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Cancer Health Risk Assessment of Exposure to Arsenic by Workers of AngloGold Ashanti–Obuasi Gold Mine

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Gold mining at Obuasi began in 1898 by private businessmen and their company has now been transformed into an international company with about 34,000 shareholders worldwide. The gold ore at Obuasi consists mainly pyrites and arsenopyrites. The company has six treatment plants, namely, PTP (Pompora Treatment), CIL (Carbon – in – Leach Plant), OTP (oxide Treatment Plant), TTP (Tailing Treatment Plant), STP (Sulphide Treatment Plant) and the BIOX (Bacteria Oxidation Plant). The PTP was shut down owing to emission of large amount of arsenic trioxide (As_2O_3) and sulphur (IV) oxide (SO_2) gases into the atmosphere from the roasting of the arsenopyrites and pyrites ores. In addition to the arsenic fallout from the atmosphere, process water used to be discharge into Kwabrafo River from the Pompora Treatment Plant (PTP). Also the mountains of tailings rich in arsenic and left at the mercy of the weather are being rain – washed into the rivers and streams. The workers at the Pompora Treatment Plant pack the arsenic rich tailings into sacks and bags as part of the arsenic recovery plant (ARP) initiated in 1990 to remove particulate As_2O_3 at the PTP (*Carboo and Serfor – Armah 1995*)

The extraction and processing of gold from ores by the company have posed serious health problems such as skin pigmentation, skin cancer diseases to the workers and residents of Obuasi. However, there are no records for risk assessment of exposure to arsenic by workers of the company. This research sought to assess the cancer health risk associated with exposure to arsenic by the workers of AngloGold Ashanti – Obuasi gold mine in line with the USEPA risk assessment guidelines (USEPA 1989).

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MATERIALS AND METHODS

Soil and water samples were collected from six treatment plants viz; PTP, OTP, CIL, BIOX and STP into labeled plastic containers. The soil samples were air dried, homogenized and sieved with a 90μm mesh. The water samples were also filtered and stabilized with 10% nitric acid and stored below 40°C for analysis.

5mL conc. HNO_3 and 5mL conc. H_2SO_4 were added to 100mL of water samples. The mixture was boiled until the volume was reduced to 15mL. It was cooled and the volume adjusted to 100mL with distilled water.

Ten liters of 1:1 HNO_3 and distilled water was added to 1.0g of soil sample and refluxed for 10mins. It was allowed to cool and 10mL of conc. HNO_3 was added and further refluxed for 1hour. It was then evaporated to 5mL and 2mL of water and 3mL of 30% v/v hydrogen peroxide added and then heated until the effervescence became minimal. It was filtered and the volume adjusted to 100mL with distilled water (AWWA 1998).

The arsenic concentrations in both the soil and water samples were determined by using flame Atomic Absorption Spectrophotometer - Shimadzu model 6401F coupled to an arsine gas generator. In the arsine generator, 4mL of 0.4%$NaBH_4$ and 5mL of 0.5M HCl were added to the sample to reduce the arsenic to arsine (AsH_3). The arsine gas is then carried by argon gas to the air – acetylene flame. The results obtained from the above determinations have been presented in tables 1 and 2 below:

Table 1. 95% Upper confidence limit of mean concentration of arsenic in soil samples.

Mine	PTP	CIL	BIOX	OTP	STP	TTP
Conc. mg/kg	898.3	212.9	-	121.8	118.9	214.8

Table 2. 95% Upper confidence limit of mean concentration of arsenic in water samples.

Mine	PTP	CIL	BIOX	OTP	STP	TTP
Conc. mg/L	-	148.1	558.5	337.8	458.8	-

The USEPA has classified inorganic arsenic as a class 'A' human carcinogen based on evidence from animal and human studies (Tseng 1977, USEPA 2001a). That is, exposure to arsenic may lead to skin cancer, lung cancer, liver cancer, hyperkeratosis and hyperpigmentation which are common sickness faced by the workers of the company.

In line with USEPA risk assessment guidelines, an exposure assessment deals with the identification of constituents of concern (COC's), and to estimate the magnitude of human exposure to the COC's. An example of COC's is arsenic. In this study, human health effects from exposure to inorganic arsenic were evaluated for the workers of AngloGold Ashanti – Obuasi using the results in tables 1 and 2 above as inputs parameters.

The exposure scenario evaluated in this study was an industrial setting. The cancer health risk was evaluated when incidentally a worker ingests orally or comes into contact with soil and water containing arsenic through the skin.
The potential subject evaluated in this study was a resident adult worker of the company aged between 20 – 45 years. The exposure duration was assumed to be 10years for chronic cancer health risk for both CTE (Central Tendency Exposure) and RME (Reasonable Maximum Exposure) parameters. CTE parameters were adopted in order to evaluate the health risk associated with typical or average exposure scenarios whiles the RME parameters were also used to calculate the health risk associated with high – end exposures (USEPA 1989, 1997a, 2001a).

The intake of arsenic by resident workers were calculated using the results in tables 1 and 2 above as input parameters in the Risk 4.02 Human Health Evaluation Software developed for Superfund sites (USEPA 1989, 2001).

Toxicity assessment criteria for arsenic are from USEPA's IRIS (Integrated Risk Information System) data base file were used to evaluate the cancer health risk. Toxicity criteria used are dermal and oral cancer slope factors for arsenic. A cancer slope factor is an upper – bound estimate of carcinogenic potency used to calculate risk from exposure to carcinogens by relating estimates of lifetime average intake to the incremental risk of an individual cancer over their lifetime. In this study, the USEPA recommended oral cancer slope factor value of 1.5(mg/kg – day)$^{-1}$ was used. This value was derived based on the incidence of skin cancer of a large population in Taiwan with chronic exposure to arsenic in drinking water and food (Tseng 1968).

In general, for dermal exposure (expressed as absorbed dose), the oral cancer slope factor is adjusted to be applicable to the oral ingested dose since the USEPA has not derived specific dermal cancer slope factors for arsenic (USEPA 1989, 1992a). This adjustment is made assuming that once a chemical is absorbed into the blood stream the health effects are similar regardless of whether the route of exposure was dermal or oral. Since oral absorption for arsenic is about 95% in water (USEPA 1999a), and the USEPA recommends adjusting oral cancer slope factor for the dermal route only when oral ingestion is lees than 50%, no adjustment was made to the oral cancer slope factor value. Hence the dermal cancer slope factor used in this study was 1.5 (mg/kg – day)$^{-1}$. The estimated intakes (from exposure assessment) and the cancer slope factors (toxicity assessment) were combined to calculate the cancer health risk using Risk 4.02 software.

RESULTS AND DISCUSSION

The cancer health risk results for exposure to arsenic by workers of AngloGold Ashanti – Obuasi has been listed in table 3 below.

Cancer risk is defined as the incremental probability that an individual will develop cancer during his/her lifetime due to chemical exposure under specific exposure scenarios.

For workers at the BIOX plant, the cancer health risk from dermal and oral contact of water was as follows; 110 and 130 by CTE parameters. This means that approximately 110 and 130 workers out of very 100,000 workers at the plant are likely to suffer from cancer related cases. Similar results were obtained for the CIL plant; the cancer health risk via oral and dermal contact of soil by both CTE parameters is: 17,000 and 56,000 workers respectively. That is, 17,000 and 56,000 workers out of 100,000 workers are likely to suffer from cancer related diseases as a result of exposure to CIL soil via oral and dermal contact respectively.

The cancer health risk via exposure to CIL water by RME parameters also indicates that, the workers are at risk (980 via oral contact and

102 by dermal contact of CIL water). The high value of cancer risk from dermal contact with CIL water is attributed to occasional leakage of CIL effluents which spill on workers as such are likely to suffer from cancer related diseases.

The estimated cancer health risk for workers at the PTP and TTP were found to be within the acceptable cancer risk range. The acceptable cancer risk range is 1 x 10^{-6} to 1 x 10^{-4}, i.e., 1 case of cancer in approximately 1 million population to 1 case of case in 10,000 population exposed to a carcinogenic chemical (ACS 2000; USEPA 1989). From table, the cancer health at PTP is 7.7 via oral contact of PTP soil and 0.26 cases of cancer out of 100,000 workers at the plant by CTE parameters respectively. However, the result is significantly different for RME exposure scenarios.

In the case of TTP, we have 1.7 via oral contact of TTP soil and 0.51 via dermal contact to TTP soil respectively. This means that 1.7 and 0.51 cases of cancer out of every 100,000 workers via oral and dermal contact of TTP soil respectively.

In the case of OTP, the cancer health risk via oral and dermal contact to OTP soil is 0.26 and 0.29 by CTE parameters. That is, approximately 0.26 and 0.29 of the workers out of 100,000 workers are likely to suffer from cancer related diseases via oral and dermal contact respectively. Using RME parameters, the cancer health from exposure to OTP soil is 15 and 12 via oral and dermal contact respectively. This means that 15 and 12 workers out of 100,000 workers at OTP are likely to suffer from cancer related disease via oral and dermal contact.

The result of this study shows that the mining activities of AngloGold Ashanti (Obuasi mine) are having serious health problems on the workers of the company. Much concerted efforts are required to ensure safety of mine workers.

It is important for all those involved in ensuring safety of the environment as well as the workers to do their work to ensure sustainable development.

Table 3. Cancer Health Risk results from exposure to arsenic in soil and water samples from AngloGold Ashanti – Obuasi mine.

Mine	Exposure Media	Exposure Route	Cancer Health Risk	
			Central Tendency Exposure	Reasonable Maximum Exposure
PTP	Soil	Oral	7.7×10^{-5}	1.2×10^{-3}
		Dermal	2.4×10^{-5}	9.5×10^{-4}
TTP	Soil	Oral	1.7×10^{-6}	2.6×10^{-4}
		Dermal	5.1×10^{-6}	2.1×10^{-4}
CIL	Soil	Oral	1.7×10^{-1}	3.6×10^{-1}
		Dermal	5.6×10^{-1}	2.0×10^{-1}
	Water	Oral	9.8×10^{-2}	9.8×10^{-3}
		Dermal	8.9×10^{-2}	10.2×10^{-3}
STP	Soil	Oral	9.3×10^{-6}	1.5×10^{-4}
		Dermal	2.8×10^{-6}	1.1×10^{-4}
	Water	Oral	4.9×10^{-3}	3.3×10^{-2}
		Dermal	4.9×10^{-3}	2.6×10^{-2}
BIOX	Water	Oral	1.1×10^{-3}	7.2×10^{-2}
		Dermal	1.3×10^{-3}	6.6×10^{-3}
OTP	Soil	Oral	9.5×10^{-6}	1.5×10^{-4}
		Dermal	2.9×10^{-6}	1.2×10^{-4}
	Water	Oral	3.6×10^{-3}	4.4×10^{-3}
		Dermal	4.4×10^{-3}	4.4×10^{-3}

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