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ENVIRONMENTAL POLLUTANTS IN THE MINING ENVIRONS OF KONONGO IN THE ASHANTI REGION OF GHANA

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Summary

The study was made to determine whether the present practice of gold mining at Konongo had affected the quality of Konongo fauna, flora and waterbed sediment. The possible environmental pollutants in the mining environs of Konongo are CN^-, Zn, Pb, B, and Mn. Zn, Pb and Mn were determined by Atomic Absorption Spectrophotometer. Calorimetric procedure was adopted to determine B. CN^- was determined by titration with rhodamine indicator. Accumulation of pollutants in waterbed sediment, fauna and flora was in the range of 0.011 - 0.064 μgg^{-1} for CN^-; 0.188 - 1.17 μgg^{-1} for Zn; 0.015 - 0.122 μgg^{-1} for Pb; 0.101 - 2.76 μgg^{-1} for Mn and 0.05 - 0.60 μgg^{-1} for B. The significant differences observed with respect to the concentrations of the pollutants at different locations in the sampling area were due to the divergence of the level of pollution. It is inferred from the results that the mining environs of Konongo are not polluted to any extent by the mining processes and that if the present surveillance of the discharge of wastes was maintained, mining could continue without any adverse effect on Konongo environs.

Introduction

The Ghanaian economy depends on cocoa, gold, and timber which together account for over 80 per cent of the country's exports. The mining sector is the largest foreign exchange earner and is playing a significant role in the economic recovery program of the country. However, the negative socio-economic impacts of mining are enormous. While the country benefits from mining, the increasing negative impact through environmental degradation must not be left unresolved.

Gold mining is the largest mining industry in Ghana and its exploitation puts immense stress on air, water, soil and vegetation. It also poses potential and real hazards to human health. Evidence is accumulating on the fact that large amounts of hazardous products from gold extraction are found in environmental samples. For instance, large quantities of arsenic and airborne particles (such as dust, sulphur dioxide and arsenic trioxide) have been found in samples from Obuasi and Prestea (Amasa, 1975; Amonoo-Neizer, 1980, 1989).

The Konongo Goldfield is based on the exploitation of lode ores, which occur fused in the earthy material, and in which the gold is contained as the native metal. The process of recovery involves excavating the ore from the earth, followed by agglomeration with cement. The agglomerated ore is conveyed to heap leach pads. The pads are sprayed with dilute cyanide solution to leach the gold content. The gold solution is subjected to treatment with zinc powder, and activated by lead nitrate, to precipitate the gold. The zinc replaces the gold in the cyanide solution. The gold precipitate is concentrated by pressing, smelted and then subjected to acid treatment to remove the bulk of the precipitant. Following the acid treatment, the gold is melted with a flux of borax, soda ash, nitre and sand rich in silica. The melted gold is cast into bars of gold and exported (Kwakye, 1990).

From the general operational methods the possible environmental pollutants from the process are CN^-, Zn, Pb, B, and Mn. Previous studies (Amasa, 1975; Amonoo-Neizer, 1980, 1989) have established the contamination of environmental samples by untreated effluent and wastes from mining processes. Since such studies have not been done at Konongo, this account must be regarded as exploratory in nature.

Konongo (1° 15' W, 6° 50' N) is about 48 km from Kumasi, the administrative capital of the Ashanti Region. It lies in a rich agricultural area and is, therefore, well supplied with food, as well as being itself a cocoa buying centre. Activities such as commerce and farming are quite important and the economy is in no way dominated by mining (Boateng, 1970).

Experimental

The sampling sites were selected along the course of the Owire river and its tributaries. River Owire is the most significant river in the Konongo district, serving for drinking, fishing and other domestic purposes. It flows through the mining areas of Obenemase and Konongo, thereby serving as a repository for mine wastes. The river joins River Anunu, which has been dammed for irrigation in the district. The sample locations were chosen to assess the possible deleterious effects of gold mining effluent on the water quality of the rivers in the area. The approximate positions of the sample sites are shown in the map in Fig. 1. River Anunu (Site 16) is far away from the rest of the sampling sites and, therefore, could not be represented on the map.

Samples were collected on monthly basis from Apr 91 to Mar 92. Fauna and flora possess a good ability to accumulate and store substances from the aquatic environment, thus usable as indicators of low level pollution of natural waters (Guldberg *et al.*, 1978; Majori & Petronio, 1973). The sediment provides proof on the pollution of waters for a relatively long duration. In the present investigation, sediment, fish (*Tillapia zilli*) and fern (*Cyclosorus* sp.) were selected to monitor pollution of the Konongo environs by the present practice of gold mining in the area. The selection of sediment, fish and fern was based on the ecosystem, seasonal availability, dominance and nature of pollution source.

Zn, Pb and Mn determination

Regarding fauna and flora, the samples were prepared for analysis by wet digestion (Coles *et al.*, 1971; FAO, 1983). 10 g of wet sample were ground in a porcelain mortar. 1g homogenized

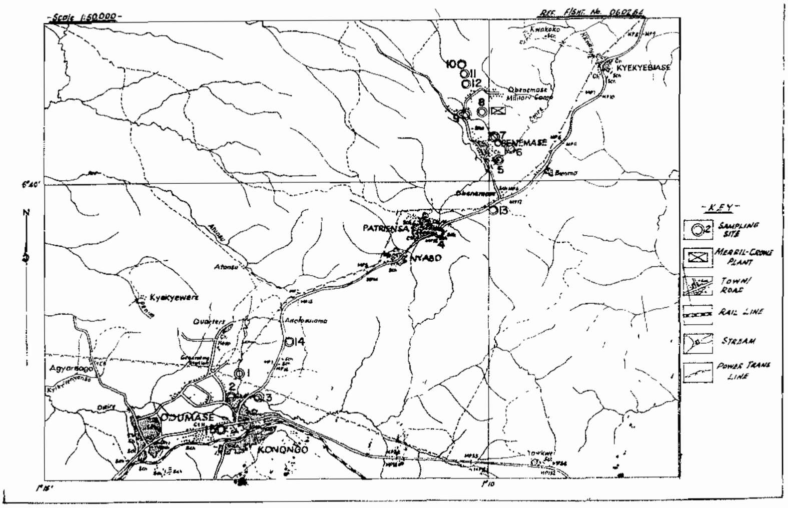

Fig. 1. Map showing sampling sites at Konongo, Petriensa and Obenemasi

sample was digested with 7 cm^3 nitric acid in a digestion tube on a water-bath (at boiling point) for 3 h. The clear digest was diluted to 25 cm^3. The elements were determined on this digestion solution. Sediment samples were, however, air-dried. 10 g of the dry sediment were accurately weighed into a 250 cm^3 tall-form beaker and 25 cm^3 of concentrated nitric acid was added. The beaker was covered and heated, cautiously (on a sand-bath), to oxidize organic matter. 25 cm^3 of 60 per cent perchloric acid was added and the digestion continued until dense white fumes of acid appeared. A little extra perchloric acid was used to wash down the sides of the beaker. The solution was cooled and diluted to 25 cm^3. with warm distilled water. The solution was filtered through a Whatman No. 41 filter paper. The elements were determined on this digestion solution (Hesse, 1971). Sample solutions of sediment, fauna and flora were analysed for Zn, Pb and Mn using Perkin-Elmer Atomic Absorption Spectrophotometer.

TABLE 1

Pollutant content in water-bed sediment (μgg^{-1})

Pollutant	*No. of samples*	*Range*	*Mean*	*SD*	*SD (%)*
CN^1	45	0.029-0.050	0.041	0.012	29.268
Zn	45	0.188-1.170	0.509	0.319	62.672
Pb	36	0.015-0.122	0.047	0.053	112.766
Mn	45	0.149-2.760	1.022	1.008	98.630
B	18	0.40 - 0.60	0.52	0.03	11.54

TABLE 2

Pollutant content in water-bed sediment (μgg^{-1})

Pollutant	*No. of samples*	*Range*	*Mean*	*SD*	*SD (%)*
CN^1	75	0.017-0.064	0.040	0.013	32.500
Zn	75	0.298-0.616	0.399	0.088	22.055
Pb	75	0.036-0.080	0.057	0.041	71.930
Mn	75	0.230-0.292	0.264	0.024	9.091
B	30	0.50-0.18	0.10	0.03	30.00

TABLE 3

Pollutant content in water-bed sediment (μgg^{-1})

Pollutant	*No. of samples*	*Range*	*Mean*	*SD*	*SD (%)*
CN	6	0.011-0.019	0.015	0.003	20.000
Zn	6	0.190-0.309	0.236	0.037	15.678
Pb	6	0.019-0.041	0.030	0.007	23.333
Mn	6	0.101-0.112	0.106	0.004	3.774
B	6	0.16 - 0.26	0.22	0.04	18.18

B and CN^- determination

Colorimetric procedure was adopted to determine B making use of curcumin to develop the colour (Anon., 1972). Cyanide was determined by titration with silver nitrate using thodamine indicator (Anon., 1972). The fish and fern were prepared for B and CN^- determination by the following procedure:

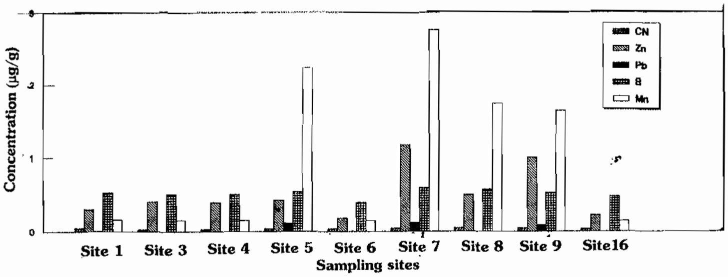

Fig. 2. Pollutant content in Water-bed sediment

TABLE 4

Cyanide concentration in samples fromKonogo (μgg^{-1})

Site	*Sediment*	*Fern*	*Fish*	*SD*
1	0.049	0.063	-	0.007
2	0.029	0.041	0.012	0.012
3	0.032	0.045	0.014	0.013
4	0.039	0.041	0.015	0.012
5	0.041	0.042	0.011	0.014
6	0.045	0.064	-	0.010
7	0.047	0.064	-	0.009
8	0.050	0.052	0.019	0.015
9	-	0.022	-	0.000
10	-	0.017	-	0.000
11	-	0.039	-	0.000
12	-	0.026	-	0.000
13	-	0.034	-	0.000
14	-	0.038	-	0.000
15	-	0.031	0.018	0.009

TABLE 5

Zinc concentration in samples fromKonogo (μgg^{-1})

Site	*Sediment*	*Fern*	*Fish*	*SD*
1	0.306	0.441	-	0.068
2	0.409	0.616	0.215	0.164
3	0.400	0.479	0.220	0.108
4	0.430	0.471	0.241	0.100
5	0.188	0.391	0.190	0.095
6	1.170	0.500	-	0.335
7	0.502	0.400	-	0.051
8	1.000	0.386	0.309	0.309
9	-	0.298	-	0.000
10	-	0.305	-	0.000
11	-	0.309	-	0.000
12	-	0.409	-	0.000
13	-	0.310	-	0.000
14	-	0.307	-	0.000
15	0.224	0399	0.239	0.079

TABLE 6

Lead concentration in samples fromKonogo (μgg^{-1})

Site	*Sediment*	*Fern*	*Fish*	*SD*
1	0.015	0.067	-	0.026
2	-	0.074	0.032	0.021
3	-	0.056	0.029	0.014
4	0.113	0.057	0.027	0.036
5	-	0.055	0.019	0.018
6	0.122	0.080	-	0.021
7	-	0.036	-	0.000
8	0.090	0.059	0.041	0.028
9	-	0.045	-	0.000
10	-	0.049	-	0.000
11	-	0.048	-	0.000
12	-	0.049	-	0.000
13	-	0.042	-	0.000
14	-	0.047	-	0.000
15	-	0.054	0.031	0.012

TABLE 7

Manganese concentration in samples fromKonogo (μgg^{-1})

Site	*Sediment*	*Fern*	*Fish*	*SD*
1	0.167	0.230	-	0.032
2	0.158	0.276	0.101	0.073
3	0.156	0.277	0.103	0.073
4	2.240	0.276	0.110	0.967
5	0.151	0.270	0.106	0.069
6	2.760	0.292	-	1.234
7	1.740	0.281	-	0.730
8	1.640	0.283	0.112	0.684
9	-	0.241	-	0.000
10	-	0.245	-	0.000
11	-	0.251	-	0.000
12	-	0.244	-	0.000
13	-	0.245	-	0.000
14	-	0.250	-	0.000
15	0.149	0.270	0.104	0.070

TABLE 8

Boron concentration in samples fromKonogo (μgg^{-1})

Site	*Sediment*	*Fern*	*Fish*	*SD*
1	0.54	0.14	-	0.20
2	0.52	0.09	0.26	0.18
3	0.51	0.11	0.24	0.17
4	0.55	0.13	0.18	0.19
5	0.40	0.09	0.16	0.13
6	0.60	0.18	-	1.21
7	0.58	0.11	-	0.24
8	0.53	0.15	0.25	0.16
9	-	0.10	-	0.00
10	-	0.08	-	0.00
11	-	0.10	-	0.00
12	-	0.05	-	0.00
13	-	0.08	-	0.00
14	-	0.07	-	0.00
15	0.48	0.10	0.24	0.016

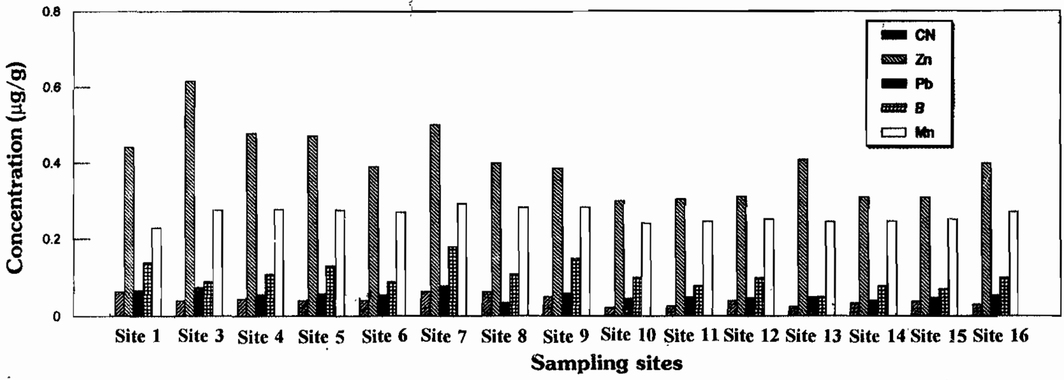

Fig. 3 Pollutant content in fern

1.0g of oven-dried (70 °C) flora material was weighed in a porcelain crucible. 100 mg of CaO powder were added. The CaO were mixed with the flora material until no CaO particles could be distinguished. The porcelain crucible was covered and heated at 550 °C for 2 h in a muffle furnace. This was allowed to cool. The cover was cleaned from adhering particles by tapping. 25 ml of H_2SO_4 (0.63 *M*) was added and swirled. This was allowed to stand for 30 min and swirled again at regular intervals. The solution was filtered through a coarse filter. The filtrate was collected in a polypropylene conical flash.

The sediment samples were air-dried. 25.0 g of the dry sample were mixed with 50 ml of water in an Erlenmeyer flask (250 ml capacity). A water-cooled reflux condenser was inserted and the mixture heated till boiling. Boiling was continued for exactly 5 min. Still connected with the condenser, the mixture was allowed to cool to room temperature. The condenser was removed and the mixture filtered through a fine filter. Coloured extracts were decolorized by shaking 10 ml extract with 0.1 g of activated carbon (quality BDH) for 30 min. Boron concentration was measured on a spectrophotometer at 540 nm.

Results and discussion

Pollutant content in waterbed sediment

The cyanide content ranged from 0.029 μgg^{-1} to 0.050 μgg^{-1} with a mean value of 0.041 μgg^{-1}(Table 1) The highest cyanide concentration of 0.050 μgg^{-1} was recorded at sampling site 9 (Table 4) which receives leachate from abandoned heaps. Sampling site 3 is comparably far from the source of cyanide pollution and hence recorded the lowest cyanide concentration (0.029 μgg^{-1}). Manganese concentration was highest in sediment at

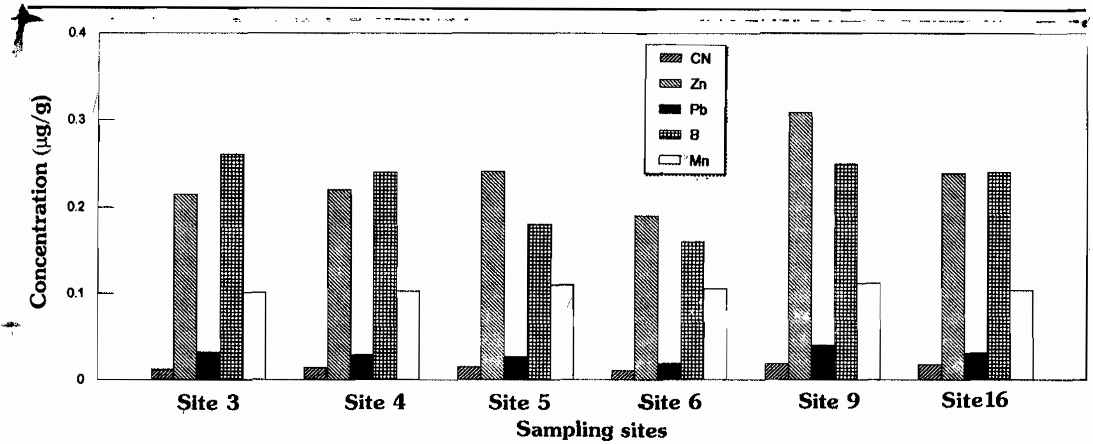

Fig. 4. Pollutant content in fish

sampling site 7 (Fig. 2) followed by sediment at sampling site 5 and diminishing in value with increasing distance from source of pollution to sampling site. Sampling site 7 recorded a mean value of 2.760 gg-1 whilst sampling site 5 recorded a mean value of 2.240 µgg^{-1} (Table 7). The concentration of boron exhibited slight changes in all the sampling sites (Table 8). Comparing the lead data with those of Madsen *et al.* (1983) and Bowen (1966) reported for river sediments collected from unpolluted areas (7-700 µgg^{-1}), it can be stated that the lead concentrations more or less correspond to the level found in sediments originating from unpolluted areas. Sampling site 6 recorded the lowest zinc concentration (0.188 µgg^{-1}) from Table 5. Sampling site 6 is at a point along the river course where the water is in a natural state; there is no direct or indirect pollution from the Obenemase mines.

Tables 4, 5, 6, 7 and 8 compare the concentrations of pollutants for the various "indicator" materials (sediment, fern and fish). Higher pollutant concentrations were found in sediment and fern. The ability of sediments and aquatic plants to accumulate Zn, Pb and Mn has been shown by Biney *et al.* (1994). The authors reported that metal concentrations in water were lower than those in fish, and the levels in sediments were higher than those in fish. However, in their analyses of sediments and aquatic plants the authors showed that higher concentrations of Zn and Pb occurred in sediments than in plants at sites characterized by industrialization. Sites 5, 7, 8 and 9 were considered as hot spots within the study area, and in regard to metal pollution from the mining processes at Obenemase. At these sites, sediment concentrations of Zn, Pb and Mn (Tables 5, 6 and 7) were higher than in fern. The higher levels were associated with the effluent discharge from Obenemase mines.

*Pollutant content in fern (*Cyclosorus *sp.)*

The cyanide content in fern at all the sampling sites of the Knongo mining environs ranged from 0.017 µgg^{-1} to 0.064 µgg^{-1} (Table 2). The highest cyanide concentration (0.064 µgg^{-1}) was found at the sampling sites 7 and 8 (Fig. 3). It may be expected that since sampling sites 7 and 8 are comparatively close to the gold-extraction site at Obenemase, contribution to the level of cyanide in fern by the extraction processes would be comparatively high at these sites. The concentration of lead exhibited slight changes in all the sampling sites. Managanese concentrations decreased with distance between source of pollution and the sampling site toward sampling site 3 (0.276 µgg^{-1}) along the Owire river. The boron content in fern at the mining environs of Konongo ranged from 0.05-0.18 µgg^{-1}, the highest value occurring at sampling site 7 (Table 8).

*Pollutant content in fish (*Tillapia zilli*)*

The fish samples were obtained from sampling sites 3, 4, 5, 6, 9 and 16 (Fig. 4). In all cases of the studied pollutants (with the exception of boron), significantly higher values were obtained in the fish samples collected from sampling site 9 (Fig. 4). For instance, as regards cyanide concentration, the highest value (0.019 μgg^{-1}) was obtained in fish from sampling site 9. Sampling site 9 receives wastes from abandoned heaps close to it. Thus it may be expected that fish samples from this site should show relatively higher pollutant concentration. In this study, pollutants concentrations in fish within the catchment area of the Konongo mining environs range as follows: cyanide (0.011 - 0.019 μgg^{-1}); zinc (0.190 - 0.309 μgg^{-1}); lead (0.019 - 0.041 μgg^{-1}); manganese (0.101 - 0.112 μgg^{-1}); boron (0.16 - 0.26 μgg^{-1}). These values compare with those obtained for fish in unpolluted rivers as has been reported by Varshney (1983), for instance, zinc (6-20 μgg^{-1}); manganese (0.2-0.9 μgg^{-1}).

Conclusion

The concentrations of pollutants (i.e. CN^-, Zn, Pb, Mn and B) varied between the sampling sites and between the indicator materials. The differences observed with respect to the concentrations of the pollutants at different locations in the sampling area could be due to the divergence of the level of pollution. Values were generally higher closer to the points of discharge of mine wastes.

In respect to the pollutants also appearing at significant levels at site 16 (River Anunu), however, it cannot be decided unambiguously whether it is the result of pollution from Obenemase mines or whether it is due to some other sources. The pollutant concentrations at site 16 can depend on various factors. The most important is the geochemical background, whereas from the variable factors, the anthropogenic sources play an important role. Most of the water from the catchment of River Anunu arrive at the river with small streams, bringing a large amount of pollution of agricultural, domestic and partly of industrial origin. Concentrations of pollutants also varied between sediment, fauna and flora. Higher values were measured in sediments in the vicinity of points of discharge of mine wastes.

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