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Examining dietary cadmium exposure levels within the population of a metal recycling village in Bac Ninh Province, Vietnam

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Photo cover: Le Thi Thuy

Abstract

Consumption of food crops contaminated with heavy metals is a major problem in many developing countries. This report examines the dietary cadmium (Cd) exposure levels within the population of a metal re-cycling village in northern Vietnam, close to the city of Hanoi. Calculations were performed in order to discover whether levels of exposure via the major diet contributors, rice, water spinach, and fish, exceed doses that have been associated with deleterious health effects. The highest concentrations of Cd were found in rice while the lowest were found in water spinach. The mean values of the Hazard Quotient (HQ; ratio of exposure to a 'safe' dose) for Cd were:3.77×10^{0} for rice, 1.14×10^{-1} for fish and 4.30×10^{-2} for water spinach. These values indicate that the dose associated with the consumption of rice exceeds the 'safe dose' as defined by the United States Health Protection Agency (U.S EPA). Values of HQ greater than 1.00 are considered to indicate a possible health risk. The mean value for concentration of Cd in rice was 0.46 mg Cd kg^{-1} (ppm), this value exceeds the limiting values set by EU (0.2 ppm) and WHO (0.4 ppm). This means that the rice in the village Man Xa is not suitable for human consumption. The mean HQ for fish and water spinach was less than 1.00, so deleterious health effects caused by these are less probable. However, the Cd concentrations in fish and water spinach was not analysed for the study village but in other villages in peri-urban Hanoi. There was no statistical evidence that there could be a difference between gender and the HQ for rice, fish and water-spinach. The average HQ for rice was greater in the age over 60 year compared to the ages under 60 year. For consumption of rice all age groups exceeded the safe reference dose set by U.S EPA (2008). For fish and water spinach the highest average HQ was found in the age group 13-60 years old. None of the age group for consumption of fish and water spinach exceeds the reference dose set by U.S EPA (2008).

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1. Introduction

Agriculture is a significant sector of the Vietnamese economy. In Vietnam there are 9.40 million hectares of agricultural land, from a total natural landmass of 33.1 million ha (Khai, 2007). Vietnam has experienced rapid development in recent decades leading to increases in population coupled with accelerated urbanisation and industrialisation. These factors have had a number of potential negative impacts on the environment, including the agricultural production systems and the food chain, that might become a threat to food safety and human health (Khai, 2007).

Increased demand for food has placed pressure on agriculture, which brings about more intensive use of pesticides and fertilizers for food used both domestically and exported. Urbanisation and industrialisation has also led to an increased production of waste and various co-products. In many cases, untreated wastewater from households and industries is regularly discharged into local watercourses that are used for irrigation. Although wastewater often contains useful concentrations of organic matter and nutrients, which farmers have used for generations as an organic fertilizer, it can also contain potentially toxic elements (PTEs) such as cadmium (Cd) or lead (Pb) (Khai *et al*., 2007; Marcussen *et al.,* 2007).

Potentially toxic elements, such as Cd, may accumulate in plants as they can take up both essential and non-essential elements. Non-essential elements at concentrations that are not phytotoxic, could still represent a significant health risk to consumers. In polluted environments, high concentrations of PTEs have been found in plants, but the accumulation rate differs between plant species (Marcussen *et al.,* 2007).

This study will provide information about Cd levels in rice and a risk assessment for Cd exposure risks through intake of rice, fish and water spinach within a metal recycling community located in Bac Ninh province in the Red River Delta of northern Vietnam.

2. Aim and Objectives

The overall aim of this report is to explore whether exposure to Cd in rice and other subsistence-level foods exceed published ‘safe’ doses such as those derived by the United States Health Protection Agency (U.S EPA. The specific objectives were (i) to estimate the ratio of total Cd dose to the safe dose (termed the hazard quotient, HQ) for all study participants, (ii) to determine if there was an association between gender and HQ, and (iii) to determine if there was any association between age and HQ. To investigate these questions, data describing the metal contamination sources at the study site, the amount of metals that are absorbed in the agricultural products, and finding out how the people are exposed to metals were collected. This study focussed on the three foods that constituted the most significant proportion of the diet and were grown in the local area: rice, water spinach, and fish.

3. Background

3.1. The Sida-SAREC project

This study was a part of a larger research project titled; "Towards the mitigation of environmental and public health risks due to heavy metal contamination in irrigated rice-based systems of Vietnam", which is a Sida-SAREC funded project. SAREC was a department of SIDA, the Swedish Agency for International Development Cooperation, a government agency under the Ministry for Foreign Affairs focused on supporting and developing research in developing countries. SIDA's aims to make it possible for impoverished populations to improve their own living conditions (SIDA, 2007). The study initially only examined soil-rice interactions, but developed into investigating exposure and public health associated with rice-based/industrial systems. The objectives are based on the identified research needs and urgent sustainability issues related to environmental and public health risks due to heavy metal contamination in peri-urban agricultural areas in Vietnam (Öborn *et al.,* 2005).

3.2. Cadmium in the environment

Cadmium in the environment comes both from natural sources and anthropogenic sources as shown in Table 1.

Table 1. Cadmium emissions to the environment from natural and anthropogenic sources

Natural sources	Anthropogenic sources
Volcanic eruptions	Primary non – ferrous metal production
Vegetation	Waste incineration
Windblown dusts	Secondary non – ferrous metal production
Forest Fires	Wood combustion
Sea salt sprays	Phosphate fertilisers
	Iron and steel production
	Fossil fuel combustion
	Industrial applications
	Rubber tyre wear
	Zinc mining

Source: (Traina, 1999)

Cadmium is a white, lustrous, and tarnishable metal. It has an atomic number of 48 in the periodic table of elements. Cadmium has a heat vaporisation of 26.8 kcal mol^{-1}, melting point of 321°C, and a boiling point of 767°C. These properties make Cd susceptible to atmospheric transport, which is a major environmental concern because of atmospheric deposition in soil and water (Traina, 1999).

There are many factors that affect the levels of Cd uptake by plants. As Table 2 shows, the availability of Cd to plants is affected by both biotic factors and abiotic factors. The mechanistic process resulting in uptake of Cd by plant roots is not fully understood, yet one explanation says that uptake is controlled by the electrochemical potential difference between the activity of Cd^{2+} in the cytosol (Welch *et al.*, 1999). Cadmium can also be absorbed as inorganic complexes such as, $CdCl^{+}$, $CdCl_2^{0}$ or $CdSO_4^{0}$ or as organic complexes such as phytometallophore complexes (Singh *et al.*, 1999). The Zn^{2+} ion interacts with Cd and reduces uptake under Zn-deficient conditions (Singh *et al.*, 1999).

Table 2. Biotic and a-biotic factors affecting Cd uptake by plants

Biotic factors	A-biotic factors
Plant species	Soil pH
Crop cultivar	Clay content
Plant tissue	Carbonates
Leaf age	Metal oxides (Fe and Mn)
Root activity	Redox potential
Rooting pattern	Organic matter (type and content)
Rhizosphere and root associated microorganisms	Complexing ligands
(for example, mycorhizal and fungi)	Soluble salts
	Soil management practices
	Phosphate fertilisers
	Manures
	Sewage sludge
	Soil tillage
	Irrigation
	Lime

Source: (Singh *et al.*, 1999)

3.3. Health risks with cadmium

It has been estimated that the dietary Cd adsorption in humans are about 5%, but this estimate may increase to 20-30% depending on the individual (Satarug *et al., 2004*). Cadmium accumulation occurs in various human tissues and organs, but it is greatest in the kidneys and liver. Cadmium levels accumulate with age, and stay in the human body for many years with a half-life of 30 years (Satarug *et al.*, 2004). Cadmium increases with age in the kidneys and liver due to the lack of an active biochemical process for its elimination, coupled with renal reabsorption (Satarug *et al.*, 2004). Increased cancer risk, end-stage renal failure, early onset of diabetic renal complications, and deranged blood pressure regulation are some examples of diseases coupled to Cd exposure (Satarug *et al.*, 2004).

4. Materials and Methods

4.1 Site description

The metal re-cycling study village Man Xa is located in the Bac Ninh Province located in the Red River delta in northern Vietnam close to Hanoi City (Figure 1). There has been metal production in the village for over 35 years. There are 525 households with 2570 people and about 80% of these are involved in Al-recycling (Minh, 2007). Nearly every family is involved in the metal recycling industry and consequently the area is polluted. The drinking water and sewage system is very simple. There are no wastewater treatment facilities in the village, and all the wastewater from the households and factories leads directly to the closest channel, stream or pond.

Figure 1. The Northern part of Vietnam, the metal re-cycling village Man Xa, BacNinh province is located close to Hanoi city.

The population who re-cycle metals use relatively simplistic methods (Figure 2). Health and safety and industrial hygiene are not priorities due to various economic drivers. For similar reasons, personal protective equipment (PPE) is not used e.g. to filter dangerous gases and particles produced during the smelting process. Between 15-30 ton coal residues and metal slag are discharged into the surrounding agricultural land (Minh, 2007). Air and water pollution and the potential impact on the local environment and health of the inhabitants is a concern. In 2005 poisonous gases caused 30 workers to require emergency medical care (Minh, 2007). Wastewater is often used to irrigate paddy fields, which grow vegetables and rice. A by-product called slag is produced during the metal re-cycling process. After production, it is placed in ponds which are utilized for fish cultivation. The fish may ingest and collect metals from their feed which could become a health risk to villagers if the concentrations in consumed fish became too elevated (Minh, 2007). The most greatly produced food product in the study village is rice. This rice is only used within village households and not sold at market. Some of the vegetables grown in wastewater are sold, but not high quantities. (Minh, 2007).

Figure 2. The picture to the left shows a man in the study village melting down metal scrap (mainly Al) for recycling. The picture to the right shows how they burn off the plastic from cables to acquire the metals.

4.2. Household survey and soil-rice sampling and analyses

The larger Sida-SAREC study collated a range of different scientific information, which formed the basis of this current study. One tool developed in the project was a household dietary and lifestyle questionnaire, which this study has been utilising as primary data (Figure 3). This survey looked at factors such as consumption, socio-economic situation, smoking habits, age etc. The questionnaire was also designed to help further studies understand what environmental conditions the people of that area were exposed to. The questionnaire was created in Microsoft Access. The data was sorted into different tables, for example, basic information, agricultural or soils (Figure 3).

Figure 3. How the questionnaire was structured into different tables

A paired soil-rice sampling was also carried out within the Sida-SAREC project. Samples were taken on different fields across the study village in order to assess the Cd concentration in locally produced rice. The sampling sites were selected to include fields from a number of households, fields with different sources of irrigation water and with different distance to the metal recycling activities in the village. For this study rice data from the farmers included in the household survey was extracted from a data base. This information provided raw data that was used to estimate exposure to Cd, the rice data in this study is from unpolished rice. Nyberg et al (2009) has compared the Cd concentrations in unpolished and polished and found that there is only a minor difference, the Cd concentration being slightly higher in polished rice.

4.3. Fish and water spinach data

Some further information was needed in order to estimate exposure to Cd from local food, such as the amount of Cd found in fresh fish and water spinach. This information was collected from secondary data published from studies in wastewater irrigated peri-urban sites in Vietnam (Table 3). Marcussen et al (2009) reported concentrations of Cd in six types of commonly consumed fish (Swamp eel, Blackskin catfish, Snakehead, Common carp, Silver carp and Tilapia). From these data a mean value was calculated and then used in the calculations. For water spinach a mean Cd concentration from a study in Hanoi was used (Marcussen *et al*., 2008). In the calculations of Cd exposure the same mean value for the Cd concentration in fish and water spinach was used for all households in the study village.

Table 3. The mean Cd concentrations, mg Cd/kg fresh weight (fw), for fish and water spinach used to calculate the Cd dose for the people in the study village

Type of food	Cd, mg/kg fw	Source
Fishes: Swamp eel, Blackskin catfish, Snakehead, Common carp, Silver carp and Tilapia	0.111	Marcussen *et al*., 2009
Water Spinach	0.019	Marcussen *et al*., 2008

4.4. Data analyses

The calculations were done in order to find the hazard risk index for Cd in the study village. It was achieved using the following equation (Eq 1):

$$HQ = \frac{ADD}{RfD} \qquad \text{(Eq 1)}$$

HQ stands for hazard quotient, ADD is the daily average dose of a chemical, i.e. Cd, in milligram per kilogram bodyweight per day, and RfD is a reference dose in milligram per kilogram per day (Hough *et al*., 2004). RfD is defined as the maximum tolerable daily intake of a specific metal that should not result in a deleterious health outcome over the duration of a lifetime (Hough *et al*., 2004). If ADD exceeds RfD, then the HQ will be greater than 1, and thus a potential health risk (U.S EPA, 2008). The RfD value for Cd used in this report was 0.001 mg/kg/day (U.S EPA, 2008).

Data had to be collected concerning the consumption, weight, and concentration of Cd in each food. The concentration of Cd and the weight were already given, but simple calculations had to be done concerning the consumption. For every household a certain amount of food in grams was given in the questionnaire for different meals per day, but only the amount of food for the whole family was given, not for each person in the family (Table 4). However, data regarding the share in percent of this amount of food for each person was also included in the questionnaire, so calculations for rice, fish and water spinach had to be done to see how much each individual person in a household had eaten (Eq 2).

Table 4. Example how the calculations was performed for the consumption of food (g, gram), share 1 and 2 are two people in the family VM34. They share different amount of rice for different meal times during the day.

House code	Food type	Whole family (g)	Share 1 (%)	Share 2 (%)	g/rice share 1	g/rice share 2
VM34	Rice	600	33	33	198	198
VM34	Rice	400	30	25	120	100
VM34	Rice	400	30	25	120	100

g/rice = percent share * consumption for the whole family (Eq 2)

Rice had different concentrations of Cd for different households, as Table 7 shows, so first calculations had to be done to see how much Cd there was in the rice for each household. The concentrations of Cd in Table 7 was multiplied with the amount of rice each person consumed (see Table 4 for example), then it had to be divided by the body weight for each person in each household to get the ADD (Eq 3). After that, the ADD is divided with the RfD value, as Eq 1 shows to get the HQ values, see Appendix for all the HQ values. The same calculation was performed for fish and water spinach to calculate the HQ.

ADD = (Concentration of Cd * Consumed food) / Body weight (Eq3)

Table 5 shows the maximum permissible concentrations of Cd in rice, according to the European Community (EU, 2006) and the World Health Organization (WHO, 2006) guidelines. WHO allows a higher concentration of Cd in rice than EU, 0.4 mg Cd/kg rice compared to 0.2 mg Cd/kg rice. Table 6 shows the lowest, highest, average and the standard deviation for the concentration of Cd in the studied households (Table 7). The highest Cd concentration in rice was 2.35 mg Cd/kg and the mean value 0.46 mg Cd/kg, which was also higher than the limit values set by EU and WHO.

Table 5. Maximum permissible concentrations for Cd in rice set by the EU and the WHO. The limiting values for Cd is set lower by EU than WHO (EU, 2006; WHO, 2006).

	European Union	World Health Organization
Unit	mg Cd/kg	mg Cd/kg
Limiting value	0.2	0.4

Table 6. The minimum, maximum, mean and standard deviation for Cd in rice in the studied households (Table 7)

Min	Max	Mean	std
4.95×10^{-2} mg Cd/kg	2.35×10^{0} mg Cd/kg	4.55×10^{-1} mg Cd/kg	4.35×10^{-1} mg Cd/kg

Table 7. Concentration of mg Cd/kg rice for each family which were participating in the questionnaire within the Sida-SAREC study

HouseCode	mg Cd/kg rice
VM34	$2.91x10^{-1}$
VM35	$2.85x10^{-1}$
VM36	$1.56x10^{-1}$
VM37	$5.57x10^{-1}$
VM38	$3.58x10^{-1}$
VM39	$2.95x10^{-1}$
VM40	$9.72x10^{-1}$
VM41	$1.73x10^{-1}$
VM42	$6.92x10^{-1}$
VM43	$4.32x10^{-1}$
VM44	$2.28x10^{-1}$
VM45	$1.59x10^{-1}$
VM46	$4.07x10^{-1}$
VM47	$4.11x10^{-1}$
VM48	$7.28x10^{-1}$
VM49	$2.47x10^{-1}$
VM50	$1.93x10^{-1}$
VM51	$2.43x10^{-1}$
VM52	$5.85x10^{-1}$
VM53	$9.29x10^{-1}$
VM54	$2,35x10^{-0}$
VM55	$2.27x10^{-1}$
VM56	$2.03x10^{-1}$
VM57	$6.28x10^{-1}$
VM58	$1.86x10^{-1}$
VM59	$4.95x10^{-2}$
VM60	$1.59x10^{-1}$
VM61	$4.85x10^{-1}$
VM62	$5.68x10^{-1}$
VM63	$2.70x10^{-1}$

A chi-square distribution test was performed to see if there was any statistically significant associations between gender (Males/Females) and the different types of food which were consumed (rice/fish/water spinach) when looking at the average HQ. The following equation was used (Eq 4):

$$\chi^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} \qquad \text{(Eq 4)}$$

O_i = Stands for observed average HQ (i) in each category, in this situation males and females

E_i = Stands for expected average HQ (i) if a zero hypothesis (H_0) is true

Hypothesises:

H_0: There is no statistic connection between gender and the HQ for the different food types

H_1: There is a statistic connection between gender and the HQ for the different food types

The Chi-square value from Eq 4 is compared to a chi-square distribution table. If the chi-square value calculated from the HQ is smaller than the chi-square value in the distribution table, then H_0 = is true.

The chi-square value from the distribution table was calculated as following (Eq 5):

$$\chi^2_{df,1-\alpha}$$

df = degree of freedom = (Row – 1) (Column – 1) (Eq 5)
α = 5%

Equation 6 shows the P-value, it is between 0.90 and 0.95. The P- value is higher than the alfa value (α= 5%), this means that there is no significant difference. The values in equation 6 is taken from a chi-square distribution table.

Probability value: $P(\chi^2 \geq 0.01) = 1 - 0.1 < P < 1 - 0.05 = 0.090 < P < 0.95$ (Eq 6)

5. Results

Table 8 summarizes the max, mean and min range of consumption of each food stuff (g dw,fw/day), mg Cd/kg food, daily dose (mg Cd/kg bodyweight/day), and the HQ for the total population included in the study. The average HQ for consumption of rice, water spinach and fish were: 3.77 $x10^0$, 0,04 x 10^0 and 0.11 x 10^0. As Table 8 shows, the greatest HQ was associated with consumption of rice, where HQ > 1.

Table 8. The max, mean and min values for consumption (g/day), Cd concentration in food (mg Cd/kg food), daily dose (mg/Cd/kgBW/day) and the HQ for rice, water spinach and fish. n is the total number of participants in this study that reported consumption of rice, water spinach and fish

Type of Food	n	Range	Consumption	Cd conc in food	Daily dose	HQ
Rice	126	Max	1.06x 10^3(DW)	$1.23x10^0$	$2.55x10^{-2}$	25.5
		Mean	$4.10x10^2$(DW	$0.17x10^0$	$3.80x10^{-3}$	3.77
		Min	1.00x 10^2 (DW)	$0.02x10^0$	$4.00x10^{-4}$	0.42
Water Spinach	126	Max	$6.00x10^{2(}$fw)	$1.14x10^{-2}$	$2.28x10^{-4}$	0.23
		Mean	$1.53x10^2$(fw)	$2.00x10^{-3}$	$4.28x10^{-5}$	0.04
		Min	$3.00x10^1$ (fw)	$5.70x10^{-4}$	$1.04x10^{-5}$	0.0104
Fish	126	Max	$3.40x10^2$(fw)	$3.76x10^{-2}$	$8.36x10^{-4}$	0.84
		Mean	$4.92x10^1$(fw)	$5.45x10^{-3}$	$1.14x10^{-4}$	0.11
		Min	$2.00x10^1$(fw)	$2.21x10^{-3}$	$5.24x10^{-5}$	0.05

In the case of rice consumption, the highest average HQ was 7,07 $x10^0$ (Table 9), which was found in the age bracket of people over 60 years old (Table 9, Figure 4) shows. For rice consumption by the remaining population sub-groups: under 13 years and 13-60 year olds had an average HQ of 3.02 $x10^0$ and 3.52 $x10^0$ (Table 9, Figure 4). The average HQ for all ages for rice consumption had values greater than 1.00, which indicated a possible health risk associated with eating rice according to U.S EPA (2008). The average HQ was relatively low in fish and water spinach (Table 9, Figures 6 and 8) in all ages, so consumption of these products was not considered to pose a significant health risk (U.S EPA, 2008). The highest average HQ for fish was 0.13 $x10^0$ and was experienced by the population sub-group aged between 13-60 years (Table 9, Figure 6). The highest average HQ for consumption of water spinach was 0.05 $x10^0$. This was also found in 13-60 years olds (Table 9, Figure 8).

The total HQ index for consumption of rice, fish and water spinach were highest in people over 60 years of age (Figure 10).

Table 9. The mean HQ and standard deviation for different age groups; under 13, 13-60 and over 60 years old, the largest HQ is found for rice and the lowest in water spinach

	Under 13, n = 19	13 – 60, n = 97	Over 60, n = 10
Rice			
Mean	3.02	3.52	7.07
Standard Deviation	3.07	2.63	9.81
Fish			
Mean	0.05	0.13	0.04
Standard Deviation	0.08	0.21	0.05
Water Spinach			
Average	0.02	0.05	0.02
Standard Deviation	0.02	0.05	0.04

The chi-square distributions test (Eq 4), showed that there is no significant difference between gender and the different kind of food when looking at the average HQ (Figure 11). Table 10 shows the observed average HQ for rice, fish and water-spinach consumed by males and females. Table 11 shows the expected average HQ for rice, fish and water-spinach consumed by males and females. These values was then put into equation 4, found in the data analysis.

Calculated $\chi^2 = 0.01$

Value from the chi-square distribution table $\chi^2 = 5.991$

P-value = $0.90 < P < 0.95$

0.01<5.991 this means that the hypothesis, (H_0: There is no statistically significant association between sex and the HQ for the different food types) is true. But we can only state that there is statistical evidence for this, not that it is actually true. The P-value is greater than 0.05, so there is no statistical significance.

Table 10. The observed average HQ for rice, fish and water-spinach looking at males and females

O_i	Sex	Rice	Fish	Water-Spinach	Total
n = 63	Males	1.73	0.09	0.04	1.86
n = 63	Female	1.74	0.16	0.05	1.95

Table 11. The expected average HQ for rice, fish and water-spinach looking at males and females

Ei	Sex	Rice	Fish	Water-Spinach	Total
n = 63	Males	1.70	0.07	0.04	1.86
n = 63	Female	1.75	0.07	0.04	1.95

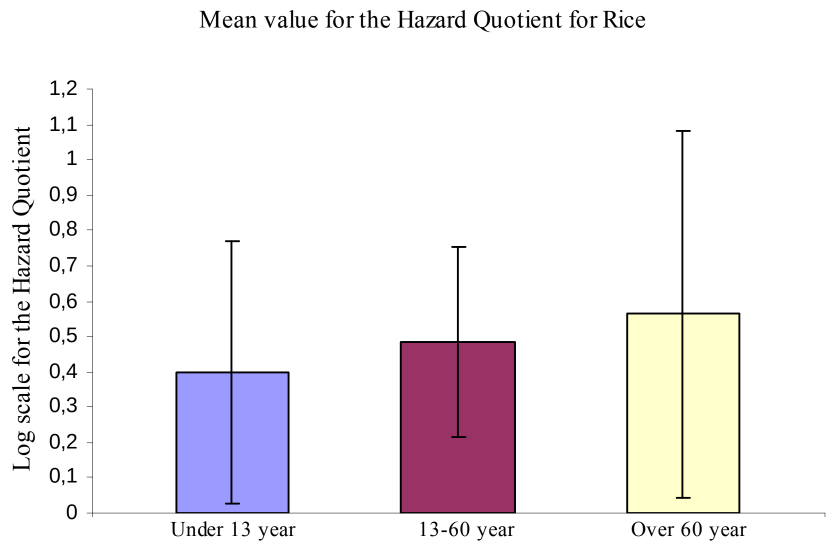

Figure 4. Mean values of the hazard risk for rice consumption were divided into three different categories: under 13 years old, 13-60 years old, and over 60 years old. The HQ was calculated as Equation 1 shows, the diagram shows that there could be potential health risks associated with Cd for all ages according to (U.S EPA, 2008).

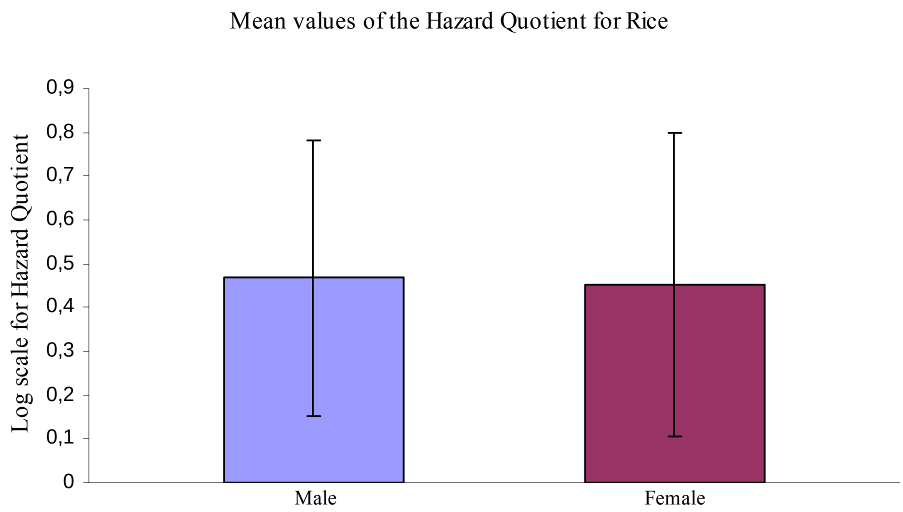

Figure 5. Mean values of the HQ for rice consumption were divided into two groups: males and females. The HQ was calculated as Equation 1 shows, the HQ for males and females are greater than one, so it could be a possible health risk according to (U.S EPA, 2008)

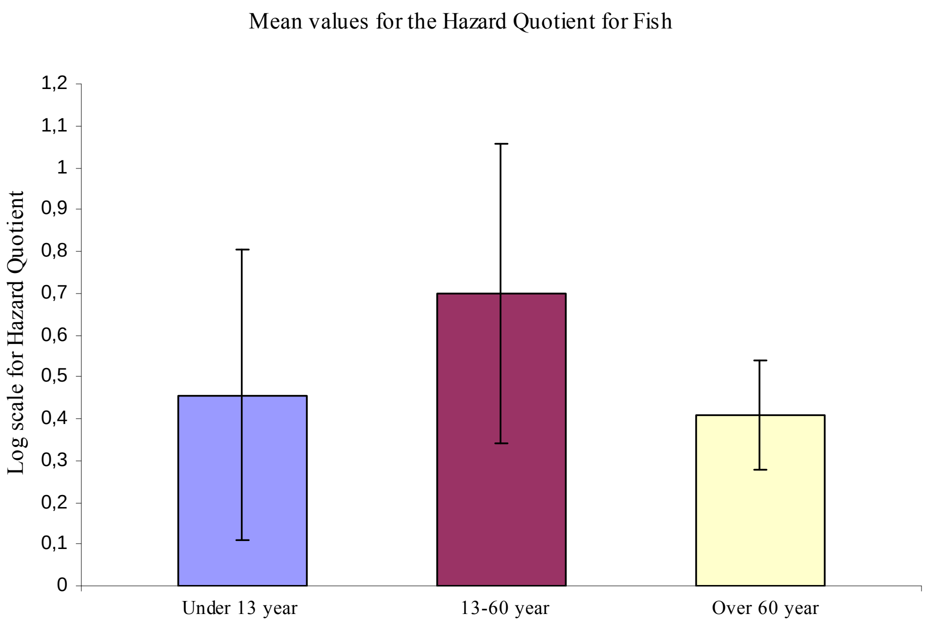

Figure 6. Mean values of the HQ for fish consumption was divided into three different categories: under 13 years old, 13-60 years old and over 60 years old. The HQ was calculated as Equation 1 shows; the diagram shows that there is no potential health risk according to (U.S EPA, 2008) .

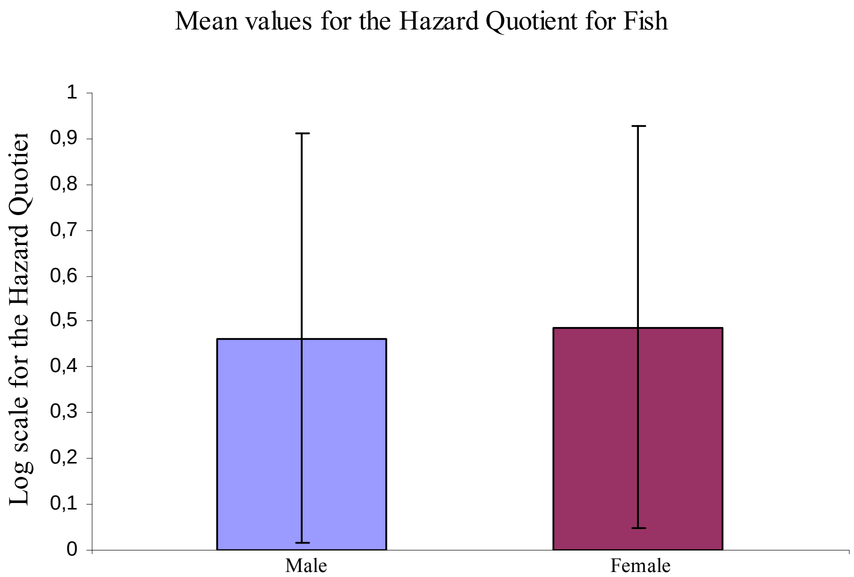

Figure 7. Mean values of the HQ for fish consumption was divided into two groups: males and females. The HQ was calculated as Equation 1 shows, the HQ for males and females are less then 1, so it is not a possible health risk according to (U.S EPA, 2008).

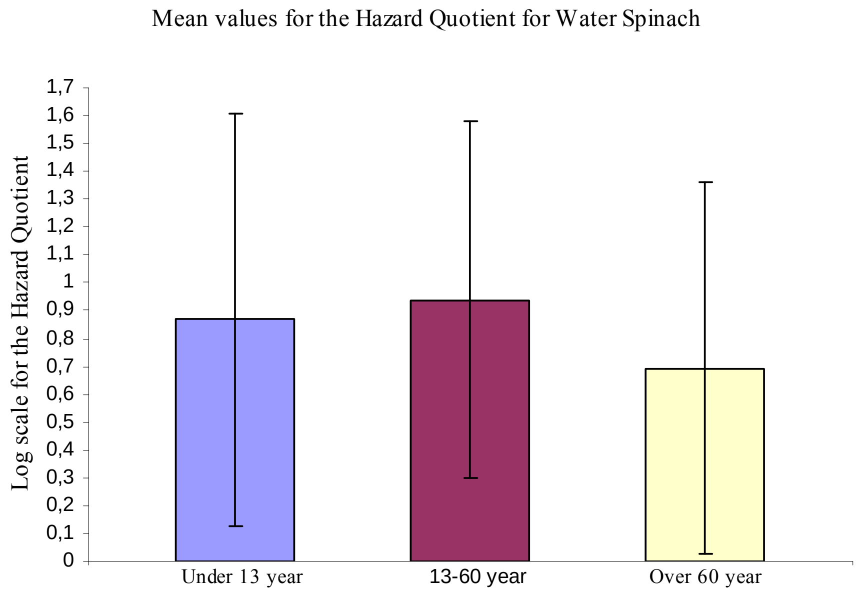

Figure 8. Mean values of the HQ for water spinach consumption was divided into three different categories: under 13 years old, 13-60 years old and over 60 years old. The HQ was calculated as Equation 1 shows; the diagram shows that there is no potential health risk according to (U.S EPA, 2008).

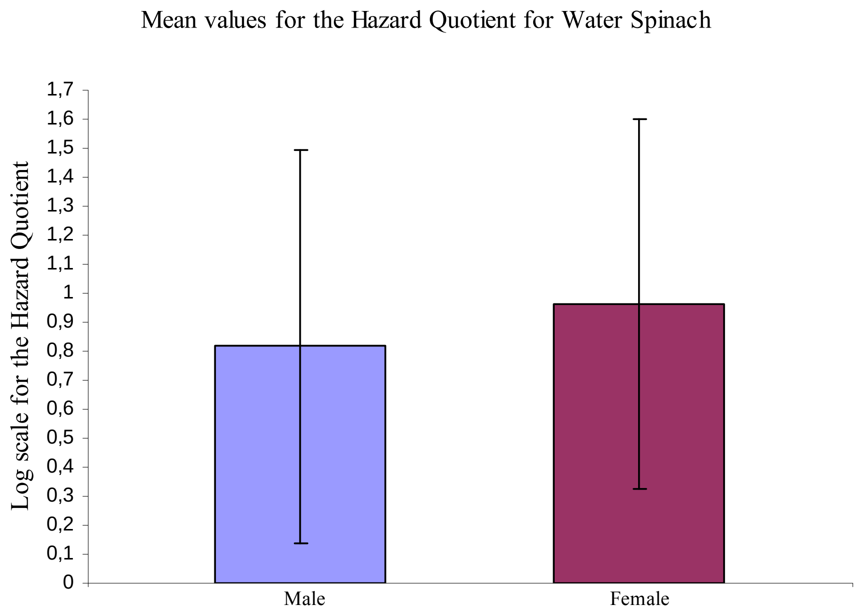

Figure 9. Mean values of the HQ for water spinach consumption was divided into two groups: males and females. The HQ was calculated as Equation 1 shows, the HQ for males and females were less then one, so there is a low probability of health risks according to (U.S EPA, 2008) .

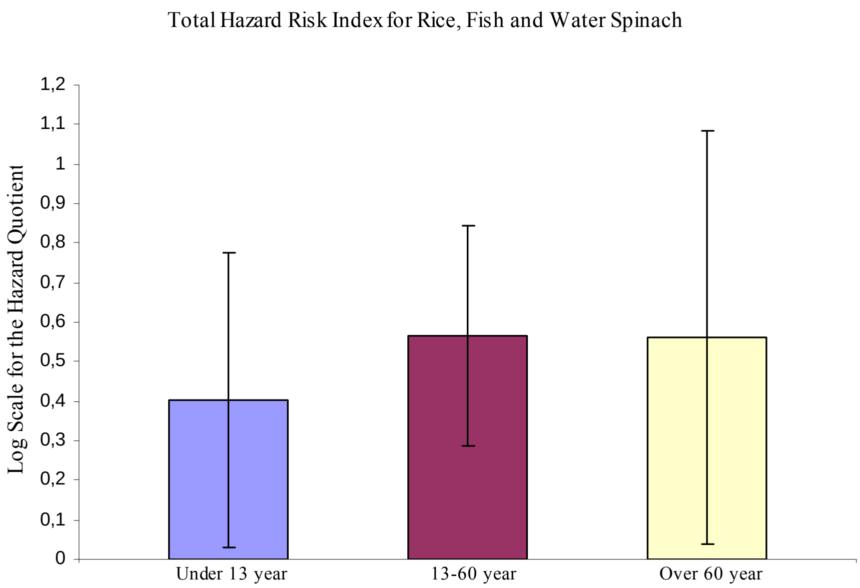

Figure 10. The total mean values for the HQ for rice, fish and water spinach consumption was divided into three different categories: under 13 years old, 13-60 years old and over 60 years old. The HQ was calculated as Eq 1 shows, the diagram shows that there is a potential health risk for all the ages from Cd exposure according to (U.S EPA, 2008).

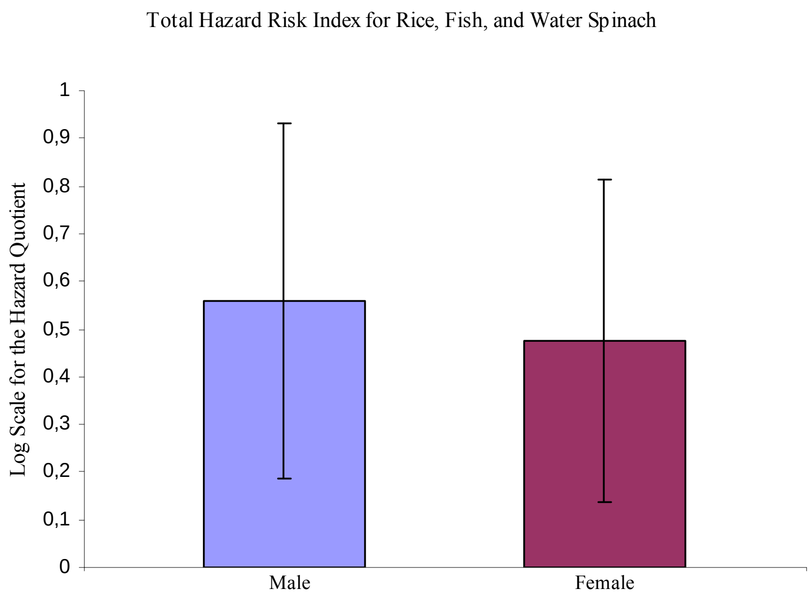

Figure 11. The total mean values for the HQ for rice, fish and water spinach consumption was divided into two groups: males and females. The HQ was calculated as Eq 1 shows, the HQ for males and females are larger then one, so there is a possible health risk according to (U.S EPA, 2008).

6. Discussion

The mean HQ for rice was 3.77, this means that consuming rice could be associated with deleterious health effects for the people of the study village. The reference dose (RfD; Eq 1) was derived from human studies involving chronic exposure (U.S EPA, 2008). The mean value for concentration of Cd in rice was $4.55x10^{-1}$ mg Cd kg^{-1}, this value exceeds the limiting values set by EU (EU, 2006) and WHO (WHO. 2006). This means that the rice in the village Man Xa is not suitable for consumption. The mean HQ is less than 1.00 for consumption of fish and water spinach. This means that the consumption should not be a potential health risk according to U.S EPA 2008. There is no statistical evidence or statistical significance that it would be any difference between gender in the HQ for rice, fish and water-spinach. The average HQ for rice was greater in the age over 60 year compared to the ages under 60 year. One reason that the mean HQ for rice is so high for the people over 60 years is that only ten people fit this category, and two of these individuals have a HQ > 25. Therefore these two data points have high leverage within a relatively low-power data set hence skewing the data to the left. All ages for consumption of rice exceeds the safe reference dose set by U.S EPA (2008). For fish and water spinach the highest average HQ was found in the ages between 13-60 years old. None of the age group for consumption of fish and water spinach exceeds the reference dose set by U.S EPA (2008).

This paper have some limitations from the part for fish and water-spinach, the concentration of Cd is derived from different scientific reports. The results doesn't show the actual risk from consumption of these foods in the study village, but the concentration of Cd used is taken from areas similar to Man Xa. So actually the results from consumption of fish and water-spinach shows a reasonable estimation of the risk of consuming these foods. To be totally safe there need to be done analytical test for fish and water-spinach to get the real concentration of Cd in Man Xa. But maybe it is not necessary, the HQ is lower than 1.00 for fish and water-spinach, 0.04 and 0.11. Because these results is a good estimation it will maybe be good to put the resources on other part of the problem in Man Xa. Rather than calculate new values for the concentration of Cd for fish and water spinach.

Information concerning Cd exposure in humans is unfortunately very limited (Chaney, R.L *et al.,* 1999). The Cd exposure in humans is dependent on many factors; for example, a person does not adsorb the majority of Cd from a meal. The majority of the Cd is in forms that cannot be adsorbed by the human body (Chaney, R.L *et al.,* 1999). Another reason, which makes Cd difficult to understand, is the chemical, biological, and environmental variables. There is too little knowledge of regarding Cd transfer and potential accumulation from soils to plants, or from animals to humans. For example, the Cd concentrations are different between plants and forms that are available for humans to uptake (Chaney, R.L *et al.,* 1999).

There must be additional research done in order to understand the bioaccessbility of Cd in the various plants and animals that are consumed by humans. Presently there is a great lack of knowledge concerning the different processes of Cd accumulation in the environment and how it works (Satarug *et al.,* 2004). For example, it is very difficult to determine exactly how much Cd is adsorbed by a human, but it has been estimated that five percent of the Cd in the diet is adsorbed (Satarug *et al.,* 2004). It is different between individuals, and in some people it could increase to 20-30 percent (Satarug *et al.,* 2004), so it is very hard to calculate the health risk from Cd due to its many factors. This report did not consider the estimated five percent as Cd adsorption from diet, as the RfD values were taken from the total oral ingestion. Hence it would stand incorrect to decrease the dosage to 5% when comparing to the RfD.

Cadmium that is accumulated in the body is stored for a long time in tissues and organs with a half life of 30 years (Satarug *et al.,* 2004), over time Cd accumulates, and the effects of this could lead to an increased cancer risk, or an early onset of diabetic renal complications (Satarug *et al.,* 2004).

Overall the result from the consumption of rice shows that something has to be done to lower the concentration of Cd, so that the people in Man Xa can continue farming and eating the food without the risk of getting sick.

6. Conclusions

The result shows that there could be a health risk from consumption of rice based on the HQ values. The average level of Cd in rice exceeds the safety standard for Cd set by EU and WHO. There is no health risk from consumption of fish and water spinach based on the HQ values. It is no statistical evidence that it would be any differences between sex in the HQ for rice, fish and water-spinach. The average HQ for rice was greater in the age over 60 year, compared to the ages under 60 year. All age groups for consumption of rice exceeds the safe reference dose set by U.S EPA (2008). For fish and water spinach the highest average HQ was found in the ages between 13-60 years old. None of the age group for consumption of fish and water spinach exceeds the reference dose set by U.S EPA (2008).

There is a need to find a solution for the problem with Cd in Man Xa in order to lower the Cd concentration in rice.

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Appendix

Table A1.Shows all data about the males which has been used in this report, HC = house code, M1, M2 and M3 and so on stands for different males (M) in each family, BY = Birth year, H= Height in meter, W = weight in kg, r = rice, f = fish, ws = water spinach, g = gram food, f.w = fresh weight, dw = dry weight, µg Cd/kg,r,f and ws = concentration of Cd per kg food, µg Cd/kg/day BW = daily average dose in microgram Cd per kg food per day and bodyweight and HQ = hazard quotient. The units in the table is different from the ones used in the report, this is due to that it had to be changed to fit all data in one table. Mark that the µg Cd/kg/day BW has the same values as the HQ, this is because it is changed from mg Cd to µg Cd.

HC	M	Y	H. m	W. kg	g.r.dw	µg Cd/kg.r	µg Cd /kg/day BW.r	HQ.r	g. f.f.w	µgCd/kg.f	µg Cd/kg/day Bw.f	HQ. f	g.ws. f.w	µg Cd/kg .ws	µg Cd/kg/ day BW.ws	HQ.ws
34	M1	1951	1.57	45	438	128	2.8	2.8	80	8.85	0.2	0.2	405	7.695	0.171	0.171
35	M1	1973	1.53	43	590	168	3.9	3.9	0	0	0		40	0.76	0.018	0.018
35	M2	1997	1.22	21	240	68.5	3.3	3.3	0	0	0		40	0.76	0.036	0.036
36	M1	1954	1.53	48	450	70.3	1.5	1.5	250	27.7	0.58	0.58	100	1.9	0.040	0.040
36	M2	1982	1.6	50	450	70.3	1.4	1.4	250	27.7	0.55	0.55	100	1.9	0.038	0.038
37	M1	1952	1.65	53	400	223	4.2	4.2	0	0	0		200	3.8	0.072	0.072
38	M1	1982	1.65	58	699	250	4.3	4.3	0	0	0		0	0	0	0
38	M2	1990	1.63	50	600	215	4.3	4.3	0	0	0		0	0	0	0
39	M1	1952	1.72	58	480	142	2.4	2.4	100	11.1	0.19	0.19	400	7.6	0.131	0.131
39	M2	1983	1.75	54	106	314	5.8	5.8	100	11.1	0.2	0.2	400	7.6	0.141	0.141
40	M1	1957	1.5	47	0	0	0	0	0	0	0		0	0	0	0
40	M1	1983	1.58	49	590	573	12	12	0	0	0		0	0	0	0
41	M1	1953	1.56	48	220	214	4.4	4.4	0	0	0		200	3.8	0.079	0.079
41	M2	1976	1.6	50	640	111	2.3	2.3	0	0	0		0	0	0	0
41	M3	1999	1.15	18	0	0	0	0	0	0	0		0	0	0	0
42	M1	1948	1.65	55	0	0	0	0	0	0	0		280	5.32	0.097	0.097
43	M1	1977	1.7	55	250	173	3.1	3.1	0	0	0		30	0.57	0.010	0.010
44	M1	1952	1.65	50	300	130	2.4	2.4	175	19.4	0.39	0.39	60	1.14	0.023	0.023
44	M2	1979	1.7	55	300	68.6	1.4	1.4	0	0	0		0	0	0	0
44	M3	2001	1.35	22	0	0	0	0	0	0	0		0	0	0	0
45	M1	1950	1.6	53	460	73.5	1.4	1.4	40	4.42	0.08	0.08	80	1.52	0.029	0.029
45	M2	1975	1.61	60	850	136	2.3	2.3	30	3.32	0.06	0.06	80	1.52	0.025	0.025
45	M3	1995	1.42	40	850	136	3.4	3.4	30	3.32	0.08	0.08	60	1.14	0.0285	0.0285
46	M1	1959	1.58	45	350	143	3.2	3.2	45	4.98	0.11	0.11	75	1.425	0.0317	0.0317
46	M2	1984	1.62	50	500	204	4.1	4.1	45	4.98	0.1	0.1	75	1.425	0.0285	0.0285
46	M3	1999	1.3	18	120	48.9	2.7	2.7	30	3.32	0.18	0.18	50	0.95	0.0528	0.0528
47	M1	1952	1.6	59	20	296	5	5	340	37.6	0.64	0.64	136	2.584	0.0438	0.0438
47	M2	1986	1.73	60	960	395	6.6	6.6	340	37.6	0.63	0.63	136	2.584	0.0431	0.0431
48	M1	1949	1.6	50	340	248	5	5	0	0	0		0	0	0	0
49	M1	1962	1.7	80	500	124	1.5	1.5	90	9.96	0.12	0.12	0	0	0	0
49	M2	1926	1.55	50	200	49.5	1	1	30	3.32	0.07	0.07	0	0	0	0
49	M3	1988	1.6	50	500	124	2.5	2.5	90	9.96	0.2	0.2	0	0	0	0
50	M1	1940	1.51	40	120	23.2	0.6	0.6	0	0	0		0	0	0	0
51	M1	1940	1.56	50	322	78.5	1.6	1.6	0	0	0		200	3.8	0.076	0
52	M1	1946	1.49	49	604	354	7.2	7.2	60	6.64	0.14	0.14	160	3.04	0.062	0.076
52	M2	1980	1.63	49	370	217	4.4	4.4	0	0	0		0	0	0	0.062
53	M1	1991	1.7	50	306	284	5.7	5.7	52.5	5.81	0.12	0.12	60	1.14	0.023	0
53	M2	1993	1.6	48	330	307	6.4	6.4	45	4.98	0.1	0.1	60	1.14	0.024	0.023
54	M1	1949	1.52	41	300	706	17	17	0	0	0		0	0	0	0.024
54	M2	1946	1.68	48	520	1225	26	26	0	0	0		0	0	0	0
55	M1	1961	1.67	58	368	83.8	1.4	1.4	0	0	0		100	1.9	0.033	0
55	M2	1989	1.62	45	496	113	2.5	2.5	0	0	0		100	1.9	0.042	0.033
56	M1	1955	1.57	51	381	77.6	1.5	1.5	0	0	0		90	1.71	0.034	0.042
56	M2	1992	1.6	44	710	145	3.3	3.3	0	0	0		90	1.71	0.039	0.034
57	M1	1958	1.61	46	288	181	3.9	3.9	0	0	0		280	5.32	0.116	0.039

57	M2	1960	1.56	45	456	287	6.4	6.4	0	0	0		280	5.32	0.118	0.116
57	M2	1986	1.65	50	456	287	5.7	5.7	0	0	0		80	1.52	0.030	0.118
57	M4	1988	1.6	50	456	287	5.7	5.7	0	0	0		80	1.52	0.030	0.030
58	M1	1953	1.65	50	320	59.6	1.2	1.2	0	0	0		300	5.7	0.114	0.030
58	M2	1992	1.55	55	480	89.3	1.6	1.6	0	0	0		0	0	0	0.114
59	M3	1944	1.55	48	459	22.7	0.5	0.5	45	4.98	0.1	0.1	0	0	0	0
59	M4	1971	1.55	55	552	27.3	0.5	0.5	45	4.98	0.09	0.09	0	0	0	0
60	M1	1948	1.7	55	500	79.9	1.5	1.5	80	8.85	0.16	0.16	250	4.75	0.086	0
60	M2	1984	1.72	58	600	95.9	1.7	1.7	120	13.3	0.23	0.23	250	4.75	0.082	0.086
60	M3	1986	1.55	50	500	79.9	1.6	1.6	120	13.3	0.27	0.27	250	4.75	0.095	0.082
61	M1	1960	1.68	63	250	121	1.9	1.9	50	5.53	0.09	0.09	0	0	0	0.095
61	M2	1988	1.63	50	400	194	3.9	3.9	50	5.53	0.11	0.11	0	0	0	0
61	M3	1997	1	17	325	158	9.3	9.3	30	3.32	0.2	0.2	0	0	0	0
61	M4	2004	80	14	175	85	6.1	6.1	20	2.21	0.16	0.16	0	0	0	0
62	M1	1962	1.63	50	475	270	5.4	5.4	0	0	0	0	600	11.4	0.228	0
62	M2	1986	1.57	50	275	156	3.1	3.1	0	0	0	0	300	5.7	0.114	0.228
63	M1	1991	1.58	54	550	149	2.8	2.8	0	0	0	0	90	1.71	0.032	0.114

Table A2. Shows all data about the females which has been used in this report, HC = house code, F1, F2 and F3 and so on stands for different females (F) in each family, Y = Birthyear, H= Height in meter, W = weight in kg, r = rice, f = fish, ws = water spinach, g = gram food, f.w = fresh weight, dw = dry weight, µg Cd/kg,r,f and ws = concentration of Cd per kg food, µg Cd/kg/d BW = daily average dose in microgram Cd per kg food per day and bodyweight and HQ = hazard quotient. The units in the table is different from the ones used in the report, this is due to that it had to be changed to fit all data in one table. Mark that the µg Cd/kg/day BW has the same values as the HQ, this is because it is changed from mg Cd to µg Cd.

HC	F	Y	H.m	W.m	g.r.dw	µg Cd/kg.r	Cd µg/kg/d BW.r	HQ.r	g.f.f.w	µg Cd/kg.f	µg Cd/kg/d BW.f	HQ.f	g.ws.f.w	µg Cd/kg.ws	µg Cd/kg/d BW.ws	HQ.ws
34	F1	1953	1.5	42	398	115.9	2.76	2.76	160	17.70	0.42	0.42	490	9.3	0.22	0.22
34	F2	1974	1.4	45	398	115.9	2.58	2.58	160	17.70	0.39	0.39	405	7.7	0.17	0.17
35	F1	1969	1.45	44	465	132.7	3.02	3.02	0	0	0	0	80	1.5	0.03	0.03
35	F2	1999	1.21	21	405	115.6	5.50	5.5	0	0	0	0	40	0.8	0.04	0.04
36	F1	1954	1.5	48	450	70.3	1.47	1.47	250	27.65	0.58	0.58	100	1.9	0.04	0.04
36	F2	1982	1.45	45	450	70.3	1.56	1.56	250	27.65	0.61	0.61	100	1.9	0.04	0.04
37	F1	1954	1.5	56	400	222.9	3.98	3.98	0	0	0	0	200	3.8	0.07	0.07
38	F1	1962	1.53	55	599	214.6	3.90	3.9	0	0	0	0	0	0	0	0
38	F2	1983	1.58	50	399	143	2.86	2.86	0	0	0	0	0	0	0	0
38	F3	2003	0	0	0	0	0	0	100	11.06	0.25	0.25	400	7.6	0.17	0.17
39	F1	1952	1.5	45	360	106.5	2.37	2.37	200	22.12	0.48	0.48	400	7.6	0.17	0.17
39	F2	1985	1.55	46	580	171.6	3.73	3.73	0	0	0	0	0	0	0	0
40	F1	1957	1.45	38	400	388.8	10.23	10.2	0	0	0	0	0	0	0	0
40	F2	1990	1.42	40	280	272.2	6.80	6.8	0	0	0	0	200	3.8	0.09	0.09
41	F1	1950	1.5	41	560	97.3	2.37	2.37	0	0	0	0	0	0	0	0
41	F2	1971	1.57	52	0	0	0	0	0	0	0	0	120	2.3	0.05	0.05
42	F1	1947	1.47	42	750	519.6	12.37	12.4	0	0	0	0	60	1.1	0.02	0.02
43	F1	1949	1.68	63	300	129.7	2.06	2.06	0	0	0	0	60	1.1	0.02	0.02
43	F2	1978	1.58	48	500	216.2	4.50	4.5	0	0	0	0	60	1.1	0.02	0.02
43	F3	1983	1.66	50	200	86.5	1.73	1.73	0	0	0	0	30	0.6	0.02	0.02
43	F4	1998	1.33	26	300	129.7	4.99	4.99	0	0	0	0	30	0.6	0.03	0.03
43	F5	2001	1.19	19	300	129.7	6.83	6.83	0	0	0	0	30	0.6	0.05	0.05
43	F6	2003	0.96	12	100	43.2	3.60	3.6	0	0	0	0	0	0	0	0
43	F7	2006	0.72	8	0	0	0	0	175	19.36	0.39	0.39	70	1.3	0.03	0.03
44	F1	1953	1.5	50	300	68.6	1.37	1.37	0	0.00	0	0	0	0	0	0
44	F2	1980	1.6	50	0	0	0	0	150	16.59	0.35	0.35	70	1.3	0.03	0.03
44	F3	1988	1.6	48	600	137.1	2.86	2.86	0	0.00	0	0	0	0	0	0
44	F4	1999	1.3	30	0	0	0	0	40	4.42	0.10	0.10	40	0.8	0.02	0.02
45	F1	1948	1.54	46	440	70.3	1.53	1.53	30	3.32	0.07	0.07	100	1.9	0.04	0.04
45	F2	1975	1.59	50	610	97.5	1.95	1.95	30	3.32	0.17	0.17	40	0.8	0.04	0.04
45	F3	1998	1.35	20	490	78.3	3.92	3.92	45	4.98	0.10	0.10	75	1.4	0.03	0.03

46	F1	1960	1.56	48	420	171.2	3.57	3.57	45	4.98	0.11	0.11	75	1.4	0.03	0.03
46	F2	1980	1.55	47	415	169.1	3.60	3.6	45	4.98	0.11	0.11	75	1.4	0.03	0.03
46	F3	1984	1.55	45	415	169.1	3.76	3.76	340	37.61	0.84	0.84	136	2.6	0.06	0.06
47	F1	1955	1.55	45	720	296.1	6.58	6.58	340	37.61	0.78	0.78	136	2.6	0.05	0.05
47	F2	1982	1.52	48	720	296.1	6.17	6.17	340	37.61	0.75	0.75	136	2.6	0.05	0.05
47	F3	1982	1.6	50	960	394.8	7.90	7.9	0	0.00	0	0	0	0	0	00
47	F4	1988	0	0	0	0	0	0	30	3.32	0.075	0.07	0	0	0	0
48	F1	1949	1.48	35	340	247.8	7.08	7.08	60	6.64	0.158	0.16	0	0	0	0
49	F1	1963	1.55	44	400	99.1	2.25	2.25	0	0.00	0	0	0	0	0	0
49	F2	1991	1.5	42	400	99.1	2.36	2.36	0	0	0	0	200	3.8	0.10	0.10
50	F1	1941	1.37	36.5	240	46.4	1.27	1.27	60	6.64	0.14	0.14	100	1.9	0.04	0.04
51	F1	1940	1.54	38.5	322	78.5	2.04	2.04	80	8.85	0.23	0.23	140	2.7	0.07	0.07
52	F1	1951	1.57	46	487	285.1	6.20	6.2	22	2.49	0.05	0.05	120	2.3	0.05	0.05
52	F2	1981	1.43	39	442	258.8	6.64	6.64	30	3.32	0.09	0.09	60	1.1	0.03	0.03
53	F1	1962	1.58	47.5	301	279.8	5.89	5.89	0	0	0	0	0	0	0	0
53	F2	1933	1.5	38	255	237.1	6.24	6.24	0	0	0	0	100	1.9	0.04	0.04
54	F1	1923	1.5	38	400	942	24.79	24.8	0	0	0	0	100	1.9	0.04	0.04
55	F1	1962	1.56	45	368	83.8	1.86	1.86	0	0	0	0	120	2.3	0.05	0.05
55	F2	1987	1.55	44	240	54.6	1.24	1.24	0	0	0	0	80	1.5	0.04	0.04
56	F1	1957	1.55	42.5	489	99.6	2.34	2.34	0	0	0	0	300	5.7	0.13	0.13
57	F1	1997	1.56	37	456	286.8	7.75	7.75	67	7.47	0.14	0.14	0	0	0	0
58	F1	1955	1.55	44.5	480	89.3	2.01	2.01	45	4.98	0.08	0.08	0	0	0	0
59	F1	1947	1.53	54	459	22.7	0.42	0.42	80	8.85	0.20	0.20	250	4.8	0.11	0.11
59	F2	1977	1.5	60	510	25.2	0.42	0.42	50	5.53	0.13	0.13	0	0	0	0.00
59	F3	2000	0.86		330	16.3	0	0	0	0	0	0	300	5.7	0.13	0.13
60	F1	1958	1.58	45	400	63.9	1.42	1.42	0	0	0	0	300	5.7	0.14	0.14
60	F2	2006	0	0	0	0	0	0	0	0	0	0	90	1.7	0.04	0.04
61	F1	1974	1.52	44	700	340.1	7.73	7.73	0	0	0	0	60	1.1	0.02	0.02
62	F1	1962	1.52	45	275	156.4	3.48	3.47	0	0	0	0	60	1.1	0.02	0.02
62	F2	1989	1.55	40	275	156.4	3.91	3.91	0	0	0	0	0	0	0	0
63	F1	1956	1.49	42	650	175.7	4.18	4.18	0	0	0	0	0	0	0	0
63	F2	1957	1.52	53	600	162.2	3.06	3.06	0	0	0	0	0	0	0	0
63	F3	1989	1.56	48	500	135.2	2.82	2.82	0	0	0	0	0	0	0	0