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CANCER AND NON-CANCER HEALTH RISK FROM EATING CASSAVA GROWN IN SOME MINING COMMUNITIES IN GHANA

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Abstract. Food crops such as cassava, cocoyam and other tuber crops grown in mining communities uptake toxic or hazardous chemicals such as arsenic, and cadmium, from the soil. Cassava is a stable food for Ghanaians. This study evaluated human health risk from eating cassava grown in some mining communities in Ghana such as Bogoso, Prestea, Tarkwa and Tamso, which are important mining towns in the Western Region of Ghana. The study evaluated cancer and non-cancer health effects from eating cassava grown in the study areas in accordance with US Environmental Protection Agency's Risk Assessment guidelines. The results of the study revealed the following: cancer health risk for Tamso, 0.098 (RME – Reasonable Maximum Exposure) and 0.082 (CTE – Central Tendency Exposure). This means that approximately 10 and 8 out of 100 resident adults are likely to suffer from cancer related cases by RME and CTE parameters respectively. For Prestea, we have 0.010 and 0.12, which also means that approximately 1 out of 100 and 10 resident adults out of 100 are also likely to suffer from cancer related diseases by RME and CTE parameters. The results of the study obtained were found to be above the acceptable cancer risk range of 1×10^{-6} to 1×10^{-4}, i.e., 1 case of cancer out of 1 million or 100,000 people respectively.

Keywords: Bogoso, cadmium, cancer and non-cancer health risk, oral reference dose, oral cancer slope factor, Prestea, Tamso, Tarkwa and upper confidence limit on mean concentration (UCLM) of arsenic, zinc and mercury respectively in cooked cassava

1. Introduction

Gold mining in Ghana has been the largest foreign exchange earner apart from cocoa, since pre- and post-independent Ghana. According to Tenkorang (2000), gold export earning rose from 107.9 million dollars to 744.2 million dollars between 1985 and 1989.

Toxic chemicals such as mercury and cyanide used in the mining operations contaminate surface/ground water and the land. The weathering of mine wastes, in tailing dams; release these toxic chemicals into the ecosystem of the catchments areas of the mines posing substantial danger to humans and other living organisms. The spilled effluents charged with these toxic chemicals persist in the environment for a long period of time.

Food crops such as cassava, plantain and other organisms including animals' uptake these chemicals from the environment, posing a substantial hazard to human beings who eat cassava and other tuber crops grown in the mining communities (Adzei, 2000; Golow and Adzei, 2002). Protecting humans from exposure to toxic or hazardous chemicals via ingestion of water and contaminated food, inhalation or dermal contact with soil and water is an issue that should engage the attention of governments, environmentalists and the entire society. Evaluating the health risks associated with eating cassava grown in mining communities in Ghana and creating awareness of the harmful effects of toxic chemicals accumulated in food crops such as cassava, cocoyam, etc in the study areas and other mining communities is the main thrust of this paper. The study was conducted in line with US EPA Risk Assessment Guidelines (RAGS/HHEM, US EPA, 1989, 2001; Essumang *et al.*, 2005).

2. Materials and Methods

2.1. Sampling procedure

Random sampling technique was adopted to select mining communities and the cassava farms in each mining community. The number of samples obtained from each sampling point is shown in Table I.

The cassava samples from each sampling point were analyzed separately for arsenic, cadmium, zinc and mercury and the mean computed.

2.2. Samples collection and samples preparation

Cassava samples were obtained from Bogoso, Prestea, Tarkwa and Tamso all in the Western Region of the Republic of Ghana. The cassava samples were uprooted from farms within the catchment areas of Bogoso Gold Limited. The samples were first washed with distilled water, peeled with a stainless steel knife, chopped into small sizes, cooked in a beaker and dried in an oven at 60 °C for three days and then ground into fine powder and stored prior to chemical analyses.

TABLE I
Sample sites and numbers of samples obtained

	Number of samples				
Sampling point	Zone 1	Zone 2	Zone 3	Zone 4	Total
Bogoso	10	10	10	10	40
Prestea	10	10	10	10	40
Tarkwa	10	10	10	10	40
Tamso	10	10	10	10	40
Total	40	40	40	40	160

2.3. Digestion of cassava samples and analysis of the digested samples

1.0 g of the sample were weighed into a 100 ml beaker and 20 ml of conc. HNO_3 was added and set on a hot plate in a fume chamber for 20 mins. It was removed from the plate and allowed to cool, filtered through a pre-washed filter paper into a 50 ml volumetric flask and later made up to the mark with double distilled water. The digest was then stored for the analysis of As, Zn and Cd.

In the case of mercury, to 1.0 g of the sample, 4 ml of conc. H_2SO_4 and HNO_3 were added, mixed thoroughly, heated over the water bath at 80 °C for 30 min. To the mixture were added 15 ml of potassium permanganate and 8 ml of potassium perusulphate. It was then heated for an additional 30 min, cooled, and 6 ml of Hydroxylamine Hydrogen Chloride was added to remove the excess permanganate and filtered into 50 ml volumetric flask and stored for analysis.

Arsenic, zinc and cadmium concentration in the samples were determined by direct analysis using Schimadzu AAS model No. 6401F (oxy-acetylene flame AAS), whilst mercury was determined by the cold vapour technique.

2.4. Recovery and reproducibility studies

To check the efficiency of the method employed for the analysis, recovery studies and reproducibility studies were conducted.

For mercury, known concentrations of mercury solutions were analyzed using the cool vapour technique after the blank had been used to zero the instrument. The results of the recovery studies have been presented in Table II.

From the results it is evident that recoveries between 97.5 to 105.0 percent were obtained. The reproducibility studies were carried out by analysis of double distilled water containing 2 μg/L of mercury using cold vapour technique. The results have been presented in Table III.

Similarly, to determine the efficiency of the digestion process, 0.5 μg/L mercury solutions were used to spike the samples. Mercury concentration in the spiked

TABLE II
Mercury recovered from double distilled water of known mercury strength

Concentration (mg/L)	Amount recovered (mg/L) 1	2	Mean	Percentage recovered	Standard deviation
0.20	0.19	0.22	0.21	105	0.02
0.40	0.38	0.40	0.39	97.5	0.01
0.80	0.78	0.78	0.78	97.5	0.00
1.00	1.02	0.98	1.00	100	0.03

TABLE III
Amount of mercury recovered from double distilled water containing 2 μg/L mercury solutions

Replicate	1	2	3	4	5	6	7	8	9	10
Amount of 2 μg/L recovered	1.93	1.98	1.96	2.01	1.99	1.96	1.99	2.02	2.03	1.99

Mean = 1.99; Percentage recovered = 99.3; Standard deviation = 0.029; Standard error = 0.009; Coefficient of variation = 1.569%.

TABLE IV
Percentage of mercury recovered from spiked solutions

Replicate	1	2	3	4	Mean	SD
Amount recovered	0.48	0.46	0.51	0.48	0.48	0.02
Percentage recovered	96.0	92.0	102.0	96.0	96.5	4.12

sample was determined using the cold vapour technique. Table IV shows quadruplicate results of such experiments.

From the results shown in Table IV, the digestion process for the recovery of mercury from the cooked cassava is very efficient.

In the case of cadmium and zinc, recovery studies were conducted by analyzing known concentrations of the metal of interest using oxy-acetylene flame AAS (Shimadzu model 6401F). Tables V and VI, shows the results of the recovery studies for zinc and cadmium respectively.

From the results it is clear that the percentage of zinc recovered is between 97.5 to 105 percent.

From the table above, it can be seen that percentage of cadmium recovered from double distilled water is between 95 to 100 percent.

The same results were obtained in the reproducibility studies conducted for zinc and cadmium using 1 mg/L zinc and cadmium solution respectively as shown in Table VII.

From Table VII, it is clear that the method used in analysing zinc and cadmium in the cassava samples is reproducible.

TABLE V
Amount of zinc recovered from double distilled water

Concentration (mg/L)	Amount recovered (mg/L)			Percentage recovered	Standard deviation
	1	2	Mean		
0.20	0.19	0.22	0.21	105	0.02
0.40	0.38	0.40	0.39	97.5	0.01
0.80	0.78	0.78	0.78	97.5	0.00
1.00	1.02	0.98	1.00	100	0.03

TABLE VI
Amount of cadmium recovered from double distilled water

Concentration (mg/L)	Amount recovered (mg/L) 1	2	Mean	Percentage recovered	Standard deviation
0.20	0.19	0.19	0.19	95	0.00
0.40	0.41	0.38	0.40	100.0	0.02
0.80	0.81	0.77	0.79	98.8	0.02
1.00	0.98	0.98	0.98	100.0	0.00

TABLE VII
Reproducibility of 1.0 mg/L zinc and cadmium solution in doubled distilled water

Replicate	1	2	3	4	5	6	7	8	9	10
Amount of 1.0 mg/L recovered	0.974	0.969	1.014	1.002	1.010	0.988	0.991	0.994	0.995	1.021

Mean = 0.996; Percentage recovered = 99.6; Standard deviation = 0.017; Coefficient of variation = 1.706% and Standard error = 0.005.

TABLE VIII
Percentage of zinc and cadmium recovered from spiked solutions

Replicate	1	2	3	4	Mean	SD
Amount recovered	0.48	0.46	0.51	0.48	0.48	0.02
Percentage recovered	96.0	92.0	102.0	96.0	96.5	4.12

Similarly, to check the efficiency of the digestion process for cadmium and zinc, 0.50 mg/L of zinc and cadmium solution was used to spike the samples respectively and the concentrations of zinc and cadmium in the spiked samples determined respectively. The same results were obtained for zinc and cadmium in the spiked samples. Table VIII shows the results of cadmium and zinc in spiked samples.

From the results shown in Table IV, the digestion process for the recovery of zinc and cadmium in the digestion process is very efficient.

To also check the efficiency of the recovery of arsenic, a recovery study was conducted using known concentration of arsenic solution determined by AAS oxy-acetylene flame. The results have been presented in Table IX.

From Table IX, the percentage of arsenic recovered is between 95 to 100.0 percent.

To check the reproducibility of the method used, reproducibility studies were also conducted. In the reproducibility studies, double distilled water containing 1.0 mg/L arsenic was determined using oxy-acetylene flame AAS (Shimadzu model

TABLE IX
Results of arsenic recovered in the recovery studies

Concentration (mg/L)	Amount recovered (mg/L) 1	2	Mean	Percentage recovered	Standard deviation
0.20	0.19	0.19	0.19	95	0.00
0.40	0.41	0.38	0.40	100.0	0.02
0.80	0.81	0.77	0.79	98.8	0.02
1.00	0.98	0.98	0.98	100.0	0.00

TABLE X
Reproducibility of 1.0 mg/L arsenic solution in doubled distilled water

Replicate	1	2	3	4	5	6	7	8	9	10
Amount of 1 mg/L recovered	0.974	0.969	1.014	1.002	1.010	0.988	0.991	0.994	0.995	1.021

Mean = 0.996; Percentage recovered = 99.6; Standard deviation = 0.017; Coefficient of variation = 1.706% and Standard error = 0.005.

TABLE XI
Percentage of arsenic recovered from spiked solutions

Replicate	1	2	3	4	Mean	SD
Amount recovered	0.48	0.46	0.51	0.48	0.48	0.02
Percentage recovered	96.0	92.0	102.0	96.0	96.5	4.12

No. 6401F) coupled with an arsine gas generator. Table X shows the result of the reproducibility studies.

From the above results it is clear that the method employed for the chemical analysis of arsenic in the cassava is very efficient.

Similar, studies were also conducted to check the efficiency of the digestion process by spiking the samples with 0.50 mg/L arsenic solution. Table XI shows quadruplicate of the results obtained.

From the results shown in Table IV, the digestion process for the recovery of arsenic in the cassava samples is very efficient.

3. Hazard Identification

The hazards from toxic metals identified from eating cassava grown in the communities have been described.

3.1. Exposure assessment

An exposure assessment is used to identify Constituents of Concern (COCs), i.e., As, Zn, Hg and Cd and to estimate the magnitude of human exposure to these COCs. The human health effects of the COCs will be evaluated when people living in the study areas eat cassava grown in the vicinity of the mines.

3.1.1. *The Chemical form of the COCs in Study Areas*

The form of the COCs in the cassava sample evaluated in this study was mainly the inorganic form of the COCs. Research work of Adzei suggests that the cassava grown in the study area absorb high concentrations of inorganic forms of Hg, Zn and Cd. Though the COCs in soil can be methylated to other forms, the organic form of the COCs in cassava grown in the study area cannot evaluate in this study.

3.1.2. *Exposure Scenario and Potential Receptor*

The exposure scenario evaluated in this study is the residential setting. In this scenario, ingestion of the COCs from eating cassava grown in the mining communities in the study areas would be evaluated.

The potential receptors evaluated in are resident and adults. The children chosen were aged between 7 and 12 years for a period of 10 years. Children residing in the community were used because of the potential for their increased exposure due to increased dose and their low body weight. A resident adult aged between 21 and 31 was also used to quantify chronic cancer and non-cancer exposure for adults for a period of 30 years.

Both Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME) parameters were used to quantify exposures via oral ingestion of the COCs from eating cassava grown in the catchments areas of Bogoso Gold Limited, Tarkwa Gold Mine of Goldfields Ghana Limited and the New Century Mines–Prestea, a subsidiary of Bogoso Gold Limited. CTE parameters are used so that health risks associated with the COCs with typical or average exposures can be calculated. The RME parameters are also used so that health risks associated with high-end exposures can be calculated.

3.1.3. *Calculation of Exposure Point Concentrations (EPC)*

In risk assessment, an Exposure Point Concentration (EPC) represents the average concentration that an individual could be exposed to. EPCs for the COCs were calculated using the 95% UCLM for the results obtained from the Laboratory analysis of the COCs in the cassava samples.

3.2. Quantification of Exposure

3.2.1. *Ingestion of Arsenic, Cadmium, Mercury and Zinc in Cooked Cassava*

The intake of arsenic from ingestion of cassava for both residential adult and children exposure scenario is calculated using US EPA risk assessment equation (US EPA, 1997; Obiri *et al.*, 2005).

4. Results

The results of cancer health risk from eating cassava grown in some mining communities in Ghana by resident adults and children are summarized in Figures 1 and 2.

Result obtained for resident adults in Tamso who eats the cassava grown in the area is shown in Figure 1. That is, 8.2×10^{-2} and 9.8×10^{-2} by CTE and RME parameters respectively. This means that, 8 and 10 out of every 100 resident adults suffer from cancer related diseases from eating cassava grown in Tamso. Other results obtained from Prestea, Tarkwa and Bogoso are as follows; 1.2×10^{-1} and 1.0×10^{-2}, 1.2×10^{-3} and 9.9×10^{-3} and 5.2×10^{-2} and 6.3×10^{-3} by CTE and RME parameters respectively. This means that approximately 1, 10, 5 and 6 out of every 10, 100 and 1000 resident adults respectively suffer from cancer related diseases in these areas.

These results are above the acceptable cancer risk range of 1×10^{-6} to 1×10^{-4} derived by the US EPA and the American Cancer Society. That is, 1 out of every 1,000,000 or 10,000 people must suffer from cancer related cases.

From Figure 2, the estimated cancer lifetime health risk for resident children in Tamso who eat cassava grown in that area by both CTE and RME parameters

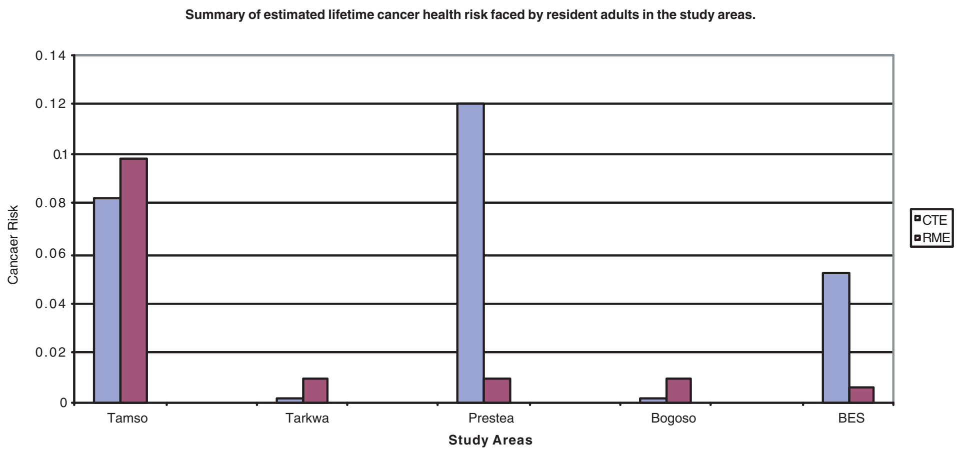

Figure 1. Cancer health risk for adults.

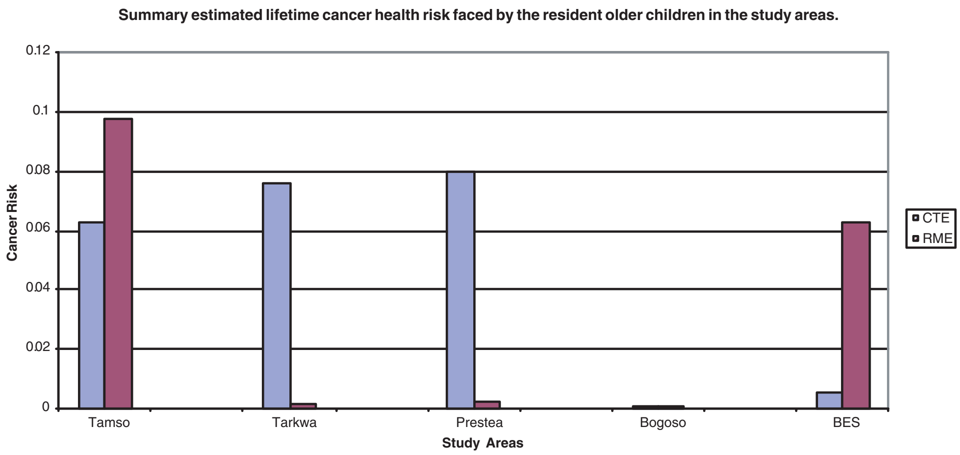

Figure 2. Summary of cancer human health risk by resident children.

are 6.3×10^{-2} and 9.8×10^{-2} respectively. This means that 6 and 10 out of every 100 resident children are likely to suffer from cancer related cases associated with ingestion of arsenic in cooked cassava. In the case of Prestea, the resident older children were found to be at risk for eating cassava grown in that area. That is, the cancer health risk for them is 8.0×10^{-2} and 2.0×10^{-3} by CTE and RME parameters respectively. This figure is quite significant judging from the fact that the children in the area have low body weight coupled with increased dose they receive from eating cassava contaminated with arsenic.

The estimated non-cancer health risk for resident adults and children (7–12 years) in the study areas are as follows: For Tamso, the hazard index for resident adults exposed to arsenic, cadmium, mercury and zinc via eating of cassava are as follows, 4.2 and 1.7, 3.5×10^{1} and 1.4×10^{1}, 4.3×10^{1} and 1.7×10^{1} and 1.2×10^{-1} and 4.6×10^{-2} for arsenic, cadmium, mercury and zinc respectively by both CTE and RME parameters. As shown in Figure 3.

For the resident older children in Tamso, we have, 1.4×10^{2} and 2.1×10^{2}, 1.4×10^{2} and 2.1×10^{2}, 1.2×10^{1} and 1.7×10^{1} respectively for arsenic, mercury and cadmium via eating of cassava grown in Tamso by both CTE and RME parameters respectively. Refer to Figure 4 for the results of non-cancer health faced by children in Prestea, Tarkwa and Bogoso.

The results of the study indicate that the health hazard associated with intoxication of arsenic, cadmium and mercury via ingestion of cassava grown in the study areas is very high. That is, the hazard index indicates whether the health hazard associated with the estimated exposures to arsenic, cadmium and mercury for resident adults during the exposure assessment segment of these study present potentially significant health problems to the resident adults in comparison to US EPA recommended Reference Dose for arsenic, cadmium and mercury. From the

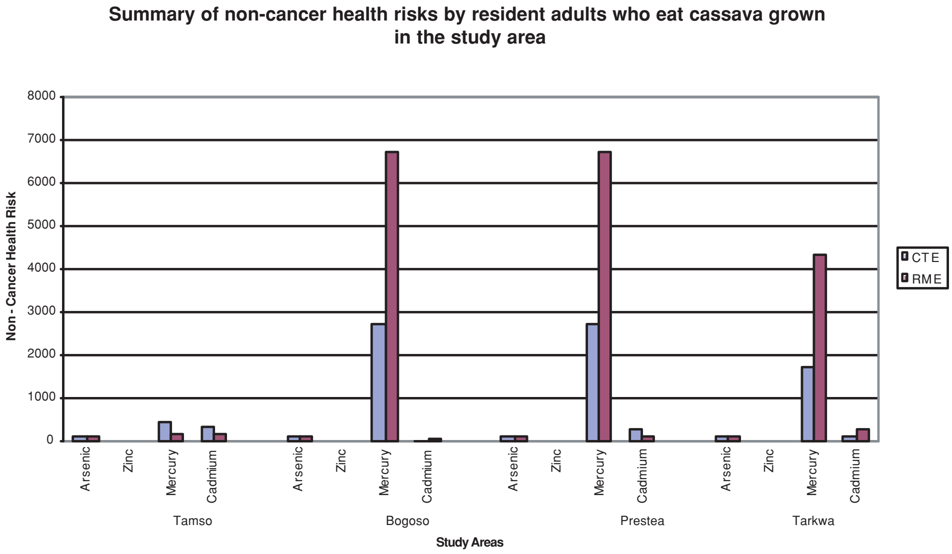

Figure 3. Summary of the non-cancer health risk.

results obtained, it is clear that, health problems associated with ingestion of mercury in the cassava sample is very high. This may be due to the large number of illegal Miners (Galamsey Operators) in the study areas who use mercury to extract the gold, after which they roast the amalgamated gold to release mercury oxide and vapors into the atmosphere. That is, the cassava absorbs high amount of mercury from the soil and from its vapors or oxides in the atmosphere.

Again from Figures 3 and 4, it is clear that zinc in cassava does not pose significant health problems to the resident children and adults who eat cassava grown in the communities. The reason may be that zinc is an essential nutrient required for the normal functioning of the body. It becomes a health hazard if its concentration is high or having cadmium as an impurity.

5. Conclusion

The results of the study revealed that the presence of cadmium, arsenic and mercury in food crops such as cassava or cocoyam grown in mining communities is very high. That is, ions of As, Cd and Hg are mobile in soil and are easily absorbed by the food crops. That consumption of food crops such as cassava grown in mining communities by human beings poses serious health risk to them.

The study also revealed that the concentration of mercury in cassava ingested by inhabitants of mining communities is very high. The high concentration of mercury in the cassava may be attributed to the large number of galamsey operators who

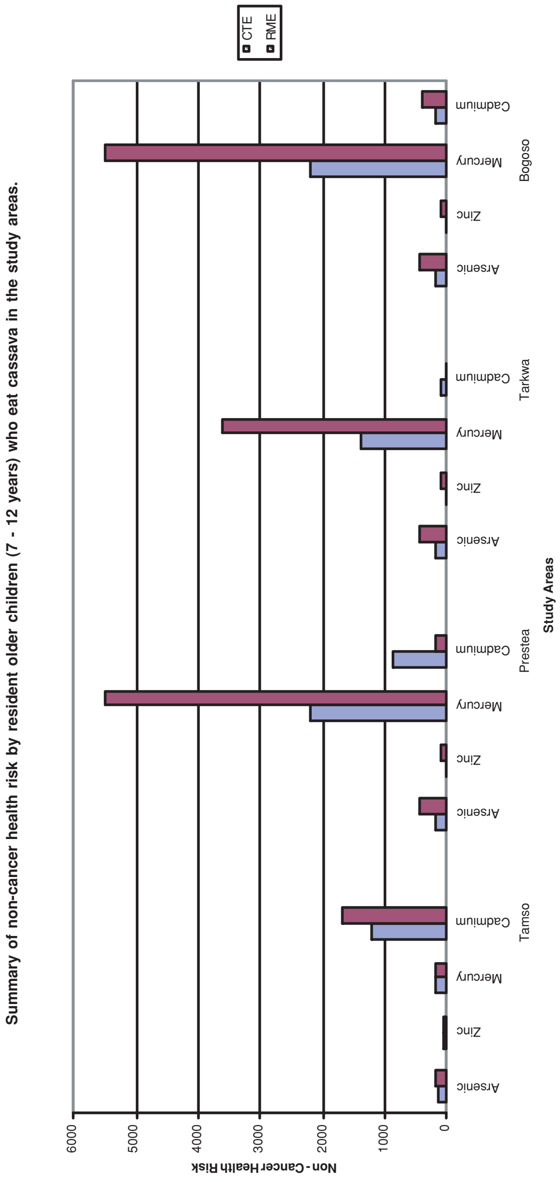

Figure 4. Summary of non-cancer health risk by resident older children in the study areas.

mercury indiscriminately. That is roasting of the amalgamated gold releases high concentration of mercuric oxide and mercury vapours into the atmosphere which are absorbed by the leaves of the cassava plant in addition to the mercury absorbed from the soil by the roots of the cassava.

Zinc ions in the ingested cassava did not pose any significant health hazard to the resident adults and children. It may be due to the fact that the cassava is able to transform the zinc ions it absorbs from the soil to synthesize proteins (as zinc is a trace element needed for the normal growth of the cassava plant). Zinc ions may be tightly bound to soil or are transformed into less toxic compounds which do not bioaccumulate in the cassava flesh. Hence zinc ions did not pose any significant health hazard to the inhabitants who ingested it through cassava.

Hence, the cancer and non-cancer health risk results from the consumption of cassava grown in Prestea, Tarkwa, Tamso and Bogoso by resident children and adults show that they are at risk eating the cassava. Their health risk is increased by multiple exposures to arsenic, cadmium, mercury and zinc as they also inhale fumes of these elements in the atmosphere or ingested them via oral or dermal contact with surface/ground water and soil, and the occasional accidental cyanide spillages, which release other potentially toxic chemicals into the environment which this study did not take into consideration. This paper seeks to bring to the attention of governments, donor communities, and environmentalists the dangers posed by these toxic chemicals in the environment and the need to help these poor communities.

Acknowledgments

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