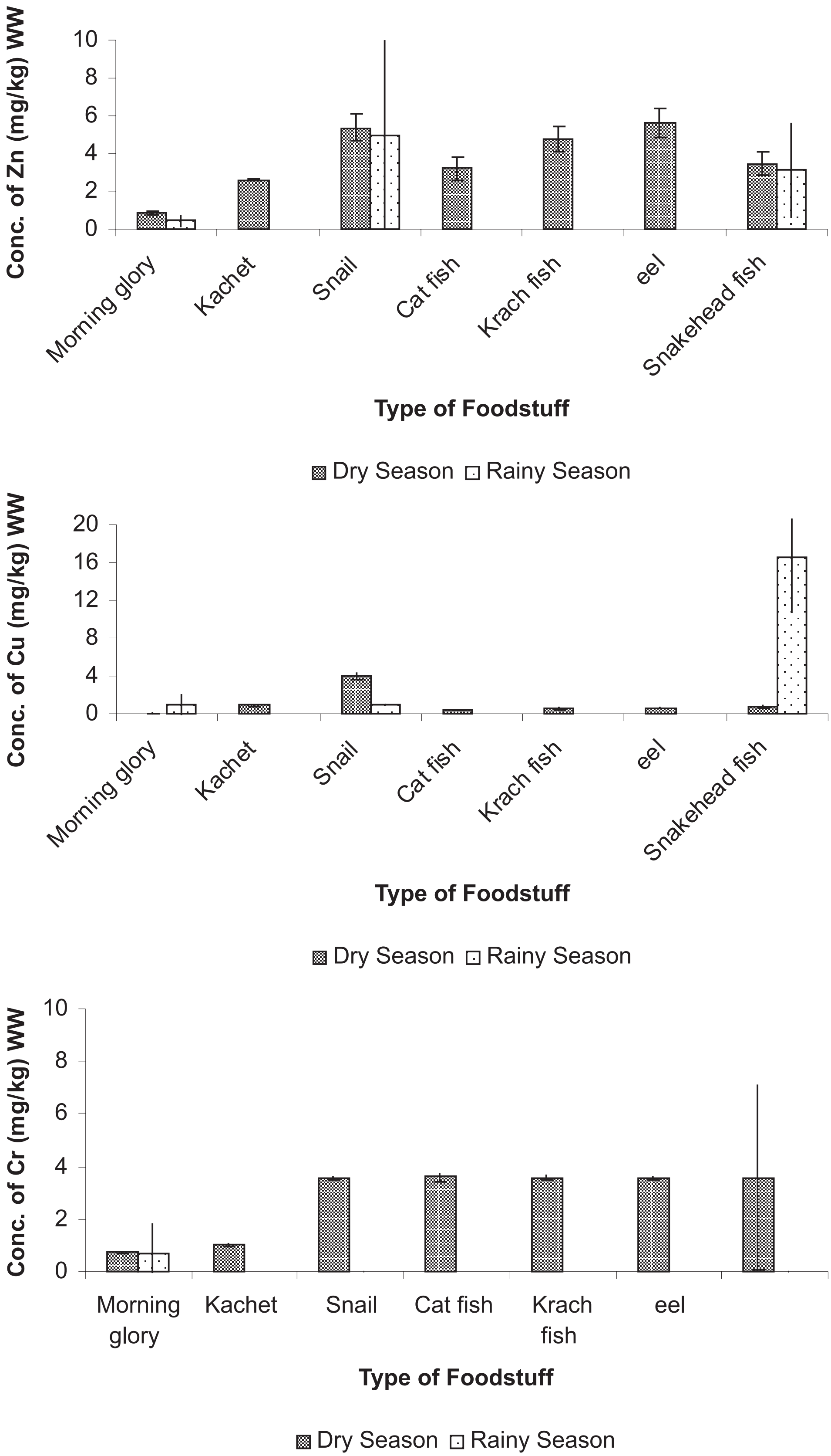

Figure 3: Selected heavy metals concentrations at Site 2.

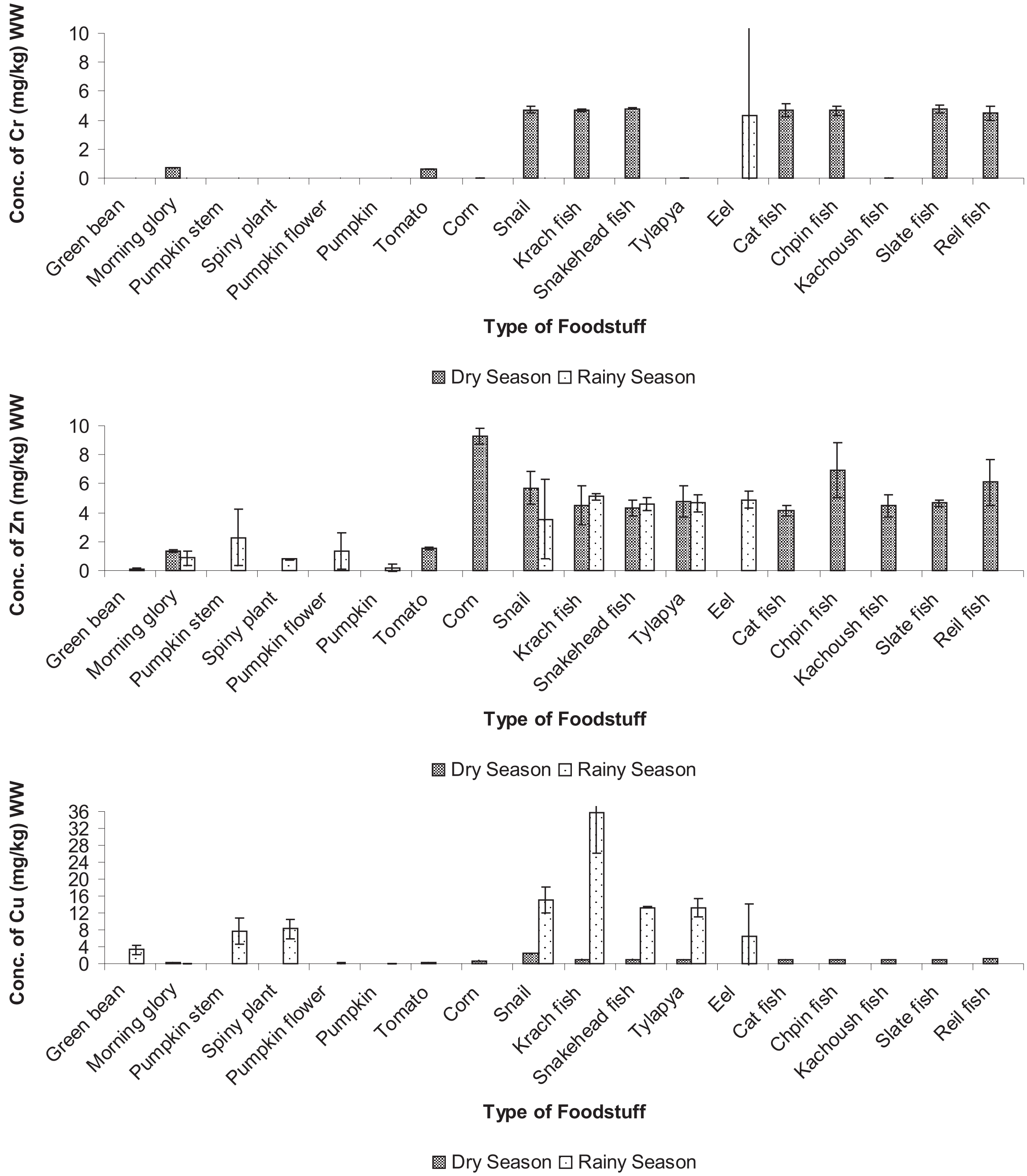

Figure 4: Selected heavy metals concentrations at Site 3.

Risk Assessment

An assessment of human exposure risks, based on measured contaminant concentrations in Morning glory, fish and snails, was done for two target groups: adults and children. The calculation was based on the average consumption rate and frequency. The calculation suggested that the wetland grown Morning glory might not be a health hazard for either adults or children since the hazard quotient for the three heavy metals was < 1 as indicated in Table 1. It is noted that by considering the season, HQ for Zn at Site 2 in the dry season (0.00139) was two times greater than in the rainy season for adults. The Cu HQ was almost ten times higher in rainy season (0.00865) compared to dry season at the same site for adults. Similar HQ was found in Cr for both seasons at the said site. A higher HQ was found for all heavy metals at Site 3 for both adults and children in the dry season. Furthermore, Cr has the highest HQ value of 0.06515 and 0.19546 for adults and children respectively.

Table 1: Calculated heavy metal ADD (mg/kg/day·BW) and HQ for adults and children consuming Morning glory

Heavy metal	*Season*	*Adult*		*Child*	
		ADD	*HQ*	*ADD*	*HQ*
Zn (Site 2)	Dry	0.00041	0.00139	0.00095	0.00317
	Rainy	0.00022	0.00076	0.00052	0.00174
Cu (Site 2)	Dry	4.13E-05	0.00082	9.44E-05	0.00188
	Rainy	0.00043	0.00865	0.00098	0.01978
Cr (Site 2)	Dry	0.00035	0.11757	0.00080	0.26874
	Rainy	0.00032	0.10899	0.00074	0.24912
Zn (Site 3)	Dry	0.00038	0.00128	0.00115	0.00384
	Rainy	0.00024	0.00081	0.00073	0.00245
Cu (Site 3)	Dry	5.36E-05	0.00107	0.00016	0.00535
	Rainy	0	0	0	0
Cr (Site 3)	Dry	0.00019	0.06515	0.00058	0.19546
	Rainy	0	0	0	0

Table 2: Calculated heavy metal ADD (mg/kg/day·BW) and HQ for adults and children consuming snails

Heavy metal	*Season*	*Adult*		*Child*	
		ADD	*HQ*	*ADD*	*HQ*
Zn (Site 1)	Dry	0	0	0	0
	Rainy	0.001342	0.004472	0.004025	0.013417
Cu (Site 1)	Dry	0	0	0	0
	Rainy	0.003516	0.117198	0.010548	0.351595
Cr (Site 1)	Dry	0	0	0	0
	Rainy	0.003569	**1.189763**	0.010708	**3.56929**
Zn (Site 2)	Dry	0.002611	0.008705	0.005969	0.019896
	Rainy	0.002416	0.008054	0.005523	0.018408
Cu (Site 2)	Dry	0.00193	0.038605	0.004412	0.088241
	Rainy	0.000506	0.010125	0.001157	0.023143
Cr (Site 2)	Dry	0.001736	0.578641	0.003968	**1.322608**
	Rainy	0	0	0	0
Zn (Site 3)	Dry	0.001629	0.005431	0.004888	0.016292
	Rainy	0.00101	0.003366	0.003029	0.010098
Cu (Site 3)	Dry	0.000664	0.013272	0.001991	0.066361
	Rainy	0.004314	0.086283	0.012942	0.431415
Cr (Site 3)	Dry	0.001345	0.448387	0.004035	**1.345162**
	Rainy	0	0	0	0

Table 3: Calculated heavy metal ADD (mg/kg/day·BW) and HQ for adults and children consuming fish

Heavy metal	*Season*	*Adult*		*Child*	
		ADD	*HQ*	*ADD*	*HQ*
Zn (Site 2)	Dry	0.002073	0.006910	0.004739	0.015795
	Rainy	0.001517	0.005058	0.003468	0.011560
Cu (Site 2)	Dry	0.000299	0.005986	0.000684	0.013681
	Rainy	0.008078	0.161563	0.018464	0.369286
Cr (Site 2)	Dry	0.001742	0.580584	0.003981	**1.327050**
	Rainy	0	0	0	0
Zn (Site 3)	Dry	0.001419	0.004729	0.004256	0.014187
	Rainy	0.001298	0.004327	0.003894	0.012981
Cu (Site 3)	Dry	0.00026	0.005203	0.00078	0.026014
	Rainy	0.004889	0.097771	0.014666	0.488857
Cr (Site 3)	Dry	0.000999	0.333085	0.002998	0.999255
	Rainy	0.000311	0.103525	0.000932	0.310575

The results for snails show that there may be some risk with respect to Cr in the rainy season for both adults and children in Site 1 as HQ is >1. The HQ also was >1 for children at Sites 2 and 3 in the dry season. Similarly, the fish risk calculation revealed that Cr is potentially a health hazard to children at Site 2 in the dry season (Table 3). In comparison to adults, the HQ for children was almost ten times greater at all locations. This was attributed to the smaller body size with a high ingestion rate.

The ADD values presented in Tables 1, 2, and 3 of course only represent the individual food stuff (although these are primary food staples) and underestimate the total ADD for an individual. The total intake must be calculated based on the cumulative ADD of all food stuffs as well as estimates of intake from inhalation through air, amount taken in by drinking water, amount taken in by eating soil, amount absorbed through skin by contact with water, and amount absorbed through skin by contact with soil (e.g. Health Canada, 1995).

In general, the HQ values for the analyzed food stuffs are <1, with the exception of Cr in snails for children (all sites, but not all seasons), Cr in snails for adults (Site 1, rainy season) and Cr in fish for children (Site 2, dry season). Marcussen et al. (2009) analyzed Morning glory from Boeng Cheung Ek for a number of metals, including Cu, Zn, Pb, Cd, and As and fish (Blackskin catfish, Snakehead, and Swamp eel) for Cd, Pb, and As. The levels of Cu and Zn reported by Marcussen et al. (2009) for Morning glory were of the same magnitude, but slightly higher, than our results. Marcussen et al. (2009) assessed intake of metals through Morning glory consumption using the Codex Alimentarious Commission Provisional Tolerable Intake approach and came to a similar conclusion as shown by our results. For fish, Marcussen et al. (2009) separately analyzed the muscle, liver, and skin and concluded that there was little health risk related to consumption, although the skin of the Blackskin catfish should be avoided.

Conclusions

This study shows that the selected three heavy metals in fish and snail species were higher as compared to vegetables collected from the Boeng Cheung Ek wetland. The HQ calculations suggest that there was limited risk to human health from the home-grown vegetable or fish with the exception of Cr for fish consumed by children (Site 2, dry season only). This conclusion is consistent with the findings of Marcussen et al. (2009). There appears to be a higher risk for Cr intake associated with snail consumption, particularly for children. There are inherent uncertainties to our study, including determination of actual exposure duration, ingestion rate and, possible heavy metal concentrations heterogeneity in food stuff. Additional sampling should be done, particularly focussing on snails and at more sample sites. If concerns regarding Cr risk for snails are confirmed with additional sampling, an education programme could be developed to work with the local community in discouraging children's consumption of snails from the wetland.

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