Bull. Environ. Contam. Toxicol. (1996) 56:703-710

Bulletin of Environmental Contamination and Toxicology

Distribution of Arsenic and Sulphate in the Vicinity of Ashanti Goldmine at Obuasi, Ghana

A. A. Golow, A. Schlueter, S. Amihere-Mensah, H. L. K. Granson, M. S. Tetteh

Department of Chemistry, University of Science and Technology, Kumasi, Ghana

Received: 16 June 1995/Accepted: 12 October 1995

The gold ore which occurs at Obuasi is made up of the metal and the combined forms such as pyrites, FeS_2 and arseno-pyrites, FeAsS (Kesse, 1985). During the extraction of the metal, the ore is first crushed and ground to fine powder. Free gold is precipitated by gravitation. The sulphide is floated and roasted. In this process the sulphur is converted to sulphur dioxide and the arsenic to arsenic trioxide and other oxides. The metal is leached with excess dilute sodium cyanide solution. The filtrate is then treated with zinc dust to precipitate the metal gold. The molten material is then reduced with HCI to give gold bullion which is 90-95% rich in gold. Thus in the processing of the ore for gold, the flue dust may contain particles of the ore, ferric oxide, oxides of arsenic and sulphur. These may be carried into the atmosphere and may settle on the soil, vegetation, crops, humans, rivers and livestock in the neighbourhood during precipitation or any other process. Studies by Amonoo-Neizer (1980, 1989) and Amasa (1975) have shown large quantities of arsenic in soil, crops and vegetation in locations near the mine. Sulphur dioxide may be oxidized to the trioxide by the air and be converted to the sulphate in dew and rainwater. The acidic dew and rainwater and oxides or arsenic may be responsible for the disappearance of the vegetation in some locations near this gold mine. According to Golow (1993), surface soil tends to adsorb pollutants which settle on it more than the vegetation, it may be *a* good material to sample for pollution studies. In any case when vegetation die and decay whatever they contain may be added to the surface soil. The only disadvantage is that whatever is deposited on the surface soil may be carried to greater depths with time by rainwater (Gish et al 1973).

The aim of the investigation reported here is to describe how arsenic and sulphate from gold mining processes are distributed in the environs of Obuasi and find out how far the effects of the activities of the Ashanti Goldfields Corporation can be experienced.

Correspondence to: A. A. Golow

MATERIALS AND METHODS

Surface soil samples were collected from various sites at measured distances from Obuasi (Fig. 1). At every site, six samples were randomly collected. The surface soil was scraped with a knife to a depth of 5cm and mixed thoroughly and put in a polyethylene bag. These were conveyed to the laboratory and spread out on sheets of polyethylene and allowed to dry to constant weight for a number of days. The samples were collected once a month for a period of one year.

Three different portions of each sample were treated and analysed as follows: Accurately weighed 5g of dried ground soil sample was put into a lOOml conical flask, 20ml of 4M HCl were added and the mixture heated for 15 mins. The extract was filtered through Whatman No.41 filter paper and made up to 100ml mark in a graduated flask.

Arsenic (V) Content. Fifty millilitres of each extract was neutralized with saturated solution of sodium hydroxide. The end point was determined with a pH meter. The neutral solution was heated in a sand bath and the volume adjusted to 50ml with distilled water in a graduated flask. To this solution in lOOm1 conical flask were added 6g of solid ammonium chloride and a few drops of 1M HCl. This mixture was stirred until all the solid dissolved and 3ml of 0.029M zirconium nitrate solution were added with constant stirring. It was heated to boil for 15 min. and then cooled and filtered through Whatman No. 41 filter paper.

The arsenic (V) was determined by Murphy et al, (1956) modification of the molybdenum blue method. To lml of each filtrate in a test tube were added lml each of 0.002M ammonium molybdate solution and 3M HCl. This mixture was mixed thoroughly and the test tubes immersed in boiling water bath for 10 min. The test tube was removed and lml of O.lM ascorbic acid solution and lml 0.3% antimony tartrate added and then heated in water bath for further 20 min. The test tube was removed and allowed to cool. A blank solution with distilled water instead of sample or standard solution was similarly treated. Calibration solution with different strengths of arsenic (V) from sodium arsenate were prepared and similarly treated.

The standard solutions, the sample and the blank were measured at predetermined 745nm in Schimazu UV-120-02 spectrophotometer. The levels of arsenic (V) in the sample extracts were read from the calibration curves and converted to mg/kg of dry soil. As stated earlier, three different portions of each sample were analysed. The mean for each of six samples collected at each station were calculated. Recovery studies with standard addition method gave 95 to 98.8% for 0.1 to 1.0mg/kg. The coefficient of variation was 2 to 11% and interference due to silica was 0.02% at l.0mg/kg.

Arsenic (III) Content. Fifty millilitres of each extract was neutralized with saturated solution of sodium hydroxide. To each

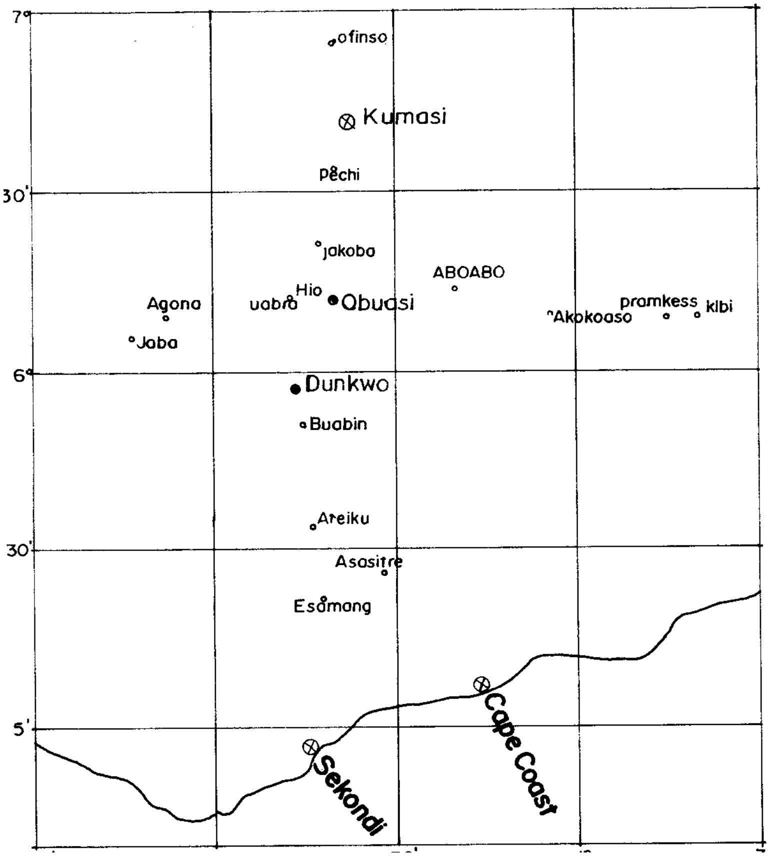

Figure 1 Map showing places sampled. O Towns sampled

were added 2.0ml of 20% hydrogen peroxide. This mixture was thoroughly mixed and allowed to stand for 15 min. The mixture was heated for 30 min. for complete oxidation and the decomposition of the excess peroxide. The solution was put in 100ml conical flask and treated with zirconium nitrate to remove phosphate as described above. Arsenic (III) content of the soil extract was obtained by difference. That is the value obtained for the unoxidized extract was subtracted from that of the oxidized extract. Spiked soil samples gave recoveries between 94 to 97.8% for 0.2 to 1.0mg/kg.

Sulphate Content. As described for arsenic carefully weighed 5g of dry surface soil was put in a 100ml conical flask and 20ml of 4M HCl were added and mixture heated in a sand bath for 15 min.

Where coloured solution was produced, the mixture was heated with 2g of activated charcoal and filtered hot through Whatman No. 41 filter paper. The filtrate was made up to 200ml in a graduated flask. To l00ml portion of the extract were added 5ml of a conditioning reagent (Greenberg et al 1992) and about 0.5 to 0.8g of ground crystals of barium chloride was added with stirring for 1 min. The turbidity was measured at 30 sec. intervals for 6 min. at 420nm in the Schimazu UV-120-02 spectrophotometer. The readings remained constant between 4 and 8 min. Calibration solutions of 0-40mg/l of sulphate from anhydrous sodium sulphate were similarly treated and the calibration curves were drawn. The amounts of sulphate in the soil extracts were read from these curves. As low as 1mg/l of sulphate was measured with coefficient of variation between 7 and 11%.

RESULTS AND DISCUSSIONS

All the three forms of arsenic (total, arsenic As (V) and As (III) were higher in places close to Obuasi. In the East-West direction, places in the East which were close to Obuasi had higher levels of arsenic in the surface soil than similar places on the West. The amounts of arsenic in surface soil close to the Eastern side of Obuasi were nearly twice as high as amounts in the Western side (see Fig. 2). This was due to the fact that the wind was blowing mainly in the Eastern direction. On each side in the East-West direction of Obuasi, arsenic decreased with distance similar to what was observed by John (1971), Burkitt et al, (1972), and Preston (1973). The decrease was nearly linear initially but levelled off to a constant at various distances from Obuasi. At the point where it became constant, the amounts could be regarded as the minimum or the natural background levels.

While on the Eastern side the levels decreased to the minimum or background within 7km from Obuasi, on the Western side the minimum level was reached at a distance of 15km from Obuasi Fig.2a). This might be because larger particles of dust were readily carried by the wind and because of their weight and low velocity travelled shorter distances from their origin and were quickly brought down to the earth under gravity. Such large particles of dust might present surface areas to the large surface areas of finer and lighter particles which might have been adsorbed on the larger particles and be carried down as well. In addition, the surfaces of the larger particles might have larger electrical charges which might be opposite to the charges carried by the finer particles. Hence the finer particles in the East were easily attracted to the bigger dust particles which conveyed them along their path. As such when the bigger particles fell, the finer ones were certainly depleted from the atmosphere in the East. But in the Western direction there might have been fewer large dust particles present because most of them might have moved with the wind to the East. Thus the West might contain mainly finer and lighter particles. There would have been lesser surface areas for adsorption. Since these finer particles might be carrying electrostatic charges of

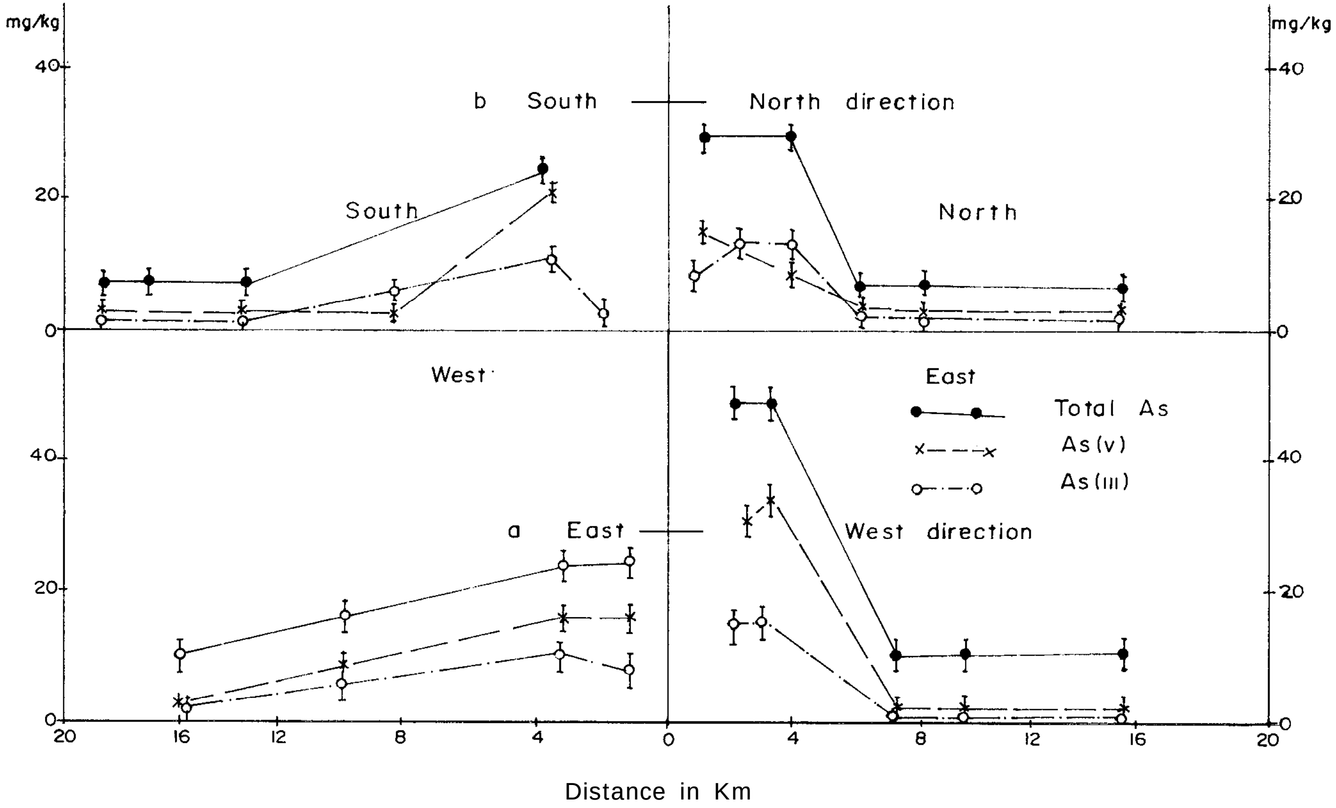

Figure 2 Variation of As in top soil with distance from the mine

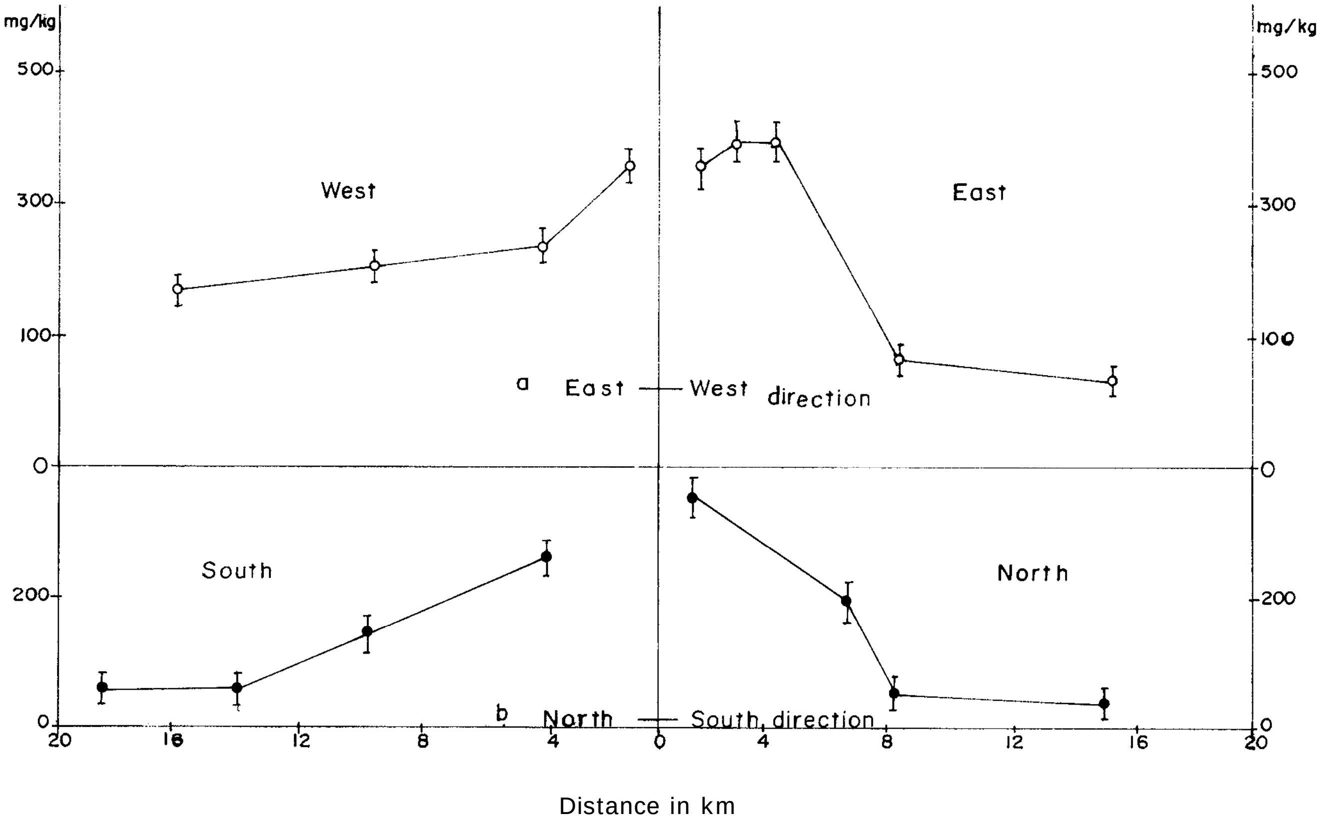

Figure 3 Variation of average sulphate in top soil with distance from the mine.

the same sign, they might be repelling each other and might not have agglomorated into bigger particles which could easily be brought down to the surface of the earth under gravity. This could be the reason why they remained bouyed longer in the atmosphere and drifted slowly to longer distances and hence the absence of a defined path range in the Western direction. The movement of the finer particles in the Western direction might be due not to the wind but other processes such as diffusion, dispersion, bouyance and others unknown.

In the North-South direction, surface soil samples close to Obuasi in the North had higher levels of arsenic than the South (Fig. 2b). The amounts appeared to decrease somewhat linearly with distance but levelled off to a constant in both directions. The minimum or background level was attained at a distance of about 6km in the North but it was at a distance of about 13km from Obuasi in the Southern portions (Fig. 2b). The explanation for the difference might be similar to that given for the pattern observed in the East-West direction. The wind direction was more to the North than to the South. The amount of sulphate in the surface soil displayed the same pattern as shown by arsenic (Fig. 3). The levels decreased with distance in the East-West and North-South directions. The larger amounts were found in the Northern and Eastern at places close to the mine. The decreases to minimum levels were attained in the North and East at distances between 6 and 8km but in the West and South the minimum was attained between 13 and 15km (Fig. 3). The pattern shown by sulphate also lends credence to the fact that particle sizes might be responsible for differences observed. It might be of interest to measure the sizes of particles of dust in the leeward and opposite directions of wind from the mine.

In the East-West direction, total arsenic background level was l0mg/kg and the North-South direction had background level of total arsenic of between 3 and 7mg/kg but arsenic (III) in both directions was between 1 and 2mg/kg in the background. According to WHO (1981), As (III) of 1 to 2.5mg/kg in drinking water will have effects on the skin of inhabitants. If the whole of arsenic (III) could be washed into sources of drinking water the inhabitants may suffer from hyperkeratosis, hyperpigmentation or dipigmentation of the skin as observed on some individuals living in Obuasi and its environs.

Acknowledgment. We wish to thank Central State University, Wilberforce, University of Science and Technology, Kumasi, for providing facilities for the study and the USAID for providing funds for UNDP.

REFERENCES

Amasa, S.K. (1975). Arsenic pollution at Obuasi Goldfine. Environs. Hlth Pers. 12, 131-133.

Amonoo-Neizer, E.H.. Busare, G.L. (1980). Arsenic Status of Ghana Soils: Contamination or soils near goldsmelter. Ghana J. Sci. 20 (1 & 2), 57-62.

Amonoo-Neizer, E.H. (1989). Isotopically exchangeable phosphate, sulphate and arsenic in some Ghana soils. J. of the University of Science and Technology 9 (3), 116-120.

Burkioo, A.J., Lester, P., Nickless, G. (1972). Distribution of heavy metals in the vicinity of industrial complex. Nature 238, 327-328.

Gish, C.D., Christinson, R.E. (1973). Cadmium, nickel, lead and zinc in earthworms from roadside soil. Environ. Sci. Technol. 7, 1060-1062.

Golow, A.A. (1993). Contamination of roadside vegetation and soil with lead in three towns in Ashanti, Ghana. J. of University of Science and Technology 13 (2), 62-66.

Greenberg, A.E., Clescerl, L.S., Eaton, A.D. (1992). Standard methods for examination of water and waste water. American Public Health Association, Washington.

John, M.K., (1971). Lead contamination of some agricultural soils in Western Canada. Environ. Sci. Technol. 5, 1199-1203.

Kesse, G.O. (1985). The mineral and rock resources of Ghana. A A Balkema, Rotterdam.

Murphy J., Riley, J.P. (1956). Storage of seawater samples for the determination of dissolved inorganic phosphate. Anal. Chim. Acta 14, 318-319.

Preston, A (1973). Heavy metals in British waters. Nature 242, 95-97.

World Health Organisation, Geneva (1981). Environmental Health Criteria. 18 Arsenic.