Determination of Total Arsenic in Environmental Samples from Kumasi and Obuasi, Ghana

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The total arsenic content of some Ghana food and cash crops from Kumasi and Obuasi farms and markets was determined. Quantitative analysis of arsenic was also conducted on vegetation, cooked food obtained from some homes, local fish, and meat, as well as some soil and water samples. In all, 266 samples were examined. Values for Kumasi samples ranged from 0.07 to 7.20 mg/kg arsenic, whereas those for Obuasi ranged from 0.12 to 70.50 mg/kg, confirming that arsenic levels for Obuasi are much higher than those for Kumasi. **Key words:** arsenic, crops, Ghana, mining, water. *Environ Health Perspect 101(1):46–49*

Mining makes up a very large portion of the gross national product of Ghana and is playing a significant role in the economic recovery program of the country. Gold mining, the largest type of mining industry, accounts for the largest proportion of foreign exchange earned by Ghana. The economic gains in Ghana are, however, achieved at a great environmental cost. Exploitation of gold puts immense stress on air, water, soil, and vegetation and also frequently poses potential and real hazards to human health. The most serious problems are in Obuasi and Prestea because of the nature of the ore and the method of processing in these areas. Most of the gold in these two locations is locked in mineralized dyke and schist (pyrite and arsenopyrite) associated with arsenic and sulfur. The extraction of the gold involves roasting, which releases airborne particles and large quantities of arsenic—14–19 tons daily in Obuasi.

The dangers of the oxides of arsenic, which are too numerous to list, impair human life from prenatal to adult stages. Arsenic oxides damage chromosomes, induce spontaneous abortions, cause congenital malformations due to placental transfer of the elements, reduce birth weight, disturb functions of the liver and the central nervous system, and contribute to lung cancer.

Previous studies (*1–4*) have established large amounts of arsenic in soils, water, plants, some food items, and human hair in Obuasi samples. Arsenic in the soils was found to be largely labile (*3*). These studies are extended here.

The arsenic content of food crops in Kumasi (Tables 1 and 2), where arsenic is not directly released into the atmosphere as a result of industrial activity, ranged from 0.07 (in oranges) to 0.97 (in pepper) mg/kg wet mass. The total arsenic in Obuasi food crops (Tables 3 and 4) ranged from 0.14 (in cocoyam leaves) to 1.86 (in plantains) mg/kg wet mass. Arsenic content was highest in plantains, with a mean value of 1.13 mg/kg wet mass (TSD, 0.13). This may be accounted for by the fact that plantains have a high iron content: high sorption of arsenate ions by iron is a well-known phenomenon.

We compared the arsenic content of various products reported by Amasa (*4*) to the values we obtained. The reported value for oranges from Obuasi was 2.29 ppm (dry mass), compared to our values of 2.94–4.10 mg/kg. For cassavas from Obuasi markets, Amasa reported 2.65 ppm arsenic, which is higher than our value of 1.28 mg/kg; however, for cassavas from an Obuasi farm, the reported value of 1.83 ppm lies within our range for produce from the same farm of 1.45–3.50 (mean, 2.55 mg/kg dry mass; SD, 0.70).

Amasa (*4*) reports the arsenic content of cocoyam leaves as 4.80 ppm, whereas we arrive at lower values, ranging from 0.89 to 2.94, with a mean value of 1.86 mg/kg dry mass (SD, 085). The cited value (*4*) for cocoyam growing 150 yards from the mine (1.89 ppm) lies within our range of 1.20–3.50 (mean, 2.26 mg/kg dry mass; SD, 0.92). For plantains from the market, the reported value of 0.615 ppm lies well below our range of 2.02–5.65 (mean, 3.43 mg/kg dry mass; SD, 1.07).

Schroeder and Balasa (*5*) give the normal arsenic content for cassava and pepper as 0.13 and 0.96 ppm, respectively. This value for cassava is lower than the lowest value of 0.73 mg/kg dry mass we obtained for a sample from a Kumasi farm. The cited result for pepper, however, is higher than the range we obtained for Kumasi farms but lower than the 2.22 mg/kg dry mass obtained for pepper from Kumasi markets.

Arsenic in cooked foods (Tables 5 and 6) was found to range from 1.26 to 3.24 mg/kg dry mass in Kumasi and from 2.04 to 3.81 mg/kg dry mass in Obuasi. Arsenic levels in food, except seafoods, have been found to be generally well below 1 mg/kg wet mass (*6*); however, concentrations between 0.6 and 58 mg/kg dry mass have been found in some food supplements prepared from kelp (*7*). Edible seaweed, a common product in Japan, has been reported to contain arsenic levels ranging from 19 to 172 mg/kg dry mass, with a mean concentration of 112 mg/kg (*8*).

Fish (tilapia) from Kumasi markets contained 3.30 mg/kg dry mass of arsenic (Table 1), whereas fish from Obuasi markets contained 2.60 mg/kg (Table 3). Meat (goat) from the same sources contained 2.59 and 3.48 mg/kg dry mass of arsenic, respectively. Fish and fish products are known to contain the highest concentrations of arsenic in the animal kingdom. Concentrations in marine bottom-feeding fish range from 2.5 to 4.9 mg/kg; in crustaceans from 1.2 to 10.9 mg/kg; and in nonbottom-feeding fish from 0.2 to 0.8 mg/kg (*9,10*).

Tables 1, 3, 7, and 8 indicate that arsenic in cash crops from both Kumasi and Obuasi markets and farms are as follows: tobacco, 2.14–2.40 mg/kg; oil-palm fruit, 1.16–5.87 mg/kg; cocoa, 2.23–2.46 mg/kg dry mass. It has been reported that the arsenic content of plants grown in soils that have never been treated with arsenic-containing pesticides varies from 0.01 to about 5 mg/kg dry mass (*11*). One may therefore infer that food and cash crops, even those from the environs of Obuasi mines, are not grown in soils that are unduly contaminated with arsenic.

Elephant grass (*Panicum maximum*) around Kumasi had concentrations of

Table 1. Total arsenic in samples from Kumasi markets

Sample	Wet (dry) mass, mg/kg
Cassava	0.70 (1.85)
Cassava peel	0.26 (0.96)
Plantain	0.51 (1.54)
Plantain peel	0.28 (1.32)
Cocoyam	0.47 (1.08)
Pepper	0.10 (0.65)
Orange	0.97 (2.22)
Beans	0.54 (3.70)
Pear	0.20 (1.02)
Fish	(3.30)
Meat	(2.59)
Tobacco	(2.40)
Oil palm fruit	(4.53)

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Table 2. Total arsenic concentration in some food crops from Kumasi farms

Sample	Number of samples	Range	Mean	SD	Relative SD (%)
Cassava	9	0.28-0.47 (0.73-1.25)	0.38 (1.03)	0.07 (0.19)	17.89 (18.35)
Cassava peel	9	0.15-0.31 (0.56-1.16)	0.23 (0.86)	0.10 (0.21)	41.74 (24.53)
Plantain	9	0.28-0.48 (0.84-1.45)	0.36 (1.10)	0.08 (0.25)	23.33 (22.64)
Plantain peel	9	0.14-0.27 (0.66-1.25)	0.18 (0.85)	0.04 (0.19)	22.78 (22.35)
Cocoyam	8	0.35-0.54 (0.81-1.24)	0.42 (0.97)	0.07 (0.16)	16.43 (16.29)
Cocoyam leaves	8	0.10-0.14 (0.60-0.87)	0.12 (0.73)	0.02 (0.09)	12.50 (12.33)
Pepper	5	0.22-0.32 (0.50-0.72)	0.26 (0.58)	0.04 (0.08)	14.31 (14.31)
Orange	6	0.07-0.23 (0.46-1.43)	0.13 (0.85)	0.07 (0.40)	50.00 (47.06)
Beans	5	0.18-0.30 (0.36-0.60)	0.26 (0.52)	0.07 (0.10)	26.92 (19.62)
Pear	7	0.11-0.19 (0.59-0.97)	0.15 (0.76)	0.03 (0.14)	18.67 (18.29)

Values are mg/kg wet (dry) mass.

arsenic in the range of 4.40–5.54, whereas star grass (*Eleusine indica*) ranged from 6.00 to 7.20 mg/kg dry mass (Table 9). The arsenic content of elephant grass around Obuasi was in the range 2.36–5.50 and for star grass was 2.23–39.30 mg/kg mass (Table 10). Around Obuasi, the arsenic content of palm leaves was 2.20–3.80 mg/kg and of ferns (*Pteris vitatae*) was 48.00–70.50 mg/kg dry mass.

With the exception of palm leaves, abnormally high values were obtained in vegetation from site B, which is opposite slime dam number 3 and about 450 m from the Pompora Treatment Plant (PTP). This site is the converging point of effluent from the ore treatment plant, water issuing from slime dams numbers 3 and 4, the Kwabrafo stream flowing from the polluted hills toward the northeast, and the freshwater dam overflow, which originates from the polluted hills to the north of PTP. Arsenic from all these waters accumulates at site B, contributing to increased arsenic concentrations in vegetation growing at the edge of the stream at this point. Sites A, B, C, J, and K, which invariably had high values of arsenic in their vegetation, lie within a 1-km radius toward the northeast of PTP, which is the prevalent wind direction from the chimney, and consequently these sites receive a lot of dust from the flue gases. Ferns contained arsenic concentrations that were far in excess of the other types of vegetation, which agrees with previous findings (*4*). The values correlated very well with wind direction and distance from the chimney, but were much lower than previous values (*4*) because the sites were farther away from the chimney.

Arsenic values at the sampling sites of star grass were 5.40–29.60 mg/kg for soil (mean, 19.39 mg/kg) and 2.80–10.40 ppm for water (mean, 5.19 ppm) (Table 10). These values correlated well with the arsenic content of vegetation found on the sites. The arsenic content of soil and water at site F was extremely low, 5.40 mg/kg

Table 3. Total arsenic in samples from Obuasi markets

Sample	Wet (dry) mass, mg/kg
Cassava	0.71 (1.88)
Cassava peel	0.34 (1.28)
Plantain	0.90 (2.71)
Plantain peel	0.43 (2.02)
Cocoyam	0.69 (3.26)
Cocoyam leaves	0.69 (2.26)
Pepper	0.35 (3.09)
Orange	0.47 (3.73)
Beans	0.59 (1.81)
Pear	0.41 (2.14)
Fish	(2.60)
Meat	(3.48)
Tobacco	(2.34)
Oil palm fruit	(4.37)

Table 4. Total arsenic concentration in some food crops from Obuasi farms

Sample	Number of samples	Range	Mean	SD	Relative SD (%)
Cassava	9	0.55-1.32 (1.45-3.50)	0.96 (2.55)	0.26 (0.70)	27.29 (27.53)
Cassava peel	9	0.29-0.90 (1.10-3.40)	0.59 (2.22)	0.19 (0.81)	32.88 (36.49)
Plantain	12	0.67-18.6 (2.02-5.65)	1.13 (3.43)	0.34 (1.07)	29.73 (31.20)
Plantain peel	12	0.23-0.92 (1.09-4.34)	0.53 (2.47)	0.20 (0.94)	37.17 (37.85)
Cocoyam	8	0.52-1.51 (1.20-3.50)	0.98 (2.26)	0.40 (0.92)	40.51 (40.08)
Cocoyam leaves	8	0.14-0.47 (0.89-2.94)	0.30 (1.86)	0.13 (0.85)	44.66 (45.91)
Pepper	8	0.19-0.97 (1.97-4.50)	0.67 (2.96)	0.28 (0.91)	42.39 (30.74)
Orange	7	0.46-0.65 (2.94-4.10)	0.55 (3.46)	0.06 (0.45)	11.09 (13.01)
Beans	5	0.38-0.67 (0.76-1.34)	0.49 (0.99)	0.13 (0.22)	25.51 (22.12)
Pear	6	0.18-0.47 (0.93-2.43)	0.31 (1.59)	0.11 (0.62)	36.77 (38.74)

Values are mg/kg wet (dry) mass.

Table 5. Total arsenic concentration in cooked food from Kumasi

Site	Cassava	Plantain	Fufu
Asawasi	1.94	2.86	1.53
University	1.81	3.24	1.26
Average	1.91	3.03	1.40

Values are mg/kg dry mass.

Table 6. Total arsenic concentration in cooked food from Obuasi homes

Site	Cassava	Plantain	Fufu
Tutuka	2.65	3.14	2.43
Wawasi	2.53	3.81	2.04
Kwabrafofo	2.84	3.21	2.65
Average	2.67	3.39	2.37

Values are mg/kg dry mass.

Table 7. Total arsenic concentration in some cash crops from Kumasi farms

Site	Tobacco	Oil palm fruit	Cocoa
Tanoso	2.14	3.70	—
Kwadaso	—	3.56	—
Tafo	—	3.24	—
Ayeduase	—	—	2.42
Kaase	—	—	2.46
Average	2.14	3.50	2.44

Values are mg/kg dry mass.

Table 8. Total arsenic concentration in oil palm fruit from Obuasi farms

Site	Dry mass, mg/kg
Akaporiso	4.63
Bomposo	2.24
Kwabenaakwakrom	1.16
Kwameduokrom	2.10
Nantrin	5.87
Akrofruom	3.44
Nhieso	1.75
Average	3.03

The concentration of arsenic in cocoa at the Cocobod depot, Obuasi, was 2.23 mg/kg dry mass. Sampling was random depending on which samples were available at the different locations.

Table 9. Total arsenic concentration in some vegetation from Kumasi

Site	Star grass (*Eleusine indica*)	Elephant grass (*Panicum maximum*)
University	6.00	4.40
Airport	7.20	5.54
Ahinsan	6.80	4.60
Average	6.67	4.85

Values are mg/kg dry mass.

Table 10. Total arsenic concentration in vegetation, soil, and water from Obuasi

Site	Fern	Palm leaves	Elephant grass	Star grass	Soil	Water(ppm)
A	48.50	3.50	—	10.17	21.50	4.40
B	70.50	3.70	—	39.30	26.60	10.40
C	59.60	3.80	—	12.41	21.90	5.60
D	—	—	—	3.75	21.30	4.70
E	—	—	—	5.99	19.80	4.90
F	—	—	—	5.65	5.40	2.80
G	—	—	2.36	2.23	16.20	3.50
H	—	—	5.10	—	—	—
I	—	—	5.50	—	—	—
J	58.00	2.20	—	—	—	—
K	62.40	4.20	—	—	—	—
Average	59.80	3.48	4.32	11.36	19.39	5.19

Values are mg/kg dry mass unless otherwise indicated. Food and cash crops, vegetation, and soil samples were air dried for about 3 weeks. Cooked food, fish, and meat were cut into small pieces and oven dried at 50°C for at least 7 days. The dried samples were then ground and screened through 2-mm openings. Arsenic content of all samples was determined by atomic absorption spectrophotometry. All determinations were conducted in triplicate.

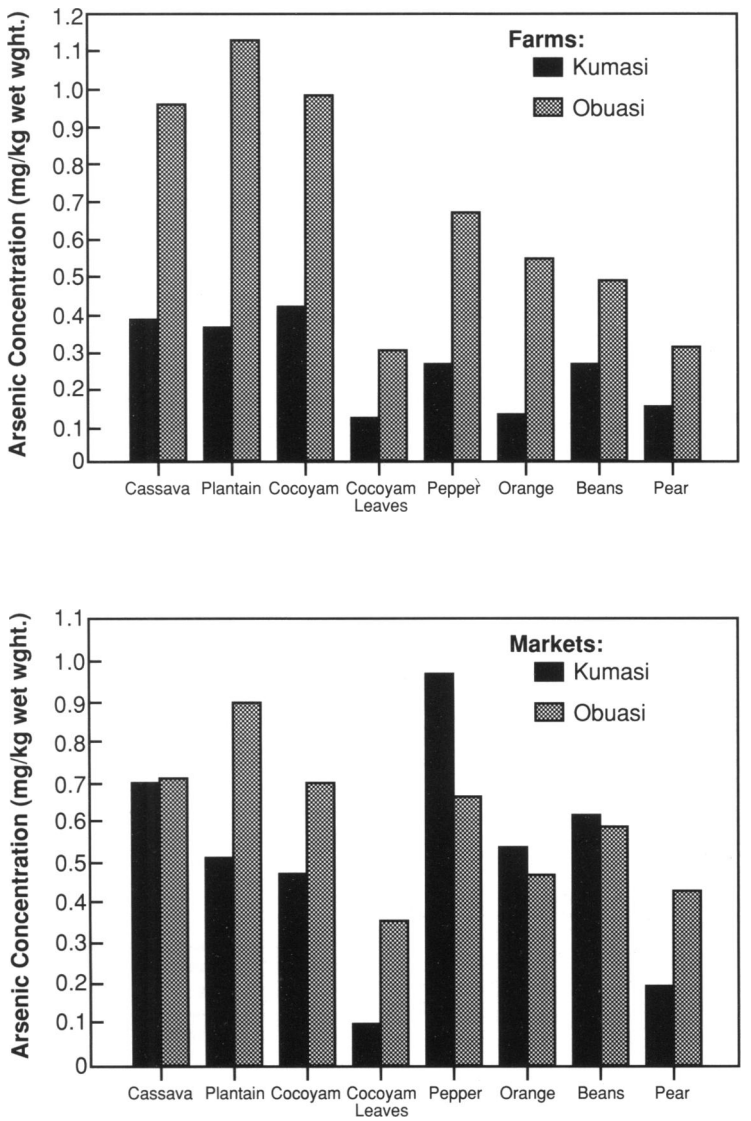

Figure 1. Comparison of mean arsenic concentrations in food crops obtained from farms and markets in Kumasi and Obuasi.

and 2.80 ppm, respectively, compared to the other values because site F is too far away and to the southeast of the chimney.

Uncontaminated soils were found to contain arsenic levels between 0.2 and 40 mg/kg, whereas arsenic-exposed soils contained up to 550 mg/kg (*12*). Soil levels in excess of 200–300 mg/kg are necessary for plants to absorb sufficient arsenic to reach edible plant levels of 1 mg arsenic/kg fresh mass. Water from site B contained an abnormally high concentration of arsenic (10.40 ppm) because of the location of this site. None of the water sampled is fit for irrigation, livestock industry, or the preservation of aquatic life (*13*).

The arsenic content of samples analyzed from Obuasi was generally higher than those from Kumasi (Fig. 1). Cassava, cocoyam, and plantain samples from Obuasi contained arsenic ranging from above or below the 1 mg/kg wet mass recorded (*6*). However, the dry weight concentrations were much lower than the highest levels (*8*) but higher than the lowest levels (*9*) of other recorded food items.

Fish and meat from Kumasi and Obuasi contained similar arsenic concentrations, which were above the concentrations generally obtained in nonbottom-feeding fish, similar to those of bottom-feeding fish, and much lower (about one-third of the highest value obtained) than values for crustaceans (*9,10*).

Because the highest recorded value of arsenic in plants grown in soils that had never been contaminated with arsenic is 5 mg/kg dry mass (*11*), it may be inferred that both food and cash crops sampled around Obuasi are not grown in soils that are unduly contaminated with arsenic. Star grass and especially fern near the chimney and in the direction of the plume are highly contaminated with arsenic and correlate well with arsenic concentrations of corresponding soils. These findings agree with evidence that increased plant residues result from increased soil arsenic content (*14*).

The arsenic content of the soils sampled, although high, is not unusual even for uncontaminated soils and will not induce plants to absorb sufficient arsenic to reach edible plant levels of 1 mg/kg fresh mass (*12,15*). The waters investigated contain too much arsenic to be useful even for the preservation of aquatic life or agricultural purposes and are definitely unfit for drinking (*13*).

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