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PROCEEDINGS

Theme:
The Mining Industry and the Environment
UST/IDRC ENVIRONMENTAL RESEARCH GROUP

THE MINING INDUSTRY AND THE ENVIRONMENT

PROCEEDINGS OF A NATIONAL SYMPOSIUM

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APRIL, 14 & 15, 1997

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FOREWORD

The importance of the mining industry to the economy of Ghana cannot be over emphasised having overtaken cocoa as the largest foreign exchange earner in 1991. However, the people of this country and the government are becoming increasingly concerned about the adverse impact of mining operations on the environment.

The International Development Research Centre (IDRC) Ottawa, Canada has, during the last few years, actively supported environmental research project to assess the nature, intensity and geographic distribution of environmental pollutants emanating from the mining activities at some mining areas.

It was against this background that the UST-IDRC Environmental Research Group, which is based in the Department of Chemistry of the University of Science and Technology, Kumasi, Ghana, organised a National Symposium on the Mining Industry and the Environment.

It is gratifying to note that participants came from the Universities, Research Institutions, Mining Industries, Government, Policy makers from the Minerals Commission, Chamber of Mines, Environmental Protection Agency and non-governmental organisations.

International financial support for the symposium came from the International Development Research Centre, Ottawa, Canada. The Minerals Commission, Ghana Chamber of Mines, Timber Export Development Board and Ministry of Mines and Energy provided the local financial support for the symposium.

This document puts together the papers presented at the National Symposium on the Mining Industry and the Environment held in Kumasi on April 14 and 15, 1997. The material can provide new knowledge and better understanding of issues related to the mining industry and the environment. It is our hope and expectation that the information will help environmental policy-makers and stakeholders in setting up the necessary framework to address the environmental problems associated with mining.
PART 1: OPENING ADDRESSES

INTRODUCTION OF CHAIRMAN

Dr. David Nyamah,
Chemistry Department, UST, Kumasi, Ghana

Honourable ministers, vice-chancellor, members of parliament, nananom, colleagues, distinguished ladies and gentlemen, it is a great pleasure for me to introduce the chairman for this morning's function. The importance of this national symposium was not lost upon the organisers when we began casting our eyes for someone to chair this opening ceremony. We looked for not only a safe pair of hands, but also for someone whose experience and capability to steer a function like this to a successful end was undoubted. Above all, we looked for a personality whose personal interest in what we are going to do here in the next two days is supreme.

Certainly, we had to look critically but not for long. Our choice of a chairman is a man of repute by all standards. He is an educationist, historian, and politician. He was educated at Wesley College here in Kumasi and then later on studied at the University of Ghana, Legon for his Bachelor of Arts honours degree in History. Our chairman also studied at the University of Sydney, Australia, where he obtained his Masters degree in Education.

Ladies and gentlemen, if there is somebody one can call a "teacher's teacher" then our chairman for this morning's function is that person. He has at various times taught at all the cycles of our educational system - the primary level, secondary level, the tertiary level, you name it! For almost two decades up till last year, he has been lecturing at the University of Cape Coast in history methods, curriculum studies in history and nature of history. He rose to the rank of senior Lecturer and acted on several occasions as the Head of the Department of Curriculum and Teaching/Arts and Social Sciences Education at the same University. Evidently, he is no stranger to the world of academia. The crowning moment to a life-long career in education came early this year when he was appointed a Minister of State by President Jerry John Rawlings.

Ladies and gentlemen, you guessed rightly. The chairman for this morning's function is no other personality than Honourable John Edward Afful, the Minister for Environment, Science and Technology. And now, I believe you all agree with me how fortunate we are in the choice of a chairman for this important event. Thank you.
CHAIRMAN'S REMARKS

Hon. Mr. J. E. Afful
Minister of Environment, Science and Technology.

Honourable ministers of state, honourable deputy ministers of state, vice-chancellor of U.S.T., members of the organising committee of this symposium, distinguished symposium lecturers and participants, distinguished invited guests, ladies and gentlemen.

It is with much pride and satisfaction that I accept to chair this very important national symposium. I commend the organisers of the symposium for their decision to create and use this forum to focus attention on the impact of mining activity on the environment. I am particularly pleased to note that the organisers have been able to obtain the enthusiastic participation of many informed personalities both in the academia and industry.

Distinguished ladies and gentlemen, this symposium could not have come at a better time. The environmental agenda for the 1990s, and as we move into the 21st century, is getting increasingly complex at both the national and global levels due to the growing threat on life support systems. There is therefore the need to examine the underlying causes of the threats to the survival of society and provide the solutions which will involve all of us.

Four years ago, the United Nations Conference on Environment and Development or the Earth Summit, was held in Rio de Janeiro. Rio was a signal to the world that after decades of pitting environmental quality against economic growth, policy makers had become aware of the crucial and potentially positive link between the two. We have reached the stage where it has become absolutely necessary to balance economic growth with a rational management of our natural resources to ensure that the resource base is not eroded in the process of development.

Humanity must learn to live within the limitations of the physical environment as both a provider of "inputs" and a "sink" for waste. We must recognise that even if environmental degradation does not reach life-threatening levels it can result in significant decline in the quality of the world we live in. We must therefore find a way that will enable all people, now and in the future, to enjoy clean water, clean air, and fertile soils.

Distinguished ladies and gentlemen, the implementation of the economic recovery programme in 1983 by the erstwhile PNDC administration led to the regeneration of the mining industry. In 1985 the Government put in place innovative policies and established a national institutional framework which created an enabling environment for direct foreign investment in the industry.

Today the contribution of the minerals industry to the national economy is very significant.

• It is the largest gross foreign exchange earner in Ghana
• It employs more than 7% of the labour force in the country
• The social services provided by the industry to the local communities may include roads, schools, scholarship schemes, potable water, clinics, electricity etc.

The potential adverse environmental impacts of mining and mineral processing activities can however be quite considerable, if adequate mitigative measures are not designed and implemented. These deleterious impacts range from land use conflicts, social dislocation, land degradation, visual intrusion, loss of water quality and reduction in air quality, noise nuisance and blast induced vibration to total relocation or resettlement of mining communities.
The Government anticipated the problems and in 1992 adopted the National Environmental Action Plan (NEAP) and the National Environmental Policy (NEP) to address the problems associated with economic development including mining. The policy instruments under NEP provides for:

• assessment of potential impacts of all major projects including mining in order to integrate mitigating measures into the planning policy.
• establishment and implementation of appropriate standards and guidelines for acceptable levels of public health and environmental protection.
• enactment of legislation to prescribe necessary environmental quality standards and guidelines for all industries including mining.

In pursuance of the policy, Environmental Impact Assessments (EIAs) for all new mining projects and Environmental Management Plans (EMPs) for existing mines are mandatory under the EPA Act 1994 (Act 490).

Further to the relevant provisions under the Minerals and Mining Law of 1986, PNDCL 153, Ghana's Mining and Environmental Guidelines have been developed by the Minerals Commission and the Environment Protection Agency to assist the mining industry operate in environmentally acceptable manner.

To demonstrate the Government's commitment to minimising the adverse impact of mining and mineral processing, the Minerals Commission is co-ordinating the implementation of the Mining Sector Development and Environment Project. The objective of the Project is to develop capacities in key sector institutions in resolving environmental problems arising from the mining sector in order to ensure sustainable development of the country's mining industry. The project also aims to achieve the following:

• minimisation or pre-emption of environment impacts of new mines
• containment of the impact of established mines and
• assessment of best practices and options for ensuring the rehabilitation of degraded lands.

New elements/components to the project would have to be developed to ensure effective monitoring and compliance enforcement.

The Environmental Protection Agency (EPA) has recently published proposed effluent quality discharge guidelines for all categories of industry and would soon submit the guidelines to a national debate. In line with this, other necessary standards and guidelines will be developed by the Agency and its collaborating networking institutions to support the industry's efforts at maintaining the integrity of the Ghanaian environment.

It is my fervent hope, ladies and gentlemen, that this symposium would provide an excellent forum to discuss the issue of mining and the environment and make recommendations for the development of the mining industry in a manner that does not undermine the integrity of our environment.

Thank you.
WELCOME ADDRESS
Prof. E. H. Amonoo-Neizer
Vice-Chancellor, UST, Kumasi, Ghana

The Honourable Minister for Mines and Energy, the Hon. Minister for Environment Science and Technology; the Executive Director Chamber of Mines; distinguished guests, ladies and gentlemen:

It is with great pleasure that I welcome you to the University of Science and Technology and to this national symposium on the theme: "The Mining Industry and the Environment". I extend a special welcome to the Honourable Minister for Mines and Energy, who is on his first official visit to this University following his recent appointment.

Mr. Minister, please accept our felicitations on your appointment as the Minister for Environment, Science and Technology. Even though the environment has become very topical worldwide, Science and Technology are likewise very important to the economy of this country and indeed to the economy of every country today. We hope that you will be able to divide your attention equally between these two sectors of your ministry.

Our presence here today, Ladies and Gentlemen, is significant for two closely related reasons. First, it is a clear expression of the importance that we collectively attach to the mining industry in the economic development of this country. Secondly, it signifies our deep concern about the escalating adverse impact of mining operations on our environment.

On my part, my further interest in this symposium is not limited merely to the dictates of protocol. Some of you may take it that, as the vice-chancellor of this University, for an event of such great national significance, I am duty bound to be here only to deliver an address of welcome, utter some platitudes and simply go away. I am not merely for these purposes today. I am here primarily as an active participant in this symposium.

Before you begin to question my credentials permitting me to be an "active participant", let me quickly remind those of you who may have forgotten that I am a chemist by profession. Notwithstanding, my present call of duty as vice-chancellor, I am still a chemist and shall always remain so. I am told that chemists make good vice-chancellors but I must confess that in Ghana, there have been more geographers as vice-chancellors than chemists.

Over the past five years, I have been leading the UST-IDRC Environmental Research Group. That has devoted much time and effort to studying certain aspects of mining-related environmental problems in some parts of the country. The other members of the group are also here at this gathering. It is significant to mention that the group's work has concentrated mainly on the impact of chemical pollutants from mining activities on the environment and the findings so far are very revealing. One of the papers resulting from our studies will be presented at this symposium.

It is also pertinent to note that this symposium is a culmination of the work that we have been doing in the last few years. As it is, the symposium is being organised by the UST-IDRC Environmental Research Group, which is based in the department of chemistry of this university with the active support of the International Development Research Centre (IDRC) of Ottawa, Canada. I would also like to acknowledge the assistance provided by some local establishments, notably the Chamber of Mines, Minerals Commission, and Timber Export Development Board, in generously underwriting part of the cost of organising the symposium.
It is particularly gratifying to note that the organisers have succeeded in bringing together participants drawn from the universities, research institutions, mining industry, government, policy-makers from the Minerals Commission, Chamber of Mines, Environmental Protection Agency, the Mines Ministry, Geological Survey Department, and non-governmental organisations. Also with us here today are local stakeholders and grass-roots activists from major mining towns like Obuasi and Tarkwa. By all standards, this is an impressive assembly of diverse expertise and experience. I hope that I am not being unduly optimistic when I say that the deliberations of such a gathering can only lead to one certain result: success.

The least that one can expect from us, are well considered recommendations for sustainable, environmentally friendly, mining operations in this country.

Honourable Chairman, the people of this country and, of course, the Government are becoming increasingly concerned about the adverse impact of mining operations on the environment. Some few months ago, just before the last general elections, we learnt through the news media that the chiefs of Fiaseman traditional area had gone on a street demonstration in Tarkwa to protest against the environmental degradation caused by the activities of mining companies in the area. In recent memory, I do not remember the last time that our traditional chiefs took to street demonstrations to register protests. That the chiefs of Fiaseman resorted to such an action is an indication of the level of seriousness and probable desperation with which they view the environmental degradation resulting from mining activities in the area.

If, when you heard the news report about this protest, you dismissed the event as a naked display of emotionalism by a group of semi-literate and ill-informed chiefs, I would like to disabuse your minds of the wrong notion. Certainly, when it comes to land and environmental problems, these people are as well informed as you and I. Evidently, the dangers of uncontrolled mining operations are real and palpable. For instance, findings from the on-going research studies by the UST-IDRC Environmental Research Group suggest that emission of dust and toxic substances such as arsenic, cyanide, sulphur dioxide, mercury and the like into the atmosphere and water-systems does pose serious health hazards. It is known that pollution levels in streams and rivers used by towns and villages around the Obuasi area are so menacingly high that the inhabitants have been advised against fetching water from these water-systems for domestic uses. Instead, they have to use water from boreholes. Again, the Tarkwa area and other places where surface mining is undertaken, vast tracts of forest and arable land are being systematically denuded of their vegetation cover and top-soil. Indeed, many other disquieting examples of mining-related environmental degradation abound in the country.

It is against this background that I deem the holding of this symposium timely and appropriate. The dilemma that confronts us between the economic benefits of mining operations and the attendant environmental problems bring to mind the mythical bird, "santrofi." According to Akan mythology, on coming across this bird, if one dared to fetch it home, this was bound to spell a misfortune; but, if this bird was not picked up where one found it, the neglect could mean the passing up of a great fortune. Such are the difficult choices that mining operations present to this country today. We all know that gold has now overtaken cocoa as the leading foreign exchange earner for the country.

As noted by the Minister of Finance in his 1997 budget statement, in the 1996 fiscal year, total export earnings from gold were US $612.4 million as against US $508.6 million from cocoa exports. If we were therefore to suggest that gold mining operations must be curtailed because of the harm they do to our ecosystems, would it not be tantamount to slaughtering the hen that lays the golden egg? On the other hand does it make sense to earn this money and use it all in treating people made unwell in the course of earning it.

It seems to me, ladies and gentlemen, that the way forward is to strike a balance. The vision, for us here at this symposium, should be to develop and institutionalize an appropriate technology that will ensure
environmentally sustainable mining operations in this country. There are no easy solutions, and the challenges are many. Collectively, as chemists, research officers, mining industrialists and policymakers, we must take up the challenge of finding solutions to problems that result from the present techniques of mining operations.

Those in the mining industries must work hand-in-hand with researchers in achieving these objectives. They must see researchers and EPA staff as partners working towards a common 'good. The mining industry should therefore, encourage and indeed support in practical terms the efforts of researchers at finding solutions to environmental problems resulting from mining operations. To the policy makers, I would urge you to pay due attention to research findings and other reports on mining-related problems and provide the necessary legal framework for tackling some of the issues, where necessary. At the same time, I hasten to caution that, as policy-makers, you should be careful not to impose such stringent and prohibitive measures that will intend to impede mining operations and, in the long run, the national economic growth.

Finally, it is essential that the proceedings of this symposium are promptly published and widely circulated to all stakeholders for further appropriate action. That way, our gathering here today and the days beyond would not have been in vain. I am also hopeful that this seminar would be a forerunner of yet more such events to be organised in the years ahead. I wish you happy deliberations.

"Thank you."
KEYNOTE ADDRESS

Hon. Kwame Peprah,
Minister of Mines & Energy

Mr. Chairman, colleague ministers, the vice-chancellor of the University of Science and Technology, distinguished guests, ladies and gentlemen:

I wish to thank the organisers of this symposium for the honour done me by inviting me to deliver the keynote address. I am very happy indeed to be here this morning to participate in this first-ever national symposium on such an important theme as "the mining industry and the environment".

There is no doubt in my mind that this is a momentous event. By itself, each of the two subjects constituting the theme of this symposium forms an urgent national issue. The mining industry, as we all know, is now the mainstay of the national economy and, for that matter, its activities must engage our serious attention and interest to ensure sustainable development for this country. It is also a fact that the environment is one key policy area that, if not carefully handled, could ultimately threaten our very existence as a people. Thus, the choice and combination of these two subjects for discussion in one symposium makes this event a truly significant one. In other words, this is one function that I could not have stayed away from, even if I had wished to.

Mr. Chairman, I commend the UST-IDRC Environmental Research group under the able leadership of the vice-chancellor for its initiative in organising this symposium. As I learn, the main objectives of this symposium are to examine and find solutions to the impact of mining operations on our environment. I salute the organisers of this symposium on the appropriateness of the theme and the timing of the event. Of late, it is becoming increasingly evident that there is the need to intensify action to ensure proper environmental management, especially as it affects the mining industry: The government is aware of the growing public concern, particularly within the local mining communities, about the environmental problems resulting from mining operations. The government would have failed in its public duty, if this issue did not arouse its deep concern. It is for this reason that the NDC administration associates itself with the objectives of this symposium.

Ladies and gentlemen, there are also two important aspects about the organisation of this symposium that appeals to the government. The first aspect relates to the diverse composition of this gathering. In line with its long-standing policy of encouraging grassroots participation in the decision-making process, the government is gratified to note that this symposium did not turn out to be just an "elitist" gathering of scholars, researchers, policy-makers and mining industrialists. Certainly, the decision of the organisers to invite other stakeholders like the grassroots activists from the local mining communities in Obuasi and Tarkwa, and also NGO's to participate in this symposium was a wise one. I have not been told about the thinking behind this decision, but I believe that the organisers acted by design and with a certain philosophy in mind. To me, the composition of this symposium is a clear demonstration of the principle that environmental protection should not be the concern of the government alone, but also that of industry, local communities, and indeed the society as a whole. While I accept that it is the fundamental responsibility of the government to provide the necessary institutional and legal framework for tackling environmental problems, I must also submit that every Ghanaian, irrespective of his or her situation in life, shares the duty to protect our environment for future generations.

Mr. Chairman, the other important aspect of this symposium that is not lost upon the government is the university-industry collaboration imminent in this gathering. The NDC government has, on many occasions, repeatedly emphasised the need for our universities to capture the initiative and be seen at
the forefront of national programmes to find solutions to the problems of society. I believe that the organisation of this symposium represents a step in this direction. In furthance of this, I would urge the UST-IDRC Environmental Research Group to remain steadfast and pursue practical and meaningful collaboration with the mining industry to find practical solutions to some of our mining-related environmental problems.

Mr. Chairman, in the very uplifting welcome address by the vice-chancellor, he mentioned the dilemma imposed by the economic benefits of mining operations on one hand, and the environmental problems resulting from these operations on the other hand. Indeed, my Ministry is very much aware of this dilemma, and I found his reference to the "santrofi" bird to illustrate this difficulty very apt and interesting. It is precisely the kind of perplexing question that the Ministry of Mines and Energy has to grapple with in the government's desire to exploit our rich mineral resources for sustainable economic growth. As I shall outline presently, concerted efforts are being made alongside the other relevant sector ministries like the Ministry of Environment, Science and Technology to ensure that mining operations do not create excessive environmental problems. In this connection, it would be most welcomed if the universities and research institutions were to join forces with appropriate ministries on continuous basis in discharging this task.

It has always been said that one cannot make omelette without breaking eggs. This means, in the context of the theme of this symposium, that it is inevitable that mining operations would result in some damage to the environment. In fact, it would be naïve on anyone's part to think that no such environmental problems would be created. Studies have shown that mining operations, whether surface or underground affect the environment in more ways than one. Some of these mining-related environmental problems include the emission of dust and toxic materials such as arsenic and sulphur dioxide into the atmosphere. Also the use and discharge of cyanide into the streams and rivers that serve local mining communities is another source of pollution. But the most obvious environmental degradation, as far as our village-folks in the mining areas are concerned, is the devastation of forests and farmlands and the attendant erosion of topsoils. The unorthodox activities of the galamsey operators are also another source of environmental concern.

Ladies and gentlemen, I am sure that many of you are wondering as to what the government has been doing to bring about proper environmental management. The government's position is that through judicious intervention it is possible to control the negative environmental impact of mining operations such that sustainable development is not impeded. The government is also conscious of its responsibility to ensure that the environment is preserved for future generations of Ghanaians. In recognition of these obligations, the NDC government has recently seen to the enactment of laws to ensure sound environmental management. I am referring here to the passage of the Environmental Protection Agency Act, 1994 (Act 490) a little over two years ago. Obviously, the ambit of this law goes beyond controlling only mining-related environmental degradation. Although, the EPA Act 490 of 1994 is broadly designed to deal with all areas of environmental concerns, it does provide sufficient legal framework for tackling environmental problems issuing from the mining industry.

Prior to the enactment of the EPA Act, the government had also caused to be prepared a comprehensive document known as the National Environmental Action Plan (NEAP). This document was published in April 1994 and, alongside the EPA Act, it defines the scope of environmental intervention in the country. It may interest you to know that one of the most important functions that the Environmental Protection Agency is required to discharge under the provisions of the EPA Act and the NEAP document is the prescription of "standards and guidelines relating to the pollution of air, water, land and other forms of environmental pollution including the discharge of wastes and the control of toxic substances". I am happy to observe that following two years of field investigations and desk-bound analyses the Environmental Protection Agency has recently completed the formulation of the requisite general and sector specific effluent guidelines for industries operating in the country. My information
that these guidelines were published at the beginning of last February in the national media for comments from the affected industries as well as the general public.

It is also pertinent to mention here that the government's environmental policy places emphasis on prevention rather than cure. In line with this policy, the Environmental Protection Agency is also charged with the responsibility of requiring industrialists wishing to set up new industries, the operations of which are likely to impact adversely on the environment to submit environmental impact assessment before they could be licensed to operate. The object of this requirement is to sensitize industrialists to their environmental obligations before they embark on their operations.

Beyond governmental intervention, it is gratifying to learn that many of the mining concerns have, on their own initiative, made attempts to mitigate some of the environmental problems resulting from their operations. The government is aware that some of these companies have of late embarked on land revegetation exercises at their mining sites. Other measures embarked on include the installation of scrubbers to remove potential pollutants, which hitherto were discharged directly into the atmosphere. It is also a credit to some of the mining companies that they have taken it upon themselves to sink boreholes to provide inhabitants in their areas of operation with wholesome potable water.

Mr. Chairman, while the government notes with satisfaction these various attempts being made by the mining companies to improve the environment, these initiatives should not lead us into complacency that all is well with our environmental management. A lot more needs to be done. If this was not so, this symposium would have been unnecessary. The Environmental Protection Agency must be vigilant and monitor and enforce the established guidelines, standards, and regulations. There is no gainsaying that if the EPA relaxes in its monitoring and enforcement efforts, some of the mining companies would be sloppy in their environmental management practices.

Unfortunately, the EPA does not have, at the moment, all the resources, including human and material, to carry out its tasks effectively. The universities, however, appear to be relatively well equipped. I would therefore charge the universities to explore seriously the possibility of collaborating with the EPA in carrying out research into and even monitoring mining-related environmental management. I believe it would also be in the interest of the mining companies to consider setting up a common fund to support the collaborative efforts of the EPA and the Universities.

Finally, Mr. Chairman, I wish to add my voice to the vice-chancellor's earlier request to the organisers to ensure that the proceedings of this symposium are published, with the view to disseminating the recommendations. One of the criticisms usually levelled, rightly or wrongly, against the universities in this country is the inability to disseminate their research findings. I trust that the organisers would act to prove the critics wrong, as far as the proceedings of this symposium are concerned. And now let me place on record the government's appreciation to the organisers for the initiative in organising this event.

At this juncture, Mr. Chairman, ladies and gentlemen, I have the pleasure of declaring this symposium officially open. I wish you all happy deliberations.

Thank you.
PART II: PLENARY PRESENTATIONS

THE ROLE OF THE MINING INDUSTRY IN THE ECONOMY OF GHANA

E. Adadey
Minerals Commission, P.O. BOX M248, Accra, Ghana

ABSTRACT

Over the past ten years Ghana has been successful in attracting investment into its mineral sector. Since 1985 over US$2 billion have been invested in the sector for expansion and rehabilitation of existing mines, mineral exploration and mine establishment. Most of this investment has been made in gold mining and exploration.

The importance of the mining industry to the economy of the country cannot be over emphasised having overtaken cocoa as the largest foreign exchange earner in 1991. Mineral exports account for 40% of the country's total gross foreign exchange earnings. This percentage has grown from about 20 in 1988 and is still growing. The large scale mines employ over 20,000 workers whereas over twice that number is engaged in small scale artisanal production of gold and diamonds. The sector also contributes to the internal economy through the payment of corporate taxes, royalties and other fiscal charges.

This paper discusses the performance of the industry since 1983 when the ERP was launched in Ghana, and the policies that were instituted to promote and accelerate growth. It also highlights the present as well as the future role of industry in the national economy.

INTRODUCTION

Ghana's mineral endowment

Ghana is well endowed with substantial mineral resources, the major ones being gold, diamonds, manganese and bauxite. Gold is the predominant mineral produced in the country, accounting for about 80% of all mineral revenues.

Ghana produces gold from the following sources.

1. Birimian rocks with their associate granitoids.
2. The Tarkwaian rocks.
3. Alluvial derivatives of the Birimian and Tarkwaian rocks.
4. Gold mine dumps and mill tailings.

Four major bauxite deposits exist in the Sefwi-Bekwai, Aya-Nyinahin, Kibi and Mount Ejuanema areas. The total potential reserves of these deposits (44% Al₂O₃ alumina content) is estimated at 520 million tonnes. The Birim, Bonsa and Jimi valleys constitute the main diamond bearing areas in the country. The main manganese deposits in Ghana are found at Nsuta, Salman (Essamang), Dixcove and Daboasi areas in the Western Region.

Salt (solar) is produced along the coastal areas of the country, (e.g. Ada, Elmina, Apam) where the potential for major commercial production beyond the present levels exists. In the Ada Songor area alone it is planned to put in infrastructure that will enable production to increase from its present 80,000 tonnes to 1,000,000 tonnes.
Apart from these minerals, the country is endowed with unexploited deposits of iron ore, limestone, brown clays, kaolin, mica, columbite tantalite, feldspar, silica sands and quartz. There are minor deposits of ilmenite, magnetite and rutile. Some of these industrial minerals - e.g. brown clays, kaolin and silica sands are being exploited on a small scale to provide raw materials to local industries in ceramic, paint and glass manufacturing. There is tremendous potential for growth in this area of the mining industry. Indeed recent promotional efforts have been to encourage the development of the country's industrial minerals as they have enormous potential for contributing to the economy.

HISTORICAL PERSPECTIVE OF THE SECTOR

Ghana has a long history of mining. Gold was mined and traded by the indigenous people long before the arrival of Europeans in 1471. Since then gold has continued to be the predominant mineral produced in the country.

It is estimated that over 14.4 million ounces of gold were produced between 1471 - 1880. Production increased steadily as more mines went on stream and reached a record peak of over 960,000 ounces in 1960 representing 2.5% of the free world's annual production. Production started to decline in the late 1960's and by 1983 only 280,000 ounces were produced.

Diamond mining plays a significant role in the mineral industry. Diamonds were discovered in the Birim valley in the Eastern Region in 1920 and by 1925, Consolidated African Selection Trust had opened a mechanised alluvial operation at Akwatia. Small scale miners (mostly indigenous people) entered the industry as soon as the mineral was discovered and helped to boost production. By 1958 the small scale miners had stepped up production to 1.8 million carats as compared to the 1.2 million carats from the mechanised mines.

Between 1969 and 1972 Ghana was the fourth largest producer of diamonds with an annual production of 2.5 million carats. Production peaked at 3.4 million carats in 1967 and by 1983 had declined to only 450,000 carats.

The manganese mine at Nsuta in the Western Region commenced operations in 1916 with a modest production of 4,000 tons per annum. By 1957 production had reached 730,000 tons per annum, but this figure declined to about 170,000 tons in 1983.

The bauxite mine at Awaso was opened in 1940 to provide raw materials for her majesty's war machinery. Production surged on steadily and in 1974, the mine produced over 383,000 tonnes per annum but this figure declined to just over 53,000 tons in 1983.

Inspite of its well known mineral potential, the country did not record the opening of any new mines or the expansion of existing ones after the 1940s. While in 1936 there were 30 operating gold mines, by 1983 only 4 were left. And indeed in the period between 1960 and 1983 production of all minerals declined dramatically. Studies of the industry have identified the following factors as the main causes of the decline:

- General macro-economic stagnation, including high rates of inflation, ever-increasing budget deficits, misalignment of various prices, severe shortages of foreign exchange, bureaucratic and tedious import licensing procedures, etc.
- Lack of a clearly formulated Mineral Policy in terms of an appropriate legal and institutional framework by successive Governments.
- The over-valued local currency, the cedi, which led to rising local costs forced mining companies to rely on bank overdrafts and Government subsidies to meet their operating costs.
- A fiscal regime characterised by high front-end charges, low capital allowances, etc.
• No clearly laid out arrangement for transfer of dividends, loan capital and expatriate emoluments.
• Deterioration of basic infrastructure such as roads, ports, telecommunications and electricity but in particular the near-collapse of the railway system and its negative effect on manganese and bauxite haulage.
• The granting of mineral rights was characterised by redtapism.

Present State of Industry:

In an effort to reverse the steep deterioration in the national economy as a whole, the Government in 1983 launched its programme of economic reforms, namely, the Economic Recovery Programme (ERP). Basically the reform package was designed to realign relative prices in favour of the productive sectors in order to increase productivity, improve the financial position of the public sector and to encourage the expansion of private investments. In order to achieve these, the Government addressed some key areas:

• priority rehabilitation of basic physical infrastructure (i.e. roads, railways, ports etc.),
• reduction in budget deficits in order to check soaring inflation;
• adoption of flexible and realistic exchange rate policy.

Because of its significant contribution to the economy and also its enormous potential, the mining sector was one of the areas that received the greatest attention under the programme. The basic policy objective for the mining sector in the short term, was to halt the decline in production by assisting the existing mines to obtain international funding for the purpose of rehabilitating equipment and machinery, up-grading mine infrastructure and improving management practices in the state owned mines.

In the long term, the objective was to institute those economic and legal measures whose effect would be to attract investments into exploration for new mining ventures and encourage expansion in existing mines and to privatize the state-owned mines. To achieve the long term objective of attracting new investments into the mining industry, a new mineral and mining law (PNDCL 153) was promulgated in 1986, and regulatory institutions responsible for development in the sector were strengthened or set up. A key institution was the Minerals Commission which was to provide as close to a one-stop-investment centre as possible. The law provided for the streamlining of mineral right licensing procedures, and a favourable fiscal and financial regime.

The financial provisions in the law are:

i) A royalty rate which varies from a minimum of 3% to a maximum of 12% with formula to determine the applicable rate (which for all practical purposes would remain close to the 3% minimum rate).
ii) A corporate tax rate which used to be 45% but has now been lowered to 35%, together with an additional profit tax provision.
iii) Accelerated depreciation of capital, namely, 75% in the year of investment and 50% in subsequent years on a declining balance basis, with a loss - carry forward provision. In addition there is an investment allowance of 5%. This provision was preferred to previous tax holiday incentives because the timing of tax payment is determined by the success or otherwise of the project.
iv) Equipment, machinery and accessories which are imported for mining operations are exempted from the payment of customs and import duties.
v) Expenditure on reconnaissance and prospecting operations may be capitalized after a commercial find.
vi) Mining companies are allowed to retain a portion of their export revenues in an off-shore account for the servicing of loans, acquisition of equipment, spare parts, raw materials for production, payment of expatriate salaries and the payment of dividends.

Next to the institution of the flexible exchange rate system which restored viability to existing mines, the fiscal package as outlined above, has been largely responsible for renewed investment in the sector - particularly in gold.

As a result of the measures outlined as well as the relative political stability and inflows of investment into the sector, minerals production and contribution to the gross foreign exchange earnings of the economy have been significant. More than U$2 billion has been invested in the sector alone since 1985. And as at February 1, 1997, 127 local and 98 foreign mining companies including some major international companies have been issued with prospecting and mining licenses mainly for gold.

NEW POLICY INITIATIVES

The implementation of these policies and the creation of a favourable legal and institutional frame-work have indeed led to some success, through increased investments, being chalked by the sector. However, the increased investment has been largely in gold, while the other minerals received little or no attention. Furthermore, these successes would not have been possible without the existence of adequate mineral resource data, to start with. But there is now very little left of the areas on which adequate information exists. Environmental practices in the existing mines have also not been completely acceptable. In view of these perceived inadequacies of the sector, the policy objectives of Government have been redirected, among others, to:

- ensure exploitation of minerals on an environmentally sustainable basis;
- promote diversification of minerals exploited;
- ensure that basic data on new areas is obtained and made available to investors in order to reduce risk of investment in exploration over those areas; and
- promote the full integration of the mining sector in the whole economy.

Government has therefore put in place plans to implement projects to see to the fulfillment of these objectives, a number of which are under a World Bank credit to the mining sector (under Mining Sector Development and Environment Project under World Bank Credit # 2743 - GH).

Present Role of the Sector

(i) Foreign exchange Earnings

The mining industry in Ghana has seen a phenomenal growth during the last ten years. Table 1 shows that all the minerals enjoyed a fairly buoyant period of growth in production. Gold, however, registered the highest and most dramatic growth. Again as table 2 shows the mineral industry is now the single largest foreign exchange earner; mineral exports have accounted for about 40% of the country's total gross foreign exchange earnings since 1992 compared to about 20% in the 1980's; gold being the highest contributor. Foreign exchange earnings from minerals have increased from $107.9 million in 1985 to $682.2 million in 1995.

(ii) Revenue Generation

The industry contributes to the internal economy through the payment of corporate taxes, royalties and income taxes on salaries and wages of employees and dividends declared.
Table 3 shows the contribution of the mining industry in the form of corporate tax and royalties to Government revenues.

(iii) Employment

The large-scale mines employ over 20,000 workers whilst over twice that number is in small scale artisanal production of gold and diamonds. Additional benefit includes manpower training.

(iv) Development of Mining Communities

Government has instituted a policy by which part of mineral royalties paid to central government are recycled back to the mining communities to be used for general development projects and for addressing some of the degradations the environs of mines suffer. A Minerals Development Fund, constituting 20% of total royalties collected from mining concerns has been put in place; it is used to improve conditions in the mining areas and to fund part of the budgets of the sector institutions.

### TABLE 1: GHANA MINERALS PRODUCTION (1980-1996)

<table>
<thead>
<tr>
<th>Year</th>
<th>Gold (Ounces)</th>
<th>Diamonds (Carats)</th>
<th>Bauxite (M.T.)</th>
<th>Manganese (M.T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>342,904</td>
<td>1,148,678</td>
<td>196,892</td>
<td>240,006</td>
</tr>
<tr>
<td>1981</td>
<td>338,042</td>
<td>836,020</td>
<td>156,769</td>
<td>197,436</td>
</tr>
<tr>
<td>1982</td>
<td>337,754</td>
<td>682,415</td>
<td>92,954</td>
<td>132,232</td>
</tr>
<tr>
<td>1983</td>
<td>285,291</td>
<td>336,309</td>
<td>82,310</td>
<td>175,288</td>
</tr>
<tr>
<td>1984</td>
<td>282,299</td>
<td>341,978</td>
<td>44,169</td>
<td>267,996</td>
</tr>
<tr>
<td>1985</td>
<td>299,615</td>
<td>636,127</td>
<td>124,453</td>
<td>357,270</td>
</tr>
<tr>
<td>1986</td>
<td>287,124</td>
<td>560,538</td>
<td>226,461</td>
<td>262,900</td>
</tr>
<tr>
<td>1987</td>
<td>328,926</td>
<td>440,681</td>
<td>201,483</td>
<td>242,410</td>
</tr>
<tr>
<td>1988</td>
<td>373,937</td>
<td>259,358</td>
<td>299,939</td>
<td>284,911</td>
</tr>
<tr>
<td>1989</td>
<td>429,476</td>
<td>285,636</td>
<td>374,646</td>
<td>273,993</td>
</tr>
<tr>
<td>1990</td>
<td>541,408</td>
<td>636,503</td>
<td>368,659</td>
<td>246,869</td>
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<tr>
<td>1991</td>
<td>845,908</td>
<td>687,736</td>
<td>324,313</td>
<td>311,824</td>
</tr>
<tr>
<td>1992</td>
<td>998,195</td>
<td>656,421</td>
<td>399,155</td>
<td>276,019</td>
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<tr>
<td>1993</td>
<td>1,261,424</td>
<td>590,842</td>
<td>364,641</td>
<td>295,296</td>
</tr>
<tr>
<td>1994</td>
<td>1,430,845</td>
<td>757,991</td>
<td>451,802</td>
<td>238,429</td>
</tr>
<tr>
<td>1995</td>
<td>1,708,531</td>
<td>631,708</td>
<td>530,389</td>
<td>186,901</td>
</tr>
<tr>
<td>1996p</td>
<td>1,606,880</td>
<td>271,493</td>
<td>383,370</td>
<td>300,000</td>
</tr>
</tbody>
</table>

1996p - Preliminary figures only; gold and diamond totals exclude small-scale production figures.
CONCLUSION

The mining sector undoubtedly contributes significantly to the economy of the country. However, viewed against its enormous potential, the sector capacity is yet to reach its maximum - it has a wide scope for expansion in the areas of diversification, value addition, fabrication of mining equipment, accessories and spare parts.

Apart from ensuring the full integration of mining activities, the enumerated areas would not only help to increase the sector's contribution to the G.D.P. but also make it a greater contributor to net foreign exchange earnings.
CURRENT ENVIRONMENTAL PRACTICE IN THE MINING INDUSTRY

G.Y. Agra,
Environmental Coordinator, Teberebie Goldfields Ltd-Tarkwa, Ghana

ON BEHALF OF THE CHAMBER OF MINES

Before I begin, I must thank the organisers of this seminar for extending an invitation to me through my employer, Teberebie Goldfields Limited (TGL) under the umbrella of the Chamber of Mines to give a talk on the Current Environmental Practice in the Mining Industry (Ghana) which will, so to speak, give a general overview of the mining industry and then highlight current environmental practices.

BACKGROUND TO THE GHANAIAN MINING INDUSTRY

GHANA'S MINERAL WEALTH

Ghana before independence, was called the GOLD COAST due to having huge deposits of gold and other minerals like manganese, iron, diamond, bauxite, etc. The first 'Gold Rush' was started by a French trader, Mr. Pierre Bonnet, who formed a company with several concessions in Ashanti. Several others also acquired concessions and established mines near Tarkwa and Prestea but due to high cost of operation, despite the richness of the ore, had to close down.

TYPES OF MINERALS AND MINING METHODS EMPLOYED.

Mining as an organised industry, however begun later part of the 19th century and was mostly gold production. There were reported cases of iron and diamond extraction also in certain areas of the country. A significant development that occurred during this period was the establishment of the Ashanti Goldfields Corporation in 1895 by a British trader. The highest production of gold of 915,000 ounces ever recorded in the country was in 1960 produced by eleven mines at that time. Three other mines not mining gold were African Manganese Company at Nsuta, British Aluminium Company of Awaso, mining bauxite, and Consolidated African Selection Trust mining diamonds. The mining sector has since 1960 and until 1983, experienced a steady decline. It is regrettable to note that this decline in production was not due to lack of available ore for mining but was mainly due to some obvious technical and administrative factors.

The above resulted in the deterioration of equipment and decline in skills. To avoid the closure of the many gold mines at Tarkwa and nearby towns which would have resulted in social upheaval, the then Government decided to acquire and run the gold mines other than Ashanti Goldfields Corporation at Obuasi which was privately owned by a British Company.

The State Gold Mining Corporation's (SGMC) gold mines at Tarkwa, Prestea and Konongo which were all underground operations and the alluvial dredging at Dunkwa continued to work at a loss, while the Ashanti Goldfields Corporation maintained its profitability. Against the background of no comprehensive regulatory mechanism to control mining operations, mining companies neglected the environmental consequences of their operations. Industrial developments, including mining, have until recently been undertaken at the expense of the environment.
OVERSIGHT OF THE MINING INDUSTRY

The introduction of the Economic Recovery Programme in April 1983 by the PNDC was designed to rehabilitate the economy and reverse the economic deterioration suffered over the past decade and a half. It is gratifying to note that the Economic Recovery Programme has restored the industry to a general state of profitability since the ERP generally introduced structural changes into the Ghanaian economy. With regards to the mining sector, there was the introduction of deregulatory measures. The effect has been the removal of most of the structural and organisational problems mentioned earlier and certain specified measures were taken to address the problems related to investments in Mining.

1) Legislative arrangements were put in place aimed at promoting new investment in the sector.

2) Regulatory instructions were straightened to ensure a smooth and orderly development of the sector.

3) The Minerals Commission was set up in 1986 under the Mineral and Mining Law of 1986 as amended by the Minerals Act of 1993:
   a) For ensuring that mining operations are carried out in an environmentally sustainable manner,
   b) To have overall responsibility for recommending mineral policy,
   c) Advising government on mineral matters,
   d) Reviewing mining sector activity and
   e) Promoting development among others.

4) All other associated bodies like the Mines Department,
   a) For inspecting the mines to ensure health and safety conditions and
   b) To enforce compliance with the licensing and leasing provisions of the Minerals and Mining Law and
   c) For environmental monitoring and enforcement.

The Geological Survey Department and the Lands Commission were strengthened and restructured to meet the current demands of a revived industry.

5) Ghana's national mineral policy

National Mineral Policy was formulated to reorganise activities in the mining sector.

6) Mining regulation 1970,

The Mining Regulations were to be completely overhauled since they were found to be obsolete and a dis-incentive to investment in the sector. Final regulations are yet to be published.

THE MINERALS AND MINING LAW, 1986 PNDCL 153

Empowers the Minister of Mines to enact environmental regulations. Draft Mining and Environmental Regulations are already underway and the Attorney Generals Department has produced a first draft of Mining (Environmental) Regulations.

UST/IDRC '97 Symposium on the Mining Industry and the Environment, UST, Kumasi, Ghana
This law made mining business very attractive by providing a broad legal framework for the mining industry; risk and uncertainty for potential investors were reduced. The law also provided financial concessions which made mining very profitable for both the investors and the Government. The introduction of this law has increased activities in the sector.

INTERNATIONAL ORGANISATION

With the assistance of the Government, International Organisations and lending institutions have since taken part in the organisation of the mining sector by providing financial support for the rehabilitation and expansion programmes of old mining companies as well as taken equity shares in some newly established ones. The International Development Agency (IDA), an affiliate of the World Bank has been actively involved in the rehabilitation of the gold industry under its Export Rehabilitation Project and Export Rehabilitation Technical Assistance Project for Ghana. In 1985, International Finance Corporation (IFC), also an affiliate of the World Bank, provided a loan facility of US $55 million in support of AGC's expansion and upgrading projects.

The New Mining Law explicitly set out the various licenses that should cover various aspects of the Mining industry.

DEVELOPMENT OF MINING IN GHANA AFTER THE INTRODUCTION OF THE ERP

ESTABLISHMENT OF NEW MINING COMPANIES

Many new mining companies were established since the late 1980, but the ownership varied from Company to Company; the State owned Corporations and joint ventures, the Government of Ghana by law has an automatic stake of 10% in all mining ventures without any financial obligation and has the option to take further 20% share.

Since 1983, a considerable number of prospecting licenses have been granted, to Ghanaian and foreign companies. To be precise, since 1988, the new gold mines which were established and are producing include, Teberebie Goldfields Ltd. (TGL) at Tarkwa; Billiton Bogosu Gold Ltd. (BBG), Bogosu; Ghana Australia Goldfields Ltd. (GAG), Tarkwa; Bonte Gold Mines Ltd., Bonte; Prestea Sankofa Gold Ltd., Prestea, and all operate as surface workings.

The SGMC Mines have all been divested to other companies and are mostly underground and surface operations. Other gold mining companies like Aboso Goldfields Ltd. etc., are expected to go into production within the shortest possible time and add up to constitute a formidable team with the old mines like the AGC.(Gh), under the umbrella of the Chamber of Mines.

Besides, ancillary industries have sprung up, and include SGS Laboratory and Environment Services (Ghana) Ltd., Analabs (Ghana) Ltd., ICI Explosives (Gh) Ltd., Ashanti Goldfields Corporation Ltd. (AGC) and MINPROC, in a Joint venture are producing limestone and limestone products to meet the needs of the mining and construction industries.

MINING AND THE ENVIRONMENT

Different types of mining are carried out at the various mines in the extracting of minerals but the operations generally involve the following activities:

- Removal of overburdens and ore blasting;
- Loading and hauling of ore to the processing plant;
- Beneficiation (the processing of ore);
- Disposal of waste generated from the ore processing;
- Drainage of mine area and discharge of mine waters;
- Extensive support facilities to such transportation network, offices and equipment shops and other utilities required for the efficient operation.

Types of mining employed in Ghana are, Surface mining, Underground mining and small-scale mining. Even though Dredging has been used in extraction of alluvial gold but it is not so widespread.

SURFACE MINING

The method includes quarries, open pits, strip and contour mines and mountain top removal. It usually covers few hectares to several square kilometres. Mining involves removal of overburden materials to waste disposal area, ore blasting, loading and hauling to the processing plant. The operations may result in total disruption of the project area with large open pits or quarry and extensive overburden piles. Because of the low-grade nature of the ore, heap-leaching technology is employed by some of the companies to recover the gold. AGC, TGL, CLUFF Mining and GAG use heap-leaching technology, either alone or in conjunction with milling operation.

UNDERGROUND MINING

This is highly complex operation involving working underneath thick overburdens connected to the outside by shafts and passageways. Equipment used ranges from relatively simple to highly automated machinery. Excavation is mostly underground and requires the use of blasting equipment.

Removal and processing of ores require the use of diesel or electric powered mining and hauling equipment and relatively skilled force depending on the size of operation.

SMALL SCALE MINING

Another development of the mining industry is the promulgation of legislation which regularises the conduct of mining activities of small scale operators for gold and diamonds, and is referred to as artisanal mining undertaken on individual basis or in groups. It employs the open cast method of mining. The processes depend on the local conditions, but consists of winnowing (wind fanning), water panning or sluicing and relying mostly on human power. Concentrates produced are hand sorted or smelted or amalgamated in mercury. Areas worked are environmentally degraded.

MEMBERSHIP OF THE CHAMBER OF MINES

The membership of the Chamber of Mines has also of consequence increased considerably and poses some challenges which relate to labour and development, the imparting of new technological skills and the problem of the Environment. In this connection it is pertinent to tackle the question of the Environment, and see what alternative provisions are made by the same Government who is interested in making mining the number one foreign exchange earner. Aware of the effect of mining operations on the environment, the government has instituted the EPC which put in place certain regulatory provisions as follows.

In March 1988, the government of Ghana initiated a major effort to put environmental issues on the priority agenda which led to preparation of a strategy to address the key issues relating to the protection of the environment and better management of renewable and non-renewable resources. The objective of what has become known as the Environmental Action Plan which defines a set of policy actions, related investments, institutional strengthening activities to make Ghana's development strategy more environmentally sustainable. The economic and social development will depend wholly on proper and responsible management of the natural resources base and the environment in general. For this reason,
the EPC, now the EPA, has introduced guidelines as to the management of the environment which in part is asking all industries to submit the relevant requirements to them for permits before certain projects could be started and managed. As part of the implementation of Ghana's Environmental Action plan, the EPA is in the process of developing guidelines, standards, regulations etc, to ensure sound environmental management in the country. The EPA has now completed the formulation of general and sector specified effluent guidelines for industries after two years of field investigation in Ghana, comprehensive desk top research and wide consultations with stake holders. Publication of some of these guidelines on sector specific effluent quality guidelines for discharges into natural water bodies, also ambient noise level and ambient air showing maximum permissible levels have started appearing in the daily papers for study and the necessary action.

ENVIRONMENTAL PRACTICES

In order to sustain and build on its contribution to the development of Ghana, the mining industry is seriously addressing the key development of environmental questions, particularly the relationship of mining and metallurgy to sustainable development. A good deal of attention is now being paid to health and safety at the workplace and the local community, and loss control strategies are being put in place because environmental problems from mining, may be contributory to environmental pollution despite being number one foreign exchange earner now. It is therefore not surprising that a lot of concern is being shown about the environmental impact of the increasing activities of the minerals industry, and hence, this symposium at the campus of the University of Science and Technology in Kumasi.

Since 1989, it has been the requirement in Ghana to subject all major development projects to the Environmental Impact Assessment(EIA) process, and mining projects which cover concession area of more than 25 acres is required to submit an EIA to Environmental Protection Agency(EPA), because the National Environmental Policy aims at a sound management of resources and the environment and to avoid any exploitation of these resources from damage to the environment.

Environmental Impact Assessment (EIA)

This is an Environmental Permitting Prerequisite and major environmental management tool, where all projects are screened and evaluated.

Purpose of the EIA

What is the purpose of the EIA?

- To support the goals of environmental management and sustainable development.
- To integrate environmental management and economic decisions at the earliest stages of planning and undertaking etc.
- To predict the consequences of a proposed project from the environmental, social, economic and cultural perspective and to develop plans to mitigate any adverse impacts.
- To provide avenues for the involvement of the public, etc. in the assessment and review of proposed undertakings.

Registration of the Project and Screening.

Every undertaking/project that may have an impact on the environment must register with the EPA and with the assistance from a cross sectoral technical committee will make a decision as to whether there is an objection or not to the undertaking, for which a preliminary EIS will be required.
Scoping

If there are indications of significant adverse environmental impact which may result from the undertaking, the proponent will need to submit Environmental Impact Statement (EIS) where thorough fact finding evaluation is undertaken involving the interested and affected parties, to determine how their concerns will be addressed.

Public Hearing

If a strong public concern over the project is indicated and impacts are extensive and far reaching, EPA shall hold public hearing relating to the assessment and the report is made public. Aboso Goldfields Ltd. (Damang Gold Mines) and Goldfields (Ghana) Ltd., Tarkwa, held such public hearing last year to iron out public concerns. The process then may extend beyond the normal 90-day period for processing an application. When it is found to be acceptable, the EIS is finalised and submitted to the EPA and Provisional Environmental Permit issued. On the other hand if the EIS is not accepted, a re-submission of a revised statement will be required.

This Permit is the initial environmental approval that allows any proposed development to commence on environmental grounds and it is effective for a period of 18 months and this must be regularised within a time span of 24 months for an Environmental Permit, depending upon satisfactory commencement of development operation and performance, observance of relevant permitting/approval conditions and compliance to nominated mitigation, etc, outlined in the EIA.

Environmental Management Plans (EMP)

After a year of operation an EMP is submitted in every two years. This is a five year management plan. Also an Annual Environmental Report to the EPA is required of all mining companies. The foregoing procedure has been put in place to safeguard the environment so that the public has nothing to fear since they are supposed to be involved from the start to finish of the issue of the Environmental Permit, for which all Mining Companies are supposed to comply before this Permit is issued.

DEMC

District Environmental Management Committees play very important roles in this exercise since they are supposed to know the localities and the concerns better and offer constructive suggestions.

The Chamber of Mines

Mining activities have increased tremendously in the recent past due to the political stability, social and economic climate. We are actually witnessing the development of new ventures coupled with new technologies. Recognising that mining has become one of the most dominant institution of Ghana, it is clear that mining techniques should be restructured in bringing about the changes necessary to reverse environmental and social degradation experienced during the past when the mining companies were free to treat the environment the way they liked and have left it in a mess. Look at the scenes at Prestea, Tarkwa, Obuasi, Bibiani and Dunkwa scattered all over with signs of the degraded environment.

The Chamber notes with pride that the environmental impact of the mining operations has in recent years received greater attention from mining industry, governmental agencies, the local communities and international lending institutions. The attitude and behaviour of the mining industries have changed from that of neglect to that of caring.
What then is the driving force behind this change in corporate environmental attitude and behaviour? It is probably because, the regulatory environment within which the mining companies have got to operate is surrounded, encompassed and controlled by:

(a) The Governmental agencies armed with Laws and Regulations, empowered by The Environmental Protection Agency Act 490, 1994, to oversee the enforcement, if it appears to the Agency that there is a threat to the environment to take such steps to prevent or stop the activities. The penalties are quite severe and may include terms of imprisonment. They have the power to ensure compliance and to use the necessary force to ensure compliance against the laws and regulations of the Act.

(b) Financial Institutions with stringent environmental conditions attached to loans which insists that the Companies shall maintain all registered permits, licenses, certificates and approval relating to:

(i) air emissions,
(ii) discharges to surface or ground water,
(iii) noise emissions,
(iv) solid or liquid waste disposal,
(v) the use, generation, storage, transportation or disposal of toxic or hazardous substances or wastes, or
(vi) other environmental health or safety matters.

The Financial institutions insist that the Companies shall carry out the projects and operate the Mines in compliance with the World Bank Standards, provided that failure to comply shall not be a breach of this provision. The Financial Institution's regards to the environment is more stringent and demanding on the companies looking for funding and if the company does not satisfy the environmental conditions, will be liable to forfeiture of the financial assistance.

(c) Local Community Pressures: There is one important aspect of mining which we believe is equally important, that is improving public awareness of environment. People are too arbitrary in our measurement and perception of the environment, too beholden to early prejudices and too easily manipulated by the exaggeration of mining and the environment. The danger is cumulative because people are fed on random information of deceit based upon misleading criteria and tend to lose over a period not only our discernment but our confidence in our ability to set intelligent appraisal of what mining and the environment are about. Since people are deceived into believing only the bad side of mining, certain pressures are also made to bear on the Mining Industry. The necessary change that needs to be wrought is to change this perception through proper education and direction like the symposium currently in session.

(d) Other organisations like the

(i) UNDP which stands for poverty elimination, job creation, environmental regeneration and the advancement of all people.

(ii) The UNEP, saddled with the task of ensuring that the air is clean, the forests and ecosystem are safe, and that human and the quality of life are protected from environmental degradation.

(iii) The UN conference on the Human Environment in Stockholm in 1972
(iv) The Earth Summit in Rio de Janeiro in 1992, which brought a major turning point in environmental history because it agreed on an elaborated plan of action to prevent the ecological degradation of the whole world.

Therefore in a nutshell, the awareness, the pressures and the provisions outlined above are bound to change the attitude of the Mining Industry so that this social responsibility of the environment is not neglected as was the case before the ERP. The Mining Industry now recognises that to resolve the environmental problems associated with mining, it is necessary to involve the local inhabitants, be sensitive to the tradition and culture of the people, and develop the locals into understanding what the companies can do to make or undo the environment by introducing better ways of mining. Our greatest challenge is not just cleaning the damage to the environment but prevent pollution in the first place.

Negative Impact of Mining

The main problems encountered with mining include land form alteration and associated sediment run-offs, possible soil degradation, water and air quality changes, chemical pollution of rivers and water bodies, forest and vegetation cover destruction, etc.

To combat these problems, the companies are using superior plants designs, adopting good operational practices and rehabilitation procedures that have been developed for similar operations elsewhere in the world and thus suitably adapted which wholly prevent or reduce to an acceptable minimum level, other potential environmental impacts.

Documents also submitted to the EPA normally presented fuller and more detailed assessment of the projects as specifically required by the Draft Ghana's Mining and Environmental Guidelines prepared by the Minerals Commission. In adopting the above approach, the Mining Industry has the firm belief that:

(a) they are and will fully comply with all legal obligations as required by the Minerals and Mining Law 1988.

(b) they are and will fully comply with the provision of the current Draft Ghana's Mining and Environmental Guidelines (DGMEG) and any Mining Environmental Regulations that will be issued at a later date.

(c) they are adopting an interpretation of the DGMEG which will provide a true and accurate assessment of the environmental influence of the developments on physical, chemical, biological and social-economic characteristics of the mining area and its environs.

(d) they are maintaining the policy of operating the mining in accordance with best available technology not entailing excessive cost (BATNEEC) in regard to the overall environment in which the mine is located. For that matter, an accrual system has been established by the mining industry from the start of operations to fund reclamation work during the life of the mining and at closure for which trial re-vegetation, etc are being undertaken.

In brief therefore, the companies have developed many procedures to eliminate or mitigate any impact on the environment within and outside the concession. Since most of the companies are operating and processing low-grade ores through application and control of solution which leach or dissolve the contained gold values it is in the best interest of the companies to control and recover all solution and to eliminate any environmental impacts. By the use of this technology, no harmful by-products are created which can degrade the environment now or in future. The major part of the planning and operational
directions cover efficient use of all possible resources for us to maximise the return from these efforts, ie strong controls are in place to ensure all process solutions are contained within the closed loop heap leach system to extract gold values and utilise any reagents because, if any solution is lost the company's main objective of winning gold is defeated hence the appropriate controls which in turn protect the environment. Likewise, all chemicals, explosives, fuels, and lubricants are carefully used and handled, and ensure minimal harm to the environment We have always maintained an aggressive policy of setting our own environmental standards and controls that are equivalent to or more stringent than those legislated in most US States, Australia, UK at a time a particular system is designed and constructed.

CONCLUSIONS AND RECOMMENDATIONS

It is established that the Government has put in place adequate provisions by introducing the ERP, by providing the basic institutional, environmental and financial framework for the Mining industry and also provides the legal basis for the small-scale mining operations which hitherto were considered illegal. Efforts are also in place to control and monitor mining operations through the Minerals Commission, Environmental Protection Agency, Mines Department and other organisations. It is established that the necessary awareness has been created pertaining to the environment. The financial institutions have also been involved in ensuring improvement in the environmental performance in the mining sector, by ensuring that adequate environmental considerations are given to projects right from the identification stage through to the preparation, appraisal, negotiation, implementation and completion and evaluation stages.

The mining industry has vowed to devote to acquisition of more efficient and environmentally benign equipment taking into consideration environmental factors in the design of projects. Control and monitoring measures have been instituted with the view to reducing negative impacts of mining operation on the environment. Training and development programmes have all been established embracing safety, health and the environment. The Chamber of Mines has instituted a Sub-Committee on the Environment to deliberate on issues of the Environment and to offer suggestions affording in improvements in the mining industry.

We will therefore conclude that current environmental practices are on the right course and that the mining industry has witnessed significant changes in corporate environmental attitudes and behaviour.

For the Government to achieve the objective it is recommended that it should put in place or establish capacity for constantly reviewing the prevailing environmental regulatory framework managing and mitigating environmental impacts of mining activities in order to identify areas where the framework is lacking and needs strengthening.

I strongly remind all of us that the problems of the environment are not only that of the Mining industry but that of everybody. The mining industry's hope is that it will continue to provide the necessary resources base for the development of the country but will allow it to be free, clean and friendly at all times.

UST/IDRC '97 Symposium on the Mining Industry and the Environment, UST, Kumasi, Ghana
THE PROTECTION OF THE GHANAIAN MINING ENVIRONMENT:
THE ROLE OF LEGISLATION.

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INTRODUCTION

Mining as an industry dates back to the dawn of civilisation and the passage of time has increased rather than diminished man's dependence on minerals occurring on or in the earth. The needs and demands of modern societies and industry have further increased the reliance on minerals.

Basically an extractive industry, mining has varying impacts on the environment. Global environmental consciousness has resulted in greater concerns about the compatibility of the mining process with environmental protection. The adverse effects of unregulated mining operations on the environment are well known. They include disfiguration of the landscape and its environs, air and water pollution through smoke and other toxic emissions, leaching, siltage of river beds and underground water tables, residual mineral and metal leachates, deforestation either to create support facilities and infrastructure for the mining activity itself or through the activities of satellite population centres and settlements which inevitably spring up near the mining site in search of job opportunities.

Ghana's Environmental Action Plan cites among the major problems associated with mining, land devastation, solid waste disposal, soil degradation, water and air quality changes. Subsidence, visual intrusion and alteration of water quality arising out of pumping of underground water to the surface are associated with underground mining. Additional concerns relate to health and safety hazards including numerous accidents, gas poisoning, high temperature, humidity effects and various occupational diseases.

In late 1993, the Financial Times of London carried a frightening account of the grave environmental consequences that can occur even where mining operations are carried out under modern methods. In a feature that focused on the Sunimitville gold mine in Colorado's Rocky Mountains in the United States, the paper reported that there was a race against time to dump 6.5m tonnes of dangerous mining effluent back into the pit from which it came, before the onset of winter of 1993. It was anticipated that if this effort failed and spring arrived, the melting snow would pour 1,000 gallons a minute of water polluted with toxic metals from the waste dump that would pose a substantial threat to the streams that feed the Rio Grande River. Sunimitville was described as an epitome of "all the worst aspects of modern mining."

In early 1994, a report on the Ashanti Goldfields, carried by the Guardian newspaper painted a picture on the state of the environment of Ghana's richest mine fields as follows: 'The gold has not been kind to the mine's environment. Vast parts of the 550sq. km. area are ravaged, either by open pit mining techniques, which have turned hillsides of tropical rainforest into scarred chalky slopes or by the deadly mixture of arsenic and sulphuric acid that processing induces. With hills honeycombed to a depth of more than 5,000 feet and top soil and vegetation eroded above, Ashanti is likely to be a wilderness when the reserves run out'

Gold, diamonds, bauxite and manganese are mined in Ghana. Of these minerals, gold constitutes the most important. That importance is underscored by the fact that gold overtook cocoa as Ghana's main foreign exchange earner in 1991. It is also important to mention that it is the mining sector particularly gold, that has attracted the most investors in response to the new investment climate. Increased
An important component of the said measures is legislation which defines the boundaries within which the mining industry must operate so that compatibility will be achieved between mineral exploration and environmental protection. It is within this context that this paper seeks to examine the legislative and institutional framework for addressing environmental problems arising out of or related to the mining industry. This presentation will further examine the adequacy or otherwise of the existing framework and conclude with a look at future prospects.

THE LEGISLATIVE FRAMEWORK

Historically, mining in Ghana dates back over a century. It is therefore not surprising that as early as 1883, the Native Jurisdiction Ordinance No. 5 was passed by the colonial authorities. The Ordinance empowered chiefs and councillors to make bye-laws inter-alia, for "regulating mines and mining for gold and other minerals." The bye-laws could also cover the regulation and protection of wells, springs, water courses watering and bathing places. There were several laws that were passed during this period which contained very important provisions on the protection of the mining environment. These include, the Mining Rights Regulations of 1905 and the Minerals Ordinance of 1936. These laws were to become the precursors of the present law on mining and minerals.

MINERALS AND MINING LAW, 1986 PNDC LAW 153

The Mining and Minerals Law of 1986 PNDCL 153 represents the principal legislation providing a regulatory framework. Law 153 follows the trend of earlier legislation in vesting all minerals in the state. Government is given a right of pre-emption over all minerals.

A system of mineral rights is created in the form of a license or lease and no reconnaissance, prospecting or mining can be effected except on the basis of a mineral right. Application for minerals rights are to be made in accordance with such regulations as may be prescribed, and the application must be accompanied by statements giving inter-alia, particulars of financial and technical resources available to the applicant for his mineral operations, an estimate of the amount of money to be spent on operations and particulars of the programme of proposed operations. The value and importance of these financial requirements cannot be underestimated particularly with respect to rehabilitation.

Under Section 17(3) of the Law, copies of applications to the Minister for Mines and Energy must be forwarded to the Minerals, Lands and Forestry Commissions.

This requirement appears to be in recognition of the complex and interlocking nature of the environment which therefore warrants an integrated and holistic approach to its management through a process of consultation and comments. The clearing of large tracts of forest land especially in surface mining underscores the wisdom in involving forestry institutions, in the application approval process. It is worth noting that a holistic approach to the regulation of the mining environment involving other line Ministries, departments or agencies, has been recognised in other jurisdictions like South Africa and South Australia.

REHABILITATION

Perhaps no industrial activity scars the beauty and pristine nature of the earth's surface like mining. Most regulations on this sector have therefore considered it absolutely necessary to provide for the rehabilitation of the mined area. Increasingly, the trend is shifting towards a continuous or 'cradle-to-grave' approach rather than waiting for the process of rehabilitation to commence after the mine has
shut down. A related trend that has developed requires a deposit of a bond up-front as a form of guarantee for the rehabilitation and restoration of the mined land. In Ghana, the provisions relating to rehabilitation are not stated with the same exactitude and clarity as obtains in some other countries.

Under section 17, before a license is granted, the applicant must show evidence of adequate financial resources to carry on effective prospecting operations. The details that ought to go into the programme is not stated. However, it is reasonable to presume that environmental management during all phases of mining operations, will constitute an important component of the programme. Indeed no mining license shall be granted to an applicant unless the proposed programme of mining operation submitted by him takes proper account of environmental safety factors.

The law also provides that boreholes and excavations, where made on land to which prospecting license relates, 'must be made safe' to the satisfaction of the Chief Inspector of Mines. The phrase 'must be made safe' is vague though it could be presumed to refer to environmental safety.

**POLLUTION**

In mining, as in other industries, water constitutes an essential element in the production process. It is common knowledge that surface water, in particular rivers, suffer substantial amounts of pollution during mining operations. In Ghana, there has been some conflict between local communities and mining concerns over pollution of drinking water.

Law 153 imposes a number of obligations on the leaseholder in the exercise of his rights. These obligations have environmental implications. He is required to take all reasonable measures on or under the surface, to mine the mineral and to stack or dump any mineral or waste product in a manner approved by the Chief Inspector of Mines. Section 56 is more explicit in terms of the obligations of the leaseholder. It empowers the Minister, in the exercise of his discretion, to require a mine leaseholder to show cause within a specified time, why wasteful mining or treatment practices should not cease.

The shift in burden on the leaseholder is a progressive development and follows a growing trend, particularly in the field of environmental law, in altering the traditional position of the leaseholder with respect to legal burdens. If the leaseholder should default in discharging the burden imposed within the specified time, the Minister may order the holder to cease using such practices within a specified period with a further provision for cancellation or temporary suspensions of the lease where the wasteful practices persist.

Basically, environmental conflicts are really conflicts about land use and in the case of mining, the rights granted invariably conflict with those of the original occupiers of the land in respect of which such rights have been granted. Section 70 of Law 153 attempts to achieve a difficult balancing act by subjecting the interests of the mineral rights holder to that of any lawful occupier of the land in respect of which rights are exercised.

The holder must exercise his rights in a manner consistent with the reasonable and proper conduct of the operations concerned. The lawful occupier also retains rights to livestock, grazing and cultivation of the surface as far as these do not interfere with mineral operations.

The conditionality relating to "interference" by the occupier expose to possible difficulties, the party whose interests the law seeks to protect. It seems to me that it is almost impossible for the lawful occupier to exercise his rights without interfering with mining operations. Compensation for such unfortunate persons is provided for under which the holder of the right can provide recompense to the lawful occupier or owner in the event of disturbance of the rights of the latter.

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The most direct and dearest expression of environmental protection in Law 153 appears in Section 72. The mineral rights holder is obliged, in the exercise of such rights, to have due regard to the effects of the mining operations on the environment and requires him to take such steps as may be necessary to prevent pollution of the environment as a result of such operation.

ACCESS TO INFORMATION

The right of access to information has assumed increasing importance in matters of environmental protection. Section 79(1) of the law provides for access to information on records of mineral rights to the public. The records can be inspected subject to such conditions as may be specified and on payment of the prescribed fee, copies can be taken.

REGULATIONS

Unlike the legislative practice on mining in countries such as South Africa when most of the details are provided in a principal act, Ghanaian mining law comprises a framework with the specifics left to the discretion of the Minister to address through a legislative instrument. A number of items are listed which may be provided for in the event of the exercise of the discretion. These include the following environmental concerns:

- the restriction of prospecting operations in or near any river, dam, lake or stream, (83) (2) (e)
- preventing the pollution of waters, springs, streams, rivers or lakes, (83) (2) (r)
- the grazing of cattle or other animals on the mining area, (83) (2) (s)
- the gathering and the cutting of firewood and the cutting down and use of timber for the purpose of carrying on prospecting and mining operations, and (83) (2) (t)
- regulating the use of explosives in mineral operations. (83) (2) (v)

No regulations have been passed under Law 153 though my understanding is that there are draft proposals under consideration by the Attorney Generals Office.

MINING REGULATIONS, 1970

Running into 301 sections and covering 94 pages, the 1970 Mining Regulations is about the longest subsidiary legislation on our statute books. It is administered by the Mines Department. Among its principal environment-related provisions are the following:

- Water containing poisonous or injurious chemical solutions must be effectively fenced off and warning signs erected. In no case may water containing any injurious matter in suspension or solution be permitted to escape without it having been treated (section 44)

- Tailing used for filling worked out areas underground and the liquids draining therefrom, shall not contain a higher cyanide content than 0.005% expressed as cyanide of potassium (section 139)

- Ventilation in active underground workings shall be free from dangerous amounts of noxious impurities and shall contain sufficient oxygen to obviate danger to worker health (section 142)

- When more than 100 persons work underground on a shift, the quantity of air circulating and dust shall be determined quarterly at each working place (section 154)

Undoubtedly, the passage of time and the technological innovations that have taken place, have rendered some provisions of the law, archaic and out of tune with modern realities. This fact has been recognised and that is why the existing Regulations are undergoing a review process.
SMALL SCALE GOLD MINING LAW 1989 PNDCL 218

PNDC Law 218 introduced a licensing scheme without which no person shall engage in or undertake any small-scale gold mining operation. While the ultimate design, grant of and conditions attached to licences was conferred on the Secretary for Lands and Natural Resources, the application for licences was to be directed to the relevant district centre. The licence is subject to such conditions as may be specified.

Part II of the law deals with the operations of small-scale gold miners. The law grants discretion to the licensee to win, mine and produce gold by any effective and efficient method. Such licensee is obliged, in his operations, to observe good mining practices, health and safety rules and pay due regard to the protection of the environment. Provision is made for user compensation from the licensee to the owner of a land in respect of a designated area i.e where the licensee is a person other than the owner of the land

The use of explosives for small scale mining operations is proscribed. The rational behind this provision is clear. If such use were permitted, the operation can no longer be classified as "small scale". Sanctions such as fines and jail terms are provided for any person who undertakes any small scale gold mining operation without a licence or valid authority. The introduction of a law to specifically govern small scale gold mining activities is a recognition of the importance of this sector in the overall development of Ghana's economy. Hitherto disorganised and uncontrolled, these operations, which mostly employed the use of mercury, are now under some form of control thus offering protection to both the user and the environment.

ENVIRONMENTAL PROTECTION AGENCY ACT 1994, (ACT 490)

The Agency created by Act 490 is a successor to the previous Environmental Protection Council (NRCD 239). The Act is a product of changing times and the emergence of fresh challenges. More importantly, it is a response to the deficiencies experienced in the operations of NRCD 239.

The Act created not just an institution but also contains several provisions necessary for protecting the integrity of the environment. It is in this regard that this law has some relevance to this seminar.

Functions of Agency

1. Adviser to the Minister for Environment, Science and Technology on all aspects of the environment.
2. Co-ordinating activities and collaborating with persons or institutions on matters relating to the life-cycle of waste from generation to disposal
3. Issuance of environmental permits, pollution abatement notices, directives, procedures and warnings.
4. Prescription of standards and guidelines and the imposition and collection of environmental protection levies.
5. Conducting investigations, promoting studies, research, surveys and analyses, education and awareness creation, conducting seminars and training programmes, publication of reports and dissemination of environment-related information.

Enforcement Notice

Section 13 of Act 490 grants power to the Agency, to serve an enforcement notice to developers in respect of activities and operations that may pose a threat to human health or the environment. Under
appropriate circumstances, the notice may require immediate cessation of the offending activity. Stringent penalties are provided in the event of a breach of an enforcement notice.

ENVIRONMENTAL IMPACT ASSESSMENT (E.I.A.)

There is now global acceptance of environmental impact assessment (EIA) as an environmental management tool. In Ghana, the concept became operational through administrative directives in 1989. It was however not until 1994 that Act 490 provided the legislative basis for EIA.

The law provides that the Agency must ensure compliance with any laid down environmental impact assessment procedures in the planning and execution development projects including compliance in respect of existing projects.

The E.I.A provisions also authorise the Agency to require of project proponents submission of E.I.A's in respect of their undertaking.

ENVIRONMENTAL IMPACT ASSESSMENT PROCEDURES

Among the regulations which may be made under Act 490 is one that may provide for: "the category of undertakings, enterprises, constructions or developments in respect of which environmental impact assessment or environmental management plan is required by the Agency".

To facilitate the implementation of the law, the Agency prepared E.I.A Procedures to provide some guidance to project proponents and investors. The procedures have been fashioned into draft regulations which will go through the legislative process shortly. The Agency approves E.I.As before the Minerals Commission grants licences for mining operations to commence.

GUIDELINES

In keeping with its mandate to prescribe standards and guidelines relating to the pollution of air, water, land and other forms of environmental pollution, the Agency has prepared environmental quality guidelines for ambient noise level, ambient air and industry effluent discharges. These guidelines are currently under review. The Agency therefore plays an important role in providing the parameters and ground rules within which industry including the mining industry must operate.

GHANA'S MINING AND ENVIRONMENT GUIDELINES

As noted earlier, the regulations provided for under Law 153 are yet to be adopted. While preparatory work is proceeding however, the need to have in place some guidance was recognised. In response to this imperative, the Minerals Commission and the erstwhile Environmental Protection Council, after broad consultations, adopted the above guidelines.

The guidelines cover broadly the whole life-cycle of mining from exploration up until decommissioning and reclamation. It is jointly implemented by the EPA, Mines Department and the Minerals Commission, and under special circumstances the Forestry and Wildlife Departments, become involved.

INSTITUTIONAL STRUCTURE

The lead government agency responsible for the mining sector is the Ministry of Mines and Energy. Additionally there is the Minerals Commission and the Mines Department.
Minerals Commission

The Commission was established primarily to help formulate government policy with respect to "exploration for and exploitation of mineral resources" and to handle all public agreements relating to minerals. The Commission is also the main sectoral agency responsible for ensuring that mining operations are carried out in an environmentally sustainable manner.

Mines Department

The Mines Department has responsibility for inspecting Ghana's mines to ensure health and safety conditions and to enforce compliance with the provisions of Law 153. It is also responsible for environmental monitoring and enforcement.

RECOMMENDATIONS

This presentation has looked broadly at the existing regulatory framework to protect the mining environment. Like any human endeavour however, we are all far from achieving perfection. Some of the areas that need some attention are:

1. Speeding up the finalisation of the draft regulations and their passage into law, subject to anti-pollution provisions being secured by clearly defined standards that the industry is required to meet.

2. The deposit of bonds for rehabilitation, restoration and reclamation as part of the conditional- ities under the application procedures. The options may include payment of the full amount of the potential liability for rehabilitation to be held in trust; compulsory insurance or the establishment of a state operated rehabilitation fund.

3. "Public" participation leading to the grant of a mining licence must be improved through education and awareness programmes designed to create a 'public' that is well informed about the issues at stake.

4. Non-traditional methods of securing compliance such as fees, subsidies, charges and information disclosure must be explored.

On the issue of enforcement the social, economic, political and related factors which hinder compliance and implementation need to be given as much attention as the passage of new laws. Lack of adequate financial resources, vehicles and appropriate equipment for monitoring, personnel with the requisite training may all contribute to defeat the goals of enforcement.

CONCLUSION

For most developing countries and no less Ghana, mining will continue to play a central role in economic development. However, the exploitation of minerals ought to be carried out in a prudent and sustainable fashion and this raises the question of the role of the concept of sustainability in relation to non-renewable resources such as minerals. Within the context of minerals extraction, sustainable development means, inter-alia, conservation and prudent use in order not to significantly narrow the range of opportunities for future generations.

Sustainable development is a desired goal and to reach it government and companies must begin to implement significant institutional restructuring, incorporating principles of co-operative decision-making and shared responsibility for the management of social and environmental problems.
There is the need to move from management based on sectoral independence and isolation to integrated planning processes that recognise and accommodate the relationship between economic development decisions affecting the sector.

I leave to John Dick (Integrating Sustainable Development and Minerals Extraction: the Role of Environmental Impact Assessment in Mineral Resource Development United Nations. NY. 1992) the last words on what ought to constitute the long-term objective of benefiting from mining without jeopardising the environment. "Mining in a sustainable environment will require much greater accommodation of environmental values in mine planning and mill process design and above all the mining industry will have to embrace the concept of planning for shutdown. Mine waste characterisation and disposal, mill waste treatment and reagent recovery and the long-term control of surface water and ground-water must all be linked to eventual land reclamation from the earliest stages of mine development if the site is to be returned to a useful and productive state.

Finally, industry and government must co-operate in the rehabilitation of past mining disturbances, of areas appropriately and vividly termed in the US as "orphaned lands."
INTRODUCTION

Iduapriem Gold Mine is a surface mine located about 10 km south west of Tarkwa in the Western Region. It was commissioned in 1993, with a production target of 125,000 ounces of gold at a milling rate of 1.5 Mt per annum. The initial method of gold extraction was Carbon-in-leach (CIL), which recovers about 95% of the contained gold.

In 1996 it was determined that there was the need for an expansion of process capacity. This has resulted in the CIL plant being upgraded to a throughput of 2.7 million tonnes per annum by adding a secondary crusher, a second thickener and a screen and various other increases. In addition heap leach technology has been introduced to allow processing of lower grade ore. All these are expected to increase gold production to 160,000 ounces per annum.

The current employee level is about 530 including 23 expatriates. In addition contractors on site provide catering services and blasthole / grade control drilling. Three pits are actively mined with a fourth one in the development stage. This is expected to be brought into production by the end of the year.

As part of the technical work carried out for the mine the IFC included an environmental assessment on the impact of mining. This study resulted in the company producing an EIA and EMP. These documents detail the impact of mining in the area and how the company was going to deal with it. These plans are reviewed annually to ensure compliance and determine if remedies or mitigative measures are adhered to or need to be modified.

Organisation Structure

The environmental unit was initially under the then Technical Services Department but was transferred to the Processing Department, whilst the monitoring systems were being established for tailings monitoring and containment. It remained under that processing department until recently when life of mine plan was being finalised. This was when it was felt that the long term plans of the mine should have all environmental aspects incorporated thus reducing after thought mitigative measures. Currently the unit is under the Strategic Planning Department.

The Environmental issues have been categorised as follows:

a. Atmospheric  
b. Water  
c. Industrial/ Domestic  
d. Land rehabilitation / use  
e. Community relationship /development  
f. Audit.
1.0 ATMOSPHERIC ENVIRONMENT

1.1 Introduction

Atmospheric pollution identified in the area have been found to be mainly dust and noise. The nature of the rock type does not require the use of roasting in the gold extraction process. Therefore, there is no toxic emission of arsenic or sulphur dioxide. (The EPA has made available guidelines indicating what sort of level for all possible emission into the environment.)

1.2 Dust Monitoring

A quarterly monitoring program for respirable dust and total dust fallout has been set up. The respirable dust monitoring is carried out on personnel working in dust prone mining areas, equipment and the treatment plant. Results obtained from such analysis are presented to the various departments with recommendations to reduce the dust intake. A dust gauge to measure the total dust fallout has also been mounted at the plant site to give an idea of how much dust is generated at the site. Another gauge is mounted in an area where no mining impact is expected and will serve as a reference. Currently all analyses of dust samples are done by SGS laboratory.

1.3 Noise Monitoring

This is done on quarterly basis on equipment around the plant site and the pits. This helps to identify areas with high - noise levels so that appropriate measures are put in place to reduce its effect. The use of ear plugs or muffs are ensured by supervisors in areas where noise levels exceed 85 dB(A). Also, most equipment are air-conditioned to reduce noise and dust intake.

1.4 Blasting

This generates both noise and vibrations. It is a potential source of complaint from local inhabitants. This has led to the need to control blasting methods, i.e., use of delays, reduced area of blasting and blaring of a siren, to reduce the effect on the surrounding communities. Some monitoring was carried out in the surrounding areas, but there has always been the problem of what is the real threshold limit for buildings (wattle and daub) in those surroundings. Here I will like to suggest a research into the extent to which such buildings can withstand blasting, i.e., threshold limits.

2.0 WATER ENVIRONMENT

2.1 Introduction

The drainage pattern of the operating area is such that it serves as one catchment area for a stream. This has made it necessary to monitor these tributaries to identify any form of pollution that may occur.

2.2 Monitoring

Sampling sites were selected with the idea of monitoring all water emanating from the operating site, which ensures that any source of contamination is easily identified. The type of water monitored could be classified into three: potable, streams and boreholes. Parameters analysed on monthly basis are as follows: pH, suspended solids, cyanide, conductivity, dissolved solids, nitrates, nitrides, and coliforms. Some full analyses which include other parameters like trace metals are done every quarter on each sample. Most communities within the lease have been supplied with wells which are analysed on completion, quarterly sampling program is being initiated after rehabilitation work on some wells are completed.
3.0 INDUSTRIAL / DOMESTIC ENVIRONMENT

3.1 Introduction

In trying to ensure that the environment is free from any discharge or effluent, the area of operation should be void of spills and other forms of contamination. Due to the presence of heavy-duty equipment oil spills are some source of pollution.

3.2 Storage Facilities

Various items are used in the mine's operations, e.g., chemicals and oil. All these have adequate storage facilities. Regular checking of these facilities are made to ensure good conditions are maintained. Areas that traps are required have been provided to prevent spillage from entering the environment. A weekly check of these facilities is made, and any adverse finding is reported to the appropriate department for rectification.

3.3 Sewage

Cesspits within the mining and residential area are emptied every two months by a contractor into the tailings dam. The cesspits are seeded with biodegradable substance which breaks down the waste material to prevent clogging of the cesspits.

3.4 Others

Containers of some materials and clinical waste are incinerated whilst others are reconditioned for use. Domestic waste is sent to the active waste dump and buried daily.

4.0 REVEGETATION / RECLAMATION

4.1 Introduction

The impact of surface mining manifests itself greatly with its immediate surrounding. The status of the vegetation gives the first impression of how destructive / constructive the operation is. However, most of the fears could be allayed if adequate measures are put in place to control these effects. Programmes which deal with restoration of the vegetation will also give a positive image of the mining activities.

In achieving these, the end use of the restored land plays an important role in the revegetation exercise. They determine what plants should be used, and the gradient that the dumps should be graded. The Company has adopted the policy of "as it was". So farms will become farms and forest returned to forest.

There are three main dumps which are active and a couple to come in the near future, in addition to the walls of the tailings dam. Work has been completed on most of the walls of the tailings dam and some parts of the waste dump. These are progressing well.

In the revegetation exercise, for the waste dumps, the top soil is pushed back to the toe. When dumping is completed, the soil is pushed back on the dump, having graded it to the required slope. Initial plants planted are grass (vetiver) to prevent erosion and nitrogen fixing trees. When reasonable vegetation is established and based on end use, different tree species are introduced. In areas where topsoil is not available, loose soil is used to dress the surface and then biological manure is used in addition to the
other plant species specified. These processes have been found to have worked effectively over the years and it is expected that much more will be done in the coming year.

5.0 COMMUNITY RELATION / DEVELOPMENT

5.1 Introduction

GAG's operation is gold production. However, other related issues come up which must be handled by the Company. One of such prominent issues is local community relation which can be categorised as social, psychological, and economical. These are addressed to ensure good relationship since mining activities do affect these communities to some extent.

5.2 Social

A number of communities have been displaced due to the Company's operations. This has resulted in some communities swelling up in population. It is important that these communities have adequate amenities to cope with the population. The Company has encouraged the communal approach and has assisted in such projects, for example, the electrification of a satellite village which also has a market, clinic, KVIP and a JSS workshop through the Company's support. Hand dug wells have also been provided to most communities.

5.3 Psychological

Most communities close by tend to complain about the mining operations. Lots of meetings have been held, yet they seem to maintain their perception about mining activities. The company out of its way, has had the occasion to take some opinion leaders to observe the mining operations especially blasting. The District Environmental Management Committee has also been invited to observe the operation so as to explain the mode of operation and its effect to the locals and any other interested party. GAG believes this should be encouraged to ensure peaceful coexistence.

6.0 CURRENT DEVELOPMENT

6.1 Heap Leach

A heap leach project was commissioned in the last quarter of 1996. This went through the rigorous of an impact statement which was approved by EPA. An approximate area of 25 hectares will be utilized for the process. The design is such that all cyanide bearing solutions will be pumped to the CIL plant which has been in operation for some time. Adequate measures have been put in place to deal with any accident which might occur.

7.0 AUDIT

As part of the conditions in our environmental commitment and currently required by EPA, annual audits are carried out on the Company's environmental activities. They also review the company's action plan to make it abreast with condition pertaining on the ground. This has been done in the past four years making the Company very pro-active.

The general view of our auditors are, to quote "There is a company commitment to developing and implementing environmental programmes, and is reflected in senior management attitudes and achievements to date in all environmental management at IGM". It went further to say, "The audit did not find any matters of major environmental concern which require urgent ameliorative action by the
company", end of quote. So in brief this has been the company’s environmental practices over the years and we believe there is still room for improvement.

8.0 HISTORY AND OWNERSHIP

Exploration began in 1987. In 1992 the plant was built under the management of G.A.G. Shareholding was

70% — G.S.M  
20% — I.F.C  
10% — Ghana Government

Commissioned in 1993. In 1996 (Nov.) GSM and AGC merged, now GAG is part of the group of companies under AGC.

8.1 Geology

Banket is in the conglomerate, ensuring free milling.

Geology of Iduapriem Gold Mine, Tarkwa
Vetiver grass is used as a soil stabilizer and is successful in trapping seeds and protecting them from wind and water erosion. It has a strong root structure and is very resilient.
Mining

It is an open cast mine with three pits currently in operation.

Mr chairman, ladies and gentlemen, I will first like to express my company’s appreciation to the organisers for being invited to take part in this national symposium. We believe that at such gatherings, findings will come a long way in assisting the industries to the benefit of the country.

ENVIRONMENTAL PROCEDURES TO DATE

<table>
<thead>
<tr>
<th>Date</th>
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<tr>
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<tr>
<td>January 1991</td>
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<td>Environmental Management Plan (EMP)</td>
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<td>Ore Treatment Commenced</td>
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<td>Environmental Audit</td>
</tr>
<tr>
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</tr>
</tbody>
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Note: The above were all done to International Standards without the need of local legislation.

ENVIRONMENTAL POLICY

1. Promoting environmental awareness amongst all employees.
2. Use of internationally accepted standard and management system for performance of environmental activities.
3. Progressive rehabilitation of disturbed areas for an appropriate end land use.
4. Ensuring that all on site contractors meet the GAG environmental standard, whilst they are employed on site.
5. Use of an annual Environmental Audit to provide Independent monitoring of site performance.
7. Minimising off site discharges that are outside agreed environmental standards.

In addition, GAG will work with the local communities on environmental issues that affect both parties.
MINING DEGRADATION OF FOREST LAND RESOURCES AND REHABILITATION

Prof. K. Tufuor
Tufuhene Consulting Forestry Services, P. O. Box 1773, Dansoman, Accra, Ghana

INTRODUCTION

The mineral industry along with agriculture and forestry form the backbone of Ghana's economy. The budget statement of February, 1997 indicated that gold exports fetched US$612 million, cocoa $508 million, and timber $250 million in that order, thus gold replaced cocoa as the number one foreign exchange earner for Ghana in 1995/96.

Both the National Forest Policy and the National Environmental Action Plan recognize that the exploitation of any of the natural resources for development must not be pursued at the expense of the environment nor the sustainable use of the other essential natural resources.

It will be recalled that the 1992 Republican Constitution of Ghana recognized the importance of natural resources in the country, and sought for their protection, and therefore mandated several "commissions" to be responsible for the regulation and management of the utilization of natural sources, and the coordination of policies pertaining to them.

Curiously, mining activities have tended to be unfriendly to other vital resources: Agriculture, Forestry, and water resources, and the trend must be reversed through cross sectoral harmonization of policies.

The major goal of all environmental protection work must be the maximization of all resources, i.e. institution of measures that will protect the air, the land resources and waters from harmful change.

Essentially, this paper highlights the importance of forest resources conservation in Ghana, the degradation of the resource through several agencies including mining, and recommends way out of a major cross-sector impasse resulting from accelerated surface mining in forest reserves.

POTENTIAL ROLE OF FOREST VEGETATION IN GHANA

Forest vegetation plays an important role in both the environment and economic development of Ghana. Three decades ago, consideration of forests influences on climate was focused at the micro-climate or local climate. Recently, more attention has been directed at the potential impact of forests on global conditions; the hot debate on the environment today is that of climate change or carbon sequestration.

Undoubtedly, forests and trees are being recognized as playing important roles in global biogeochemical cycles, especially global carbon cycling, because they store large quantities of carbon in vegetation and soil, and exchange carbon in the atmosphere through photosynthesis and respiration. Apparently, humans have the potential to use forest management to change the size of carbon pools.

The proper management of the standing forest biomass is therefore critical in sustaining the physical environment, and reducing erosion of surface soils by water and wind. Our forests and woodlands supply about 78% of total energy (as fuel wood and charcoal) and industrial forest products contributes about 12% of GDP, and 9% of total trade in Ghana.
Forests are the main home of earth's species including *Homo sapiens*, with tropical forests (only 6% of the planet's land surface) containing at least 50% of all species.

We can also look forward to entire pharmacopoeias of new products provided our forests and their species survive. Who knows, the cure for AIDS could come from a plant in Ghana's forests!

**DEFORESTATION AND FOREST LAND DEGRADATION**

Deforestation, in broad terms refers to the removal of woody vegetation, and becomes a problem when the removal and use of woody biomass is not matched by natural vegetation regeneration and/or reforestation.

There are several causes of deforestation

- forest clearing for unsustainable shifting agriculture
- the need for fuel wood and charcoal. About 78% of household energy demands in both rural and urban areas are met through fuel wood.
- commercial tree felling, effects of fires, urban expansion
- mineral extraction, especially open pit mining (both large-scale and Galamsay) and illegal chainsaw operations pose the biggest threat to the very existence of forests in Ghana today.

**EXAMPLES OF MINING IN FOREST RESERVES**

Records abound in winning of diamond in the 1960's in the forests of Oda District in the Eastern Region, with Akwatia open cast mining providing a classic example of dereliction of land associated with mining. With the boom of gold mining in the past decade, forest reserves have become targets of major operations with Western Region leading.

**Western Region**

- Bonsu River Forest Reserve
- Nueng South Forest Reserve
- Nduprim Forest Reserve
- Afao Hill Forest Reserve (covered by bauxite concessions)

**Upper East Regions**

- Tankwidi East Forest Reserve
- Red Volta Forest Reserve

In early 1996, Tankwidi Forest Reserve was virtually invaded by gold-diggers, food sellers, gold buyers and pito brewers - all numbering over 4,000 and the security forces assisted in the evacuation of the illegal gold miners.

**EFFECTS OF MINING ON THE FOREST ENVIRONMENT**

The small-scale mining operations (Galamsay) especially pose danger to Forest Reserves in the:

- destruction of vegetation, including economic timber species and natural forest regeneration of all age classes.
stagnant pools left behind pose danger to wildlife and human beings, and will remain unproductive sites for vegetation growth for several years. Generally, excavation of open pit cause disfigurement and dereliction of land association with abandoned mines of the landscape, making the spoils very inhospitable to vegetation growth.

intrusion into the Forest Reserve of these operations do not take any account of management plans of the Forests, and runs counter to protected values and sustained management of forests for both tangible and imponderable benefits to society.

the permission of small-scale mining into reserves has also encouraged non-miners to encroach upon the reserves to collect other non-timber produce.

the disposal of waste rock and tailings from large-scale mining operations cause both chemical and physical pollution. Dumps inundate land, extend and encroach over more land often on forested water-catchment areas.

ponded effluents are inimical to wildlife in surrounding areas

the effluents (containing arsenic, cyanide) from processing plants in Obuasi have been implicated in the blighting of trees in Pomposo and Dampia Forest Reserves.

The vegetation of Dampia and Pomposo Forest Reserves located 12km from the Obuasi Goldfields is fast disappearing. Villagers intimate that wildlife is now virtually non-existent in the reserves. According to residents and forest officers, barely 20 years ago, Pomposo Headwater Forest Reserves was flourishing with ever-green forest, and clear potable water, but has been affected by smoke effluent from the mine treatment plant which drifts over the surrounding hills and therefore suspected to be responsible for the denudation of the hills.

People are worried about the serious impairment of water catchment regulatory functions of forest cover over slopes affected by surface mining. Evidently, surface mining system recently introduced in Ghana is causing severe shocks to the ecology of the mining areas.

CONTROVERSY OVER MINING IN FOREST CONSERVATION AREAS

1. The activities of small-scale miners in forest reserves raise the issue of which agency has primary authority over forest resources and the processes precedent to the grant of prospecting licenses.

Since the enactment of the First Concessions Ordinance in the early 1900, leases and licenses in reserves have been subject to the chief conservator of forests imposition of conditions and limitations for operating a concession in forest reserves thus safeguard the integrity of the reserve.

Unfortunately, local forestry authorities were often not aware of the grant of licenses to operate within forest reserves until they had been granted by the Minerals Commission.

By mid-1996, the Ministry of Lands and Forestry came out boldly and maintained that mining should not be permitted in reserves. Accepted conservation principles dictate that a minimum of 10%+ of representative ecosystems should be fully protected from extractive industries.
In the wisdom of the earlier colonial conservation efforts at least 11% of the land area of Ghana was set aside as forest reserves, and lately we have added 5% for wildlife conservation. What is implied here is that 16% of the land area of Ghana is permanently set aside for ecosystem conservation; and the remaining land area including water bodies for other uses.

II. On the other hand, others believe that forests are sitting on gold and that mining should be allowed in cases where there is no direct threat to the purpose of the reserve, and maintain again that with suitable rehabilitation the conservation values of the mined areas can be retained, while providing economic benefits to the state and the community.

III. Conservationists' opposition to mining: While rehabilitation is possible after mining, many foresters and conservationists dispute this, and maintain that changes in hydrology by mining could preclude mature vegetation (to its original, pristine floristic and faunal richness) being reestablished and restored close to the pre-mining condition.

In other parts of the world, opposition is very strong against mining in National Parks, Nature Reserves, Forest Watershed areas, classified as Management Priority Areas for Conservation.

They point to the lip service being paid by mining agencies on their feeble rehabilitation efforts, and the general lack of commitment by companies to regenerate land already mined.

IV. Large scale surface mining has brought about re-settlement of several rural communities, i.e. local inhabitants have become "refugees" in their own native habitat. It was apparent in the field visit to the mining areas in Western, Central and Ashanti Regions in April, 1992 by the Forestry Commission that, to-date, mining companies have not adequately demonstrated their ability to rehabilitate mined areas to the standards expected of E.P.A. nor to the environmental conservationists.

V. Mining in forests will imply abandonment of scientific management of forest reserves, and consequent loss of goods and services derived from our forest heritage set aside some 60 - 70 years ago.

VI. At present levels of forest land degradation, Ghana may not be able to sustain current levels of exports of both industrial and non-timber products.

RESOURCE USE CONFLICTS AND DISTORTIONS IN GHANA

Ghana is now witnessing a rather dramatic and complex interaction between the exploitation and utilization of its major natural resources, and efforts to ensure their sustainability for economic development has been the subject of intense public debate, including this symposium.

Conflicts and distortions in the use of environmental resources arise as a result of lack of coordination of inter-sectoral policies, and institutional failures.

These conflicts also arise from contradictions in our perceptions of resources' value among different users. Forest resources and agricultural land are under-valued when it comes to mining of any sort in Ghana - be it for diamonds, gold, bauxite and manganese. Such conflicts and distortion of resource values will make the attainment of a balanced sustainable development in Ghana a very distant reality and may often aid and legitimize environmental degradation.
GHANA'S RESPONSIBILITY TOWARDS HER FORESTS

Ghana has sovereignty over her own forests, but she is a strong signatory to several international conventions, and efforts developed over the past decade to save the world's forests e.g. Convention on Biodiversity, CITES, UNCED Declaration of Earth Summit of June, 1992/Forest Principles, FAO/World Bank/UNDP/World Resources initiatives on TFAP, ITTO Agreement.

The incalculable benefits, especially the environmental benefits supplied by forests are well known. Worse, the incipient decline of Ghana's forests through uncontrolled surface mining and chain-saw operations will virtually make a mockery of our support of global efforts to save the forests - a planetary treasure - the predominant type of vegetation on the earth for hundreds of millions of years.

RECOMMENDED GUIDELINES FOR REHABILITATION OF FORESTED AREAS AFFECTED BY MINING

I. Legislation is required now to make it quite clear that mining and explorations will not be allowed in areas of the highest cultural/ecological significance such as national parks, nature reserves forested watersheds.

II. Essentially, forest management plans should permit some level of mining for the general economic benefit of the surrounding communities.

Ideally, the management plan should divide the forest land area into management units and assign priorities to those areas (management priority areas) and decide whether or not mining can be accommodated, and then ensure a rehabilitation plan for mined areas that may help the area to be integrated back into the surrounding area, with its future use and management being compatible with that of the surrounding forest.

Unfortunately, zoning land/excising land selected for potential mining in forest reserves may lead to the creation of too many "window", and in the end destroy the effectiveness of any conservation area.

III. New legislation and leases for mining to require that clear objectives for restoration need to be established by the mining company in consultation with government agencies responsible for natural resources management and utilization viz. EPA, Minerals Commission, MEST, M.LF / Forestry Commission.

IV. Mining Companies should have permanent rehabilitation staff and utilize technical services of forestry officers, or environmental consultants.

V. EPA should provide guidance on post-mining land use options in accordance with existing land use policies and objectives.

VI. Research and Development of techniques for revegetation of mine spoils to be funded through the Minerals Fund. Mine-site rehabilitation offers the opportunity for research into the development and management of both native and introduced species.

Essentially, the objective of any rehabilitation effort is to establish an ecosystem as close as possible to that present before the mining operation began in accordance with existing national land-use policies.
VII. More effort should be made to re-establish indigenous vegetation on rehabilitated areas through agroforestry; this will assist in achieving soil stability and nutrient cycling on the poor soil types.

CONCLUDING REMARKS

Recent mining activity has reached a scale where it is capable of inflicting major irreversible damage to forest and wildlife conservation areas; and timely cross-sector policy intervention is required.

(a) Only when the real economic value of the national forest estate is recognized through the multiplicity of goods and services it offers, will it be able to compete with other possible users of land. National interest will then be aroused in conserving and exploiting it as a permanent source of wealth, stability and progress. The remarkable thing about forest is its renewability. Our forests considered as 'Green Gold', and can be "mined"/exploited.

(b) Mining is a major contributor of our foreign exchange earnings, but it must not be allowed to destroy other equally vitally important natural resources especially, agriculture, forestry, water resources - necessary for our very survival.

(c) No nation can prosper for long if it continues to deplete its forest and agricultural land resources, and would eventually become dependent on other countries for such prime necessities as food, fibre and shelter.

(d) Mining is a non-renewable resource, and it is almost imperative to use a % of mining revenue to rehabilitate and sustain the relatively renewable natural resources for development.

(e) We can envision the adaptation of "ecological mining" in Ghana; i.e. synthesizing contemporary mining technology with sensitivity for environmental restoration, and thus create arable land and healthy water systems in the process of mineral extraction.

REFERENCES


ACKNOWLEDGMENT

The Writer wishes to acknowledge with thanks assistance received from valuable discussions with Deputy Chief Conservator of Forests, Mr. J. Otoo on the subject.
ABSTRACT

Forests are destroyed as a result of such demanding and immediately rewarding land-use options as agriculture, mining, logging and urbanization. Other causes of forest destruction come from bush fires. In general, much of the forest destruction experienced anywhere in the world, have come from human activity in the pursuit of some economic gain for survival.

The effects of these land use activities on the forests are varied. Thus measures to mitigate these effects in order to reclaim the land back or close to a seemingly original forest estate, must necessarily be varied. Strategies for revegetating a mining site, must of necessity be different from that for an agricultural land or logged field because of the change in the nature of the soils in particular, and other abiotic and biotic characteristics at the sites.

Experiences gained from a land reclamation exercise at a mining site in Ghana would be used to illustrate the point.

It is important that revegetation exercises are taken seriously in order to make up for the fragmented forests which have been created all over the place because of these other land use activities. The choice of revegetating material is considered crucial and must be related as much as possible to the original flora in order to enhance the proper healing of the forest gaps and the mitigation of the forest fragmentation.

1.0 INTRODUCTION

A little over a year ago, between 26 and 29 February 1996, the Forestry Commission of Ghana organised a workshop on Forest plantation development in Ghana, under the theme: Forest Plantation, the key to restoring Ghana's forest heritage and environment. This workshop attracted a large number of people including stake holders in the forestry industry. Over 40 well researched articles were presented and discussed. The general conclusions were that plantation development was the best option left for Ghana to meet its future timber and non-timber forest products whilst at the same time, reversing the deforestation trends to enhance a healthy environment. Research into the silviculture of indigenous species was very highly recommended since knowledge in this area was found to be inadequate (Oteng-Yeboah 1996). When I knew I was going to present this paper on revegetation of destroyed forests as part of this national symposium on the mining industry and the Environment, I was very glad indeed. This is because an opportunity was going to be given to all stake holders in this Industry to interact, indeed think aloud about ways to ensure a good environmental health after or even before the mining operations have ceased. Mining in Ghana takes place in the forest belt of the country, and since mining operations tamper with the forest estates, it is quite in order to examine ways in which the effects can be mitigated.

A general review of causes of forest destruction and their effects on the forest estate including the soils is necessary, to set the stage for an illustration and discussion of a revegetation exercise conducted on a mining site in the Western Region of Ghana.
1.1 Causes of Forest Destruction

Generally, causes of forest destruction come from two main sources

- Anthropogenic (man-made)
- Natural

1.1.1 Anthropogenic: from land use activities

- Agriculture: conversion into arable lands to grow food and cash crops
- Logging: extraction of timber for export and domestic wood requirement
- Mining: extraction of mineral ores from their deposits for foreign exchange earnings
- Urbanisation: provision of such infra-structural facilities as roads, housing, dams, schools for development.

1.1.2 Natural Sources, through:

- Spontaneous fire: out break from lightning and ignition from rocks
- Earthquake
- Floods
- Volcanic eruption

1.2 Effects on forests and nature of soil

1.2.1 Agriculture: Using cutlass, fire
- removal of all species of the ground floor, herbs, shrubs and small trees, including seedlings and saplings
- Large trees often killed by ringing or by fire
- Unless used for cash crop plantation, site abandoned after a few years of food cropping
- site now dominated by Chromolaena odorata or grass (Panicum maximum)

1.2.2 Logging: Using chain saw and axe
- initial removal of an economic tree which, on falling breaks the forest canopy and destroys several other plants
- creation of trails often 6 meters wide using heavy machinery like skid trails and caterpillars, to drag logs: in this process, species of the ground floor including seedlings, saplings and herbs, shrubs and small trees are either removed or trampled upon and crushed.
- soil becomes compacted and rugged.

1.2.3 Mining: Open pit or surface mining using heavy sophisticated earth moving equipment to excavate and transport rocks after blasting.
- whole landscape including vegetation, hills, sub-soils and rock base removed
- creation of huge dump heaps made of milled or ground rocky material mixed with cement and continuously leached with arsenic acid.
- spent dump heaps are loose, and their exposed surfaces are crusty and hard forming concretions.
1.2.4. Urbanisation: depending on the type of infra-structural development.
- only the vegetation may be removed as for housing
- or the whole landscape may be removed as for road or airport construction
- or the whole landscape may be inundated as for dam construction

2.0 REVEGETATION

Revegetation is the process of bringing back vegetation on to the landscape. For a forest, it is the attempt to reclaim land back or close to a seemingly forest estate. Forest estate may refer to either plantation forest or a natural forest. Of the 4 land uses which transform natural forests it is only the use for urbanisation which is permanent and therefore in very general cases cannot be revegetated.

2.1. The Process

The process of re-vegetation involves basically the concept of tree planting. Depending on the kind of landscape and the purpose of the exercise, the tree planting may be considered under different categories:

- Enrichment planting such as in logged or degraded forests, where a deliberate selection of certain species are made and planted to replace those already extracted.
- Plantation forestry for pure or mixed stands of desired species to be adopted on abandoned farm lands or any degraded landscape.
- Agroforestry, which integrates with other forms of agriculture, is feasible in home gardens near settlements and can provide a useful link in the revegetation of areas converted into urban settlements.

2.2. The Revegetation of a Mining Site

An experiment to re-vegetative one of the dump heaps of Teberebie Goldmines Limited was started in 1995. Seven tree species which were available in the company's nursery were used for trials. The species were Adansonia digitata, Adenanthera pavonina, Azadirachta indica, Blighia sapida, Delonix regia, Gmelina arborea, and Leucaena leucocephala.

After the site was levelled, some top soil (sub-soil) were tipped onto the surface and spread to cover the dump heap soil. Planting holes up to 30cm were dug at intervals of 5m x 5m. The micro-catchment technique developed at IRNR and refined during the CIPSEG Project (Telly and Fiajoe 1996) was adopted. It involved a systematic layering of humus, mulch and soil and the planting material with its ball of earth, and the top of the hole covered with mulch and soil.

The seedlings were watered twice a day during the dry season. For a whole year from March 1995 to March 1996 there was 100 per cent seedling growth survival. Within this period also, there was over 46 vascular plant species that were voluntarily recruited into the plots (see Appendix 1). Many of the species were herbaceous which are considered opportunistic, but which also constitute the first batch (pioneers) of invaders during the early seral stages of a vegetation development. It is understood that these plants will accumulate organic material on the soil surface to be used later by other plants for growth.
2.3. Lessons from the exercise

- It is possible to re-vegetate dump heaps
- With the use of proper topsoils which contain humus and mulch, many vascular plants would voluntarily appear, provide cover and increase organic matter. This will prevent formation of concretions.
- With time, indigenous tree species prevalent in the locality and forming part of the original forest can be interplanted to take advantage of the shade and organic matter provided by the trial plants.
- To ensure access to all parts of the heap dump for revegetation, all steep sides are to be reduced and planted.
- Watering is an essential requirement in this exercise, and must be ensured, particularly during the dry season period.

3.0 GENERAL CONCLUSIONS

Having established that re-vegetation is possible even on most unlikely places such as dump heaps of mining tailings, it is important that the exercise is taken seriously.

This will help to address the issue of fragmented forests which have been created all over the place because of other land use activities which necessitate the removal or destruction of the forests. The choice of the revegetating material is reduced to indigenous species because of the role they can play in the proper healing of the forest gaps and the mitigation of the effects of the forest fragmentation.

REFERENCES


ADDRESSING THE GALAMSEY PROBLEM: THE VIEW FROM THE GHANA CHAMBER OF MINES

G.T. Lewis, Goldfields (Ghana) Ltd., Tarkwa, Ghana

1.0 INTRODUCTION

1.1 Introduction to Report

This report aims to identify the costs of galamsey activities to large scale mining operations, the Ghanaian economy, the Ghanaian government and to Ghanaian society as a whole. The problem is analysed from the perspective of one large scale mining operation, namely Gold Fields (Ghana) Ltd. (GFG), but clearly the experience of GFG is multiplied by the many gold mining operations active in Ghana. This paper also presents a number of approaches that can be considered to address the galamsey problem.

1.2 Overview of Report

This report is divided into six sections. This first section introduces the topic and the general organisation of the report, summarising the main argument. The second section describes the general activities of the galamsey and their incidence at the Gold Fields (Ghana) operation at Tarkwa. The third section reviews the negative impacts of the galamsey on large scale mining operations, the community and on the galamsey personally. The fourth section itemizes the benefits of large scale mining activity: to the Ghanaian government and to, the economy of Ghana, both nationally and locally. The fifth section discusses the risks which galamsey activities pose to ongoing and proposed large scale mining operations. The sixth and final sections propose some strategies for addressing the galamsey problem.

1.3 Summary of Report

This report maintains that the galamsey pose a very serious threat to existing legal mining operations in Ghana. After cataloguing the negative impacts of galamsey activities and summarising the benefits of large scale mining, the report outlines the risks which the galamsey pose to ongoing mining operations primarily in terms of undermining the profitability of such undertakings and threatening the availability and affordability of investment and loan funds. The ultimate concern is that these large scale operations may not be able to continue or expand, resulting in substantial loss of government revenue, local employment and local purchase of goods and services. The report then proposes a three-pronged strategy for addressing the problem, which includes reviewing the framework for legal small scale mining with an eye to improving it (thus making it more attractive to galamsey), advancing economic development (addressing some of the root causes of galamsey activity) and increasing enforcement measures (ensuring that legal mining activity is protected and illegal activities suppressed). This strategy depends on a comprehensive approach, as no one stand can address the problem by itself.

1.4 Some Definitions

It must be made clear from the outset that this report does not criticize legal small scale or artisanal mining. Small scale mining has a rich tradition in Ghana, having been practised for hundreds of years. Historically, small scale mining which was at the root of the tremendous wealth of the Asante Empire,
formed the basis of extensive exchange between this region and European and Arab traders; indeed, this activity was the reason behind the original name for this country, that being the Gold Coast.

In this report, small scale or artisanal mining refers to largely manual, low technology mining conducted on a small scale, usually involving one to ten persons operating in a legal manner. This means that they are licensed to operate in their locations under the provisions of the **Small Scale Mining Law of 1989**. Ghana has been at the forefront of nations in creating a regulatory environment to permit small scale mining to take place. Given the absence of large capital investment or sophisticated technology, small scale mining is all suited as an economic activity for enterprising workers. However, these circumstances also mean that small scale mining has its shortcomings, in terms of the efficiency of its operations, the nature of the extractions it can undertake, and safety, health and environmental considerations. Small scale mining in Ghana in 1995 produced approximately 119,000 ounces of gold.

Galamsey refers to illegal small scale mining, and ranges from operating a small scale mine without a licence (either on or off an existing mining concession) to pilfering ore from existing mining operations. Given the illegal nature of the works galamsey activity is far more likely to be transient, slipshod with regard to safety, health and environmental standards, and confrontational with respect to existing mining claims and other property rights.

Large scale mining involves major capital undertakings, represented by substantial investment in exploration activity, ore extraction and ore processing, combining extensive mechanical processes with significant labour input, and hence the capability of extracting a greater proportion of the resource profitably, to the benefit of the nation as a whole.
2.0 ACTIVITIES OF THE GALAMSEY

It is useful to focus on the actual activities associated with the galamsey generally and the extent of their presence, specifically at Gold Fields (Ghana) Ltd. in Tarkwa.

2.1 Nature of Mining Activities of the Galamsey at Gold Fields (Ghana), Tarkwa

The GFG operations at Tarkwa offer several examples of typical galamsey work. Firstly, the nature of the ore dispersal means that the concession is dotted with various sites where surface or near-surface operations may permit some recovery of ore. Thus the GFG concession contains numerous current and abandoned galamsey operations over the length and breadth of its holdings.

In addition, however, are the longstanding and continuing underground operations of the company. These involve several shafts and many tunnels, creating an underground labyrinth of workplaces and access points. Galamsey not only search out abandoned underground sites for possible exploitation, but they also take advantage of the existing mining work of the company, in particular by rushing underground blast sites and selecting choice rocks before GFG mine personnel are permitted to enter these recently blasted areas (GFG mine personnel are required to wait before entering recent blast areas, to avoid inhalation of dust smoke and chemicals).

2.2 Nature of Galamsey Activities at Open Cast Operations

Gold Fields (Ghana) Ltd. does not yet undertake surface mining, although plans are well underway to do so. However, the experiences of Ashanti Goldfields Company (AGC) may be illustrative of what lies ahead for GFG if the galamsey problem is not addressed.

Where in earlier years galamsey activities normally took place outside of the usual working areas of the formal mining operations, the current open pit mining at AGC has seen a significant increase in direct galamsey encroachment on the existing work. Thus, galamsey will await blasts within the pit and rush the blast area to carry away choice ore. They will even carry on their picking in the presence of AGC mining personnel, to the extent that AGC mining personnel are prevented from operating their machinery, either to avoid unintentionally hurting a galamsey, or on account of having been threatened by the galamsey. (Galamsey have even been known to climb inside the buckets of pay loaders to scavage for ore.) The galamsey also access the stock pile on the site, where gold bearing ore blasted and collected from the pits is stocked, ready to be treated. Finally, the galamsey are even known to operate within the tailings dam looking for gold residue.

2.3 Associated Activities of the Galamsey

The mining of gold ore is only one part of the galamsey chain of activity. Once the ore has been selected, it must be taken away from the extraction point, pounded, then washed and panned. The mining work itself involves the greatest risk and the greatest effort, while the other tasks are relatively routine, and may often be performed by women or children. Galamsey work is often undertaken in teams of five to ten miners, with associated "support", where the ratio of miners to support workers is approximately one to two (1:2).

The galamsey work also has associated with it processing activities (involving mercury) and a network of gold purchasers. For the galamsey work to be sustained, there is need for a network of suppliers and purchasers to exist. While the galamsey miners themselves may make enough money to maintain themselves, the true beneficiaries of their work are this network of suppliers and purchasers, as well as any authorities (both formal and traditional) whose assent may be necessary to sanction this activity.
Finally, as galamsey often involve transient populations (with the miners overwhelmingly made up of young single males), they support a range of services from food and drink sellers and traders to illicit drug traders and prostitutes.

### 2.4 Incidence of Galamsey Activity at GFG, Tarkwa

The incidence of galamsey activities at GFG, Tarkwa has remained in broad terms relatively stable over the last year. The following table represents counts taken by GFG Security Personnel of galamsey active around several communities on the concession.

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<tr>
<td>TOTAL</td>
<td>6135</td>
<td>4128</td>
<td>4751</td>
</tr>
</tbody>
</table>

*UST/IDRC '97 Symposium on the Mining Industry and the Environment, UST, Kumasi, Ghana*
Table 2: Number of Galamsey Arrested and Charged, GFG, Tarkwa, July 1, 1993 to May 25, 1996

<table>
<thead>
<tr>
<th>YEAR</th>
<th>NUMBER ARRESTED</th>
<th>DISPOSITION OF CASE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 cautioned and discharged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21 discharged</td>
</tr>
<tr>
<td>1993</td>
<td>Surface Mining: 22</td>
<td>3 received ₵150,000 fine or 22 months jail term</td>
</tr>
<tr>
<td></td>
<td>Underground: 28</td>
<td>1 received ₵80,000 fine or 22 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 received ₵40,000 fine or 18 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 received ₵30,000 fine or 18 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 received 18 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 discharged</td>
</tr>
<tr>
<td>1994</td>
<td>Surface Mining: 15</td>
<td>1 received ₵60,000 fine</td>
</tr>
<tr>
<td></td>
<td>Underground: 4</td>
<td>1 received ₵50,000 fine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 received ₵15,000 fine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 received 2 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7 acquitted and discharged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 cautioned and discharged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 pending court case</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 received ₵30,000 fine or 9 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 received ₵50,000 fine or 2 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 received 10 months jail term</td>
</tr>
<tr>
<td>1995</td>
<td>Surface Mining: 24</td>
<td>2 received ₵150,000 or 10 years jail term</td>
</tr>
<tr>
<td></td>
<td>Underground: 20</td>
<td>1 received ₵80,000 fine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 received ₵60,000 fine or 3 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4 received ₵50,000 fine</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 received ₵40,000 fine or 3 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 received ₵30,000 fine or 3 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 acquitted and discharged</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 bonded over</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 received 4 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 not guilty</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3 pending</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11 received ₵150,000 fine or 7 years jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 received ₵100,000 fine or 12 months jail term</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8 received ₵50,000 fine</td>
</tr>
<tr>
<td>1996</td>
<td>Surface Mining: 13</td>
<td>2 received ₵40,000 fine or 6 months jail term</td>
</tr>
<tr>
<td></td>
<td>Underground: --</td>
<td>11 pending court action</td>
</tr>
</tbody>
</table>

The presence of galamsey has resulted in a number of arrests and prosecutions, although the actual results of enforcement activity, in relation to the total incidence of galamsey, remains quite small.
3.0 NEGATIVE IMPACTS OF THE GALAMSEY

The negative consequences of the galamsey have impacts on the mine, the community and the galamsey themselves.

3.1 Negative Impacts on the Mine

3.1.1 Direct loss

The galamsey operate as "freelance" miners with no regard for concession rights, laws or the efforts and investments of others. At its most basic, the galamsey are extracting gold from lands allocated by way of concession to GFG. What they take diminishes the rightful proceeds due to the mine, as a result of its concession rights and investment in resources and effort.

3.1.2 Inefficiency loss

Moreover because of their cruder recovery methods, in most cases the galamsey are cherry-picking the higher grade ore, depleting the high return sites before the mine can access that gold. Their extraction methods lead to perhaps 50% extraction of the ore, and their processing methods elicit perhaps a recovery of 50% of the gold, so that in the end their efficiency rate may be only 25%, a further waste of the resource. In other words, 75% of the gold in the ore which the galamsey seek to exploit is not recovered, and because of the galamsey intervention, is most often no longer recoverable resulting in a further loss not only to the legal mining sector but to the country as a whole.
3.1.3 Profitability loss

Cherry picking, or high-grading, can result in a further "sterilization" of the surrounding lower grade resource. Consider a potential extraction area where the gold is found in three layers with varying degrees of concentration. For the sake of illustration, these layers are at concentrations of 60 parts per weight, 25 parts per weight and 20 parts per weight. Consider further that a large scale mining operation can economically be undertaken where the concentration is at 35 parts per weight while galamsey only operate where concentrations are 55 parts per weight or more. Given the proximity of these layers, the entire deposit can justifiably be mined, as the richer ore body attracts the initial effort. However, should galamsey exploit the richer layer; not only is that ore mined in a wasteful fashion but the depletion of that one layer results in that entire location being no longer economical to mine, resulting in all three layers being "sterilized." Thus, the remaining gold, both what the galamsey do not recover through their own work and the other sites now made uneconomical, stays in the ground, to no one's benefit.

3.1.4 Health and safety threats

Because of their unregulated and undocumented methods, the galamsey pose a hazard to other mining operations (both large and small scale): ignorance of the presence of an underground shaft or tunnels may lead to a cave-in or other unforeseen consequences, especially where blasting is taking place; where the galamsey have undertaken unauthorized and often forced entry to shafts and other underground operations their own blasting and processing work can pose a threat to the formal miners operating under regulated conditions (this includes damage to ventilation seals).

3.1.5 Theft, vandalism and threats of violence

The presence of so many illegal operators naturally results in regular theft, especially of production equipment such as cables, starters, pumps and even explosives.
The escalation of galamsey activities has also brought with it emboldened galamsey tactics and attitudes. At GFG Tarkwa, galamsey use both bribe attempts on security personnel to gain access to underground workings as well as injury and death threats to mine personnel who impede their work. There have been assaults on security personnel as well as unauthorized entry into the mine’s mill area. These experiences have also occurred at AGC, where security personnel and police have been attacked and injured, and property vandalized (one assault involved the destruction of production equipment costing approximately three million cedis). More worrisome are reports of offensive weapons among some galamsey, including firearms.

3.2 Negative Impacts on the Community

3.2.1 Direct impacts on community life

The galamsey lifestyle is not very supportive of stable community. In an uncontrolled mining situation, there often is a breakdown of authority, and the get-rich mentality of the galamsey undermines traditional values, can encourage child labour or neglect and may lead to other social ills. The drudgery and danger of their work draws them to rely on a range of stimulants, including marijuana, chemicals and coffee beans. Their predilection for release and entertainment leads to increased alcohol use and prostitution. The money they bring into the local economy, while attractive no doubt to some extent, also causes distortions in that it may divert resources from other productive work. As well, the galamsey may outbid others for basic goods or drive prices up. The illicit network of their work and of some of their diversions creates a shadowy chain of suppliers and mentors who wield an inappropriately acquired wealth, and hence influence.

3.2.2 Impacts on local environment

Unlike legal mine operators, whether large or small galamsey are neither regulated nor do they abide by Ghana’s environmental legislation, resulting in horrific consequences for the local environment. This can include the widespread alteration of the landscape leaving unstable piles of wastes, abandoned excavations, siltation of streams and destruction of river banks. Spillage or leakage of solvents, reagents and cyanide or mercury compounds are major sources of water pollution.
3.2.3 Impacts on the broader community

Being unregulated, galamsey activities are outside of the regular economy, which means they pay no taxes, licence fees or royalties. Thus a national resource is exploited with no benefits accruing to the broader community. These foregone revenues mean that either various beneficial social expenditures, such as for the provision of schools, hospitals or roads, cannot be incurred, or the tax burden on lawful citizens must be increased.

3.3 Negative impacts on the Galamsey Personally

Galamsey work has two main deleterious effects on the miners. Firstly, the nature of the work (and perhaps of the lifestyle and self-image) seems to promote a reliance on various stimulants, which often leads to some form of drug dependency. Secondly, because of the freelance and basically unregulated nature of their work, they benefit from few of the safety and health laws and procedures which are a normal part of mining these days. As a consequence, they are more likely to suffer injury and death on the job. Moreover, they are also far more susceptible to a broad range of diseases, as discussed below.

3.3.1 Silicosis

Small-scale mining is often carried out close to the surface in weathered rock made up almost exclusively of silica. The galamsey do not water down the rock face to enable dust to settle and the surrounding vegetation is accordingly poor. This leads to galamsey contracting very early severe pneumoconiosis (dust lung disease) or very specific silicosis (dust lung disease caused by silica). Silicosis is a severely disabling disease and the patient eventually ends up as a respiratory cripple in need of oxygen therapy on a daily basis. Silicosis has also been proven to make a patient more susceptible to contracting tuberculosis.

(This potential problem is controlled in deep mines such as at GFG, Tarkwa, due to the fact that less dust is generated, mining takes place in solid rock where the silica content is lower, the ventilation is better and the rock face is watered down to control dust. There are also routine medical examinations to detect early silicosis, thus enabling affected employees to be relocated to a safer area).

3.3.2 Tuberculosis

Tuberculosis is a disease spread by droplets in sputum. The germ spreads more easily when people are in close proximity with one another, such as the poorly ventilated mining holes where the galamsey work. This makes the galamsey very prone to tuberculosis. Tuberculosis, unlike silicosis can spread through communities due to human interaction. This is well controlled in large scale mining operations, but not among the galamsey.

The problem of tuberculosis is further exacerbated due to its interaction with the AIDS virus. AIDS leads to a reduction in the immune system making a person more susceptible to contracting tuberculosis. Tuberculosis contracted in these circumstances is usually multi-drug resistant and extremely difficult to treat, therefore often leading to death.

3.3.3 Sexually transmitted diseases

It has been clearly shown that the incidence of sexually transmitted diseases including AIDS is high among galamsey. This is likely due to the loosening of family ties, resulting in more promiscuous behaviour and relations with prostitutes.
3.3.4 Other diseases: malaria, cholera and diarrhoeal disease, effects from mercury

The holes dug by galamsey often fill up with water. These holes together with the streams that galamsey activities block up, lead to standing water which serves as a breeding ground for mosquitoes, resulting in an increase in malaria. As well, by defecating in the water catchment areas where they work, the galamsey spread diarrhoeal disease and possibly cholera. The handling of mercury in the processing treatment may have an effect on the kidneys and skin of those exposed to it over time, and may also lead to numbness in the fingers.

4.0 BENEFITS OF LARGE SCALE MINING OPERATIONS

There are a number of ways in which the large scale mining contributes to the wealth of Ghana, both at the broad national level and within the localities where they operate. These will be examined in relation to Gold Fields (Ghana) Ltd., in terms of its current contribution to the national government and the local community. As well, some estimate will be made of the projected contributions rising from a typical surface mining undertaking.

4.1 Benefits of Existing Underground Mining at GFG, Tarkwa

4.1.1 Benefit to National Government
The most obvious and direct benefits accruing to the national government from GFG (as with all large mining operators) are in relation to corporate taxes and royalties. For the last two financial years (ending June 30), the relevant figures are:
Table 3: Corporate Taxes and Royalties paid By GFG in 1994 and 1995

<table>
<thead>
<tr>
<th></th>
<th>1994</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate tax (in cedis)</td>
<td>198 803 000</td>
<td>664 770 000</td>
</tr>
<tr>
<td>Royalties (in US dollars)</td>
<td>461 000</td>
<td>457 000</td>
</tr>
</tbody>
</table>

However, GFG also pays other amounts either to the national government or to national parastatal organisations as follows (for the financial year ending June 30, 1995):

<table>
<thead>
<tr>
<th>Item</th>
<th>Cedi Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>21% withholding tax</td>
<td>72 356 009</td>
</tr>
<tr>
<td>SSNIT (pensions -- company's portion)</td>
<td>212 157 807</td>
</tr>
<tr>
<td>Electricity and water</td>
<td>1 771 450 000</td>
</tr>
</tbody>
</table>

4.1.2 Benefit to the Ghanaian Economy

In addition to direct payments to the national government and national parastatal organisations, GFG contributes to the national and local economy, through the payment of salaries and wages and significant local purchases of goods and services. These can be itemized as follows (for the financial year ending June 30, 1995):

<table>
<thead>
<tr>
<th>Item</th>
<th>Cedi Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaries and wages (1438 Ghanaians)</td>
<td>3 114 644 000</td>
</tr>
<tr>
<td>Local purchases</td>
<td>1 771 450 000</td>
</tr>
<tr>
<td>Food contractor (mine workers)</td>
<td>382 460 000</td>
</tr>
<tr>
<td>SSI (support services -- senior staff and consultants)</td>
<td>139 343 987</td>
</tr>
<tr>
<td>Sundries (telephone, postage, printing, etc.)</td>
<td>507 437 900</td>
</tr>
</tbody>
</table>

Clearly, these spending items generate further economic benefits: local and regional purchases support Ghanaian enterprises and jobs while local salaries and wages support local spending, which in turn support other Ghanaian enterprises and jobs. (As well, the 1438 Ghanaian staff also pay taxes to the government).

4.1.3 Benefit to the local community

Quite apart from contribution through taxation and spending for wages, goods and services, GFG also provides voluntary payments and services to the community. In 1995, these included such items as: improvements to the Atuabo school and Awudua clinic; renovation of the School of Mines; grading of roads; addition of a classroom at Atuabo and the Presbyterian church; sponsorship of competitions; usage of mine hospital by outsiders (485 people monthly and the employment of casual labour. In total, these payments and services totalled U.S. $ 205,150 for the year ending June 30, 1995 (at the time, c266 695 000).

4.2 Projected Benefits of Surface Mining

The following is an example of the projected benefits of a surface mining operation for selected categories (primarily involving benefits to the national government and the Ghanaian economy, both
national and local). These amounts are for a period of 20 years based on minimum and maximum working cost projections. All amounts are in current U.S. dollars.

Table 4: 20 Year Projections of Selected Benefits Arising from a Surface Mining Operation (In current U.S. dollars)

<table>
<thead>
<tr>
<th>Royalties</th>
<th>Low Working Cost Projection</th>
<th>High Working Cost Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate Tax</td>
<td>$ 263,000,000</td>
<td>$ 150,000,000</td>
</tr>
<tr>
<td>Spending in Ghana</td>
<td>$ 1,644,000,000</td>
<td>$ 2,145,000,000</td>
</tr>
<tr>
<td>Spending Locally</td>
<td>$ 1,196,000,000</td>
<td>$ 1,560,000,000</td>
</tr>
</tbody>
</table>

In short, a surface mine operation in this example stands to contribute for at least 20 years U.S. $20 to 40 million annually to the Ghanaian government coffers in corporate tax and royalties alone, and U.S. $80 to 107 million annually to the Ghanaian economy (of which U.S. $60 to 75 million would be spent annually in the immediate vicinity of the mine).

5.0 RISKS TO LARGE SCALE MINING ARISING FROM GALAMSEY ACTIVITIES

It might be assumed that the major impact of the galamsey on large scale mining activity is limited to petty theft and vandalism and a general nuisance factor, resulting in heightened security measures and periods of increased tension. At this level alone the impact should not be minimised — the activities of the galamsey not only continue, but they appear to be bolder and more confrontational in their tactics particularly if the experiences of GFG and AGC are anything to go by. However, there are far larger risks resulting from the galamsey activities, which could, in the case of GFG, Tarkwa, threaten its proposed surface mining operation. These risks fall in two categories: the threat to profitability and the threat of uncertainty.

5.1 Threat to Profitability

As discussed in section 3.1, 3. profitability loss, the activities of the galamsey can have a much larger effect on a broader scale, where the high grading of deposits with higher concentrations of gold ore not only deplete that deposit, but may well make it no longer economically viable to mine surrounding lower grade deposits (the issue of "sterilisation"). Should the galamsey activity persist over the relevant sites for a sufficient length of time where they would substantially deplete the concentration of gold ore, then there arrives a point when the economic viability of the proposed surface mining operation is affected. The loss of this project would be a tremendous blow to the local and Ghanaian economy, given the extent of projected taxes and royalties accruing to the national government, as well as the benefits flowing to the economy, through the payment of salaries and wages and the local purchase of goods and services.

5.2 Threat of Uncertainty

A project of the magnitude of GFG’s proposed surface mining operation involves a substantial degree of up-front investment in exploration activity, relocation and resettlement of affected populations, reparation of the site, assembly of excavation and extraction machinery, and establishment of the
processing facilities. As a great portion of this work needs to occur before a single ounce of gold is produced, such work is financed by investments and loans from overseas financiers. Every project has associated with it degrees of risk, ranging from technological considerations, projections of working costs and commodity prices, and estimates of the degree of political and economic stability in the host country. Every project must compete for finances with projects in other sectors and other parts of the world, each of them exhibiting different degrees of risk.

Quite apart from the normal risks which may be associated with this sector (i.e. gold mining and processing) and with this area (Western Africa), the galamsey pose an extra consideration for investors and financiers in several respects. Firstly, it is unclear to what extent they may effect the ultimate resource (the amount of gold which may be mined, as discussed in section 5.1), and indeed the actual profitability of the venture. Secondly, their volatile presence raises the spectre of potential violence, as well as interruptions in the mining and processing activities. Thirdly, to the extent they affect the negotiations relating to the relocation and resettlement of villages affected by the surface mining operation, the galamsey can affect the timing of when the surface mining operation may begin, delaying the time when the first gold can be shipped, that is, delaying the revenue stream.

All these impacts increase the uncertainty surrounding the surface mining operation, at the very least increasing the premium which must be paid to entice investments and loans, and increasing the period of time these monies would be needed (thus prolonging the interest payment period). Again, at a certain point, the delay in beginning the operation, the extension of the time over which the project must borrow money, and the degree of uncertainty, can raise the costs to such an extent that the project as a whole may be jeopardised.

5.3 Multiplying these impacts

This analysis of the benefits derived from a mining operation and the risks which the galamsey pose has been largely limited to the circumstances of one firm (that is Gold Fields Ghana). It takes little imagination to consider the broader consequences for this entire sector, especially having regard for the importance which this activity has assumed for the Ghanaian economy. Most recent government projections estimate that gold will make up 44% of total estimated exports in 1996, totalling U.S.$678.4 million, substantially more than the value of cocoa exports (U.S. $425.3 million, making up 28% of total exports).

6.0 WHAT SHOULD BE DONE

From the perspective of GFG, Tarkwa, the galamsey represents a serious problem which must be addressed not as an isolated irritant but as a widespread obstacle to the continued viability of gold mining operations across Ghana. What follows is a proposal for a three-pronged approach to dealing with the galamsey, a strategy which requires a concerted government effort and which seeks cooperation from affected mines and local authorities.

6.1. A Proposed Strategy

As discussed at the outset of this report, small-scale mining in Ghana has a venerable tradition and will continue to have a place in the spectrum of mining operations in this country. The proposed strategy supports the strengthening of the legal small-scale mining sector. At the same time, galamsey activity also represents the desperation of individuals who cannot find work in other sectors. To address the galamsey problem also requires addressing its root causes, namely poverty and the lack of employment opportunities. Finally, the galamsey problem also represents a failure by government to embrace existing laws and protect individual rights. To resolve the galamsey problem requires a recommitment to extinguishing illegal activities, supporting lawful activities and protecting the property and economic
6.2 Strengthening Small Scale Mining

As noted earlier, Ghana has been at the forefront of supporting small scale mining among developing countries, especially with its introduction of a legal regime for small scale mining in 1989. There is certainly a niche for small-scale mining in Ghana, particularly in relation to those sites where the absolute volume of gold deposits and/or the nature of its dispersal makes large scale extraction unprofitable. That being said, the proliferation of galamsey suggests some inadequacies in the existing framework for small-scale mining. That is the question needs to be examined, why would individuals opt for illegal small scale mining when a framework exists for legal small scale mining?

Such an issue needs to be investigated through a collaboration between the Minerals Commission, existing large scale mining corporations, representatives of small scale miners, and if possible, representatives of galamsey, or those familiar with their activities. (Other resources may also need to be called upon.) Among issues such a group must study would be:

- Are current arrangements for securing concessions and mining licences appropriate?
- Is the regulatory framework being administered in an efficient, timely, easily comprehended and fair manner?
- Are the taxes and/or royalties being paid a fair amount?
- Do small-scale miners have access to sufficient financial supports to undertake their work or to upgrade their activities?
- Are there other obvious disincentives to undertaking small scale mining within the current legal framework, and how might these be overcome?

In addition, such a group should examine what supports should be made available to small scale miners to assist in their exploration, extraction and processing activities, to improve their efficiency and productivity, as well as the conditions of their work, having regard to issues of health, safety and environmental impacts. Special attention needs to be paid to the allocation of concession rights to legal small-scale miners. In this regard, various forms of collaborative or sub-contracted arrangements with large scale mining operations could be explored, having regard for which types of deposits can more efficiently and more profitably be mined by which level of mining operator. Finally, what assistance can be provided to strengthen the social setting of small-scale mining communities, to avoid a tendency towards creating conclaves of drug dependency, petty crime and settings inappropriate for normal family life and the upbringing of children.
6.3 Promoting Economic Development

As noted earlier, galamsey activity does not only represent a burning desire to engage only in mining. It is also a reflection of people's efforts to secure the means of subsistence by whatever means possible, including in this case pursuing illegal activities. Indeed, one measure of the desperation of these individuals is that they would pursue an activity where they have no security in the efforts of their work (they have no property or concession rights) and where they are operating in clandestine or otherwise unregulated circumstances, leaving themselves open to threats to their health and safety.

One remedy to this situation is the availability of subsistence and income generating opportunities. This is a primary function of government, and clearly more effort has to be made to promote economic development, particularly in the sectors of agriculture and industry. Given the royalties which are paid to the national government by the gold mining industry, consideration could be given to directing some portion of that revenue to local economic development and economic diversification within mining regions.

One area where the large-scale mining sector can assist is in identifying opportunities for import replacement of goods and services, which are currently brought into the country for the support of these operations. Oftentimes, these various mining companies have their separate arrangements with overseas suppliers with little thought given to the overall local market represented by their total purchase. A joint effort by these companies to identify products which they each purchase overseas and which could be produced locally could be useful information to local entrepreneurs, industrialists and economic development officers and could be the stimulus to seeding local initiatives. (Gold Fields Ghana has made substantial efforts to identify opportunities for local purchasing. Indeed, its activities have provided local companies with the track record to allow them to successfully pursue business with other large-scale mining operations.)

6.4 Enforcement

Finally, the galamsey also represent a law enforcement challenge. The encroachment of the legal rights of others (including property rights, concession rights and licence provisions of both large scale and small scale mining operators) is a serious problem which not only harms beneficial economic activity but also undermines respect for authority and the rule of law in this country. The fundamental role of the state is to ensure the protection of individuals against threats to the security of their life and property. The galamsey problem represents a challenge to this primary function, and it is no satisfactory substitute for individuals or corporations to secure their own private protection. The state must be the ultimate enforcement authority within a country and it should not countenance continuing illegal activity which threatens the security of communities and the economic development of the nation. The government must be called upon to enforce existing laws if Ghana is to secure the benefits of its natural resources for its own people.

7.0 CONCLUSION

The galamsey are a growing problem affecting the gold mining industry in Ghana. Their activities have always raised concerns relating to environmental degradation, social disintegration and the health and safety risks experienced by the galamsey themselves. As well, the unnecessary loss of gold resulting from their poorer extraction and recovery methods is an unfortunate cost to the Ghana economy as a whole. However, the multiplying presence and the increasingly aggressive nature of the galamsey operations directly threatens the viability of the legal mining sector, both small and large scale, through the disruption of the production processes, the sterilisation of gold deposits and the uncertainty regarding production which these activities engender.
This report proposes a three-pronged, comprehensive strategy for addressing the galamsey problem. Firstly, the regulatory framework governing the legal small scale mining sector should be reviewed, to reduce any obstacles inhibiting individuals from participating and to identify ways to strengthen the legal small scale mining sector, including expanding the identification of appropriate sites for small scale mining. Secondly, greater efforts must be made to promote economic development in and around mining communities, to offer economic alternatives to galamsey work. Using some portion of royalties to finance such initiatives examining opportunities for import replacement of mining sector purchases are some possible approaches.

Finally, the government must commit to a greater emphasis on enforcing existing laws and defending property rights, to ensure security and stability within this critical component of the Ghanaian economy.
PART III: SCIENTIFIC PRESENTATIONS

ANALYZING RAINFALL FACTORS TO ESTIMATE SOIL LOSS FROM DEGRADED LANDS AND MINE SPOILS

A. Ayensu
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ABSTRACT

One serious impact of surface mining on the environment is the creation of degraded lands and mine spoils which when exposed to severe tropical weather conditions of heavy storms and high temperatures cause extensive erosion, sedimentation in rivers and atmospheric pollution from dust particles. There is considerable evidence of a close association between erosion and rainfall intensity and kinetic energy; and the ability to assess numerically the erosive power of rainfall has important applications in soil conservation practices in the mining sector, as well as enhancing or understanding of erosion processes. Wischmeier El30, Hudson KE>25, Roose 0.85H and Fournier p^3/P indices were calculated to assess the storm erosivity and to compare the relative levels of erosion hazards in areas of degraded lands and bare soils. The values of the annual erosivity indices are very high, particularly, for the Western Region of Ghana where there is extensive surface mining operations and therefore appropriate conservation measures must be adopted to protect the vegetation cover after the mining operations have ceased. From the analysis of the rainfall data and computation of the erosivity indices, an empirical relationship, Q = 1.12P, was established between the amount of soil loss, Q (tonne/hectare) and precipitation, P (mm).

1.0 INTRODUCTION

All mining activities disturb the soil on which they occur and hence, destroy the protective vegetative cover over much of the area. The subsequent exposure of the soil to raindrops together with compaction of the soil surface reduce soil infiltration, and increase runoff and erosion. Surface or strip mining consists of removing the over burden from the mineral vein and removing the ore with large power shovels. Surface mining in Ghana is expected to develop faster than shaft mining in the future and for each unit of mineral produced, surface mining will disturb more than ten times as much land as shaft mining. In addition, the mine spoils degrade the environment and must be stabilized by vegetation. These problems have become much more serious in areas where surface mining concessions have been granted, such as Tarkwa.

The exposure of degraded and unprotected lands to rainfall kinetic energy and intensity and the associated soil loss is the subject of this paper. Following previous work done [1, 2, 3], a presentation will be made to estimate the amount of soil loss resulting from interaction of raindrops with bare soil, and discuss an iso-erodent map for Ghana based on an erosivity index. The amount of soil loss and the potential erosion hazards will be correlated with the amount of rainfall.

2.0 SOIL LOSS TOLERANCE

It is not possible to prevent erosion, but it is both possible and necessary to reduce erosion losses to tolerable rates. Tolerable soil loss is the maximum rate of soil erosion that will permit indefinite maintenance of soil productivity.
A loss of one tonne of soil per hectare is equivalent to 0.075 mm depth of soil loss [4], and if this loss occurs each year then 1 cm of soil will be lost in approximately 133 years. The depth of soil development, \( Y \), from fertile land can be predicted from the equation [5]

\[
Y = 0.36t^{0.6}
\]  

(1)

where \( t \) is time in years. From eqn (1), the rate of soil development can be estimated as

\[
\frac{dt}{dY} = 11Y^{0.8}
\]  

(2)

where \( \frac{dt}{dY} \) represents the number of years to form 1 cm of new soil. Equation (2) indicates that new soil develops at the rate of 1 cm/11 years at 1-cm depth, 1 cm/230 years at 50-cm depth, and 1 cm/405 years at a depth of 1 m. The rate, of course varies with the nature of the parent material and the climatic conditions as well as the depth of the overlying soil.

Erosion is generally influenced by the extent to which the soil is protected from the energy of the rainfall or surface runoff by vegetation cover. The experimental results obtained for the relationship between relative soil loss and soil cover is shown in Fig.1 [6], which clearly illustrates the importance of soil cover in minimizing soil erosion.

![Fig 1. Relationship between cover and soil loss](image)

3.0 EROSION PREDICTION MODELS AND EROSIVITY INDICES

Estimating soil loss from either empirical or processed-based models is difficult because of the many naturally occurring variables involved, such as soil types and rainfall characteristics. In the tropics, the effect of extreme rainfall events dominate the total amount of soil loss, and the prediction of soil loss becomes heavily dependent upon rainfall probability studies. Losses represent the gross amount of soil detached and transported, including soil re-deposited, since movement of soil by water in particular occurs in the three stages of detachment of individual grains (particles and aggregates), transportation over the land surface and deposition of soil floating in suspension as sediment.
3.1. The Universal Soil Loss Equation (USLE)

USLE provides an estimate of the long-term average annual soil loss from segments of arable land under various cropping conditions, and is represented in the form [7, 8]

\[ A = R \times K \times L \times S \times C \times P \]

where \( A \) is the average annual soil loss (tonnes/hectare); \( R \) is a measure of the erosive power of rainfall and runoff (MJ/ha x cm/h); \( K \) is soil erodibility factor, i.e., the susceptibility of a soil type to erosion or reciprocal of soil resistance to erosion (m/ha) per (MJ/ha x cm/h); \( L \) is length factor, \( S \) is slope factor, \( C \) is crop management factor and \( P \) is conservation practice factor. The terms \( L \), \( S \), \( C \), and \( P \) are dimensionless.

The erosivity index, \( R \), is determined as \( EI_{30} \), which is computed by the summation for each storm the kinetic energy, \( E \) (MJ/ha or J/m²) multiplied by the greatest amount of rain in any 30 minute period, or the maximum 30 minute intensity, \( I_{30} \), (cm/h or mm/h). The erodibility factor, \( K \) is the average soil loss in tonnes/hectare for each unit of \( R \) measured in MJ/ha x cm/h or kJ/m² x mm/h. It must be mentioned that the effect on erosion of the state of the ground becomes critical if the ground is bare and rains are highly erosive (see Fig. 1).

3.2. Other Empirical Models

In most developing countries, there are few available climatic data base as compared to the USA, where the USLE has been found to be most applicable. Other forms of erosion prediction models are therefore required to handle the estimation of soil loss. A very good example is the soil loss estimation model for Southern Africa (SLEMSA) [9, 10] as shown in Fig 2. The rainfall erosivity index, \( R \), is a measure of the total annual kinetic energy of the rainfall, \( KE \), which is easier to compute from rainfall records than \( EI \).

![Fig 2 Structure of SLEMSA](image)

3.3 Erosivity Indices

For tropical rain of intensity, \( I \), Hudson [11, 12] proposed an erosivity index based on the kinetic energy per rainfall amount, \( KE \) (Jm²/mm)
\[ KE = 29.80 - 12.75 \frac{I}{I} \]

The index is referred to as KE > 25, because it assumes that erosion in the tropics is almost entirely caused by rain falling at intensities greater than 25 mm/h.

Wischmeier and Smith [7] suggested that for soil loss by splash, overland flow and rill erosion, the kinetic energy of the rainfall can be calculated from the equation

\[ E = 11.89 + 8.73 \log_{10} I \]

from which the index, R, can be determined.

To establish a correlation between the EI30, and KE >25 indices, it is expedient to represent Hudson index as KEI25, which can be computed in similar manner as EI30, by using energy values for which the intensity equals 25 mm/h or greater. Equations (4) and (5) give nearly the same results for the rainfall energy.

It is not essential to have all the detailed information or data on kinetic energy and intensity before making erosion predictions. Roose [13] studied the limited climatic data available in West Africa and outlined that an iso-erodent map of an area can be prepared from a rainfall erosivity index based on the average annual rainfall, H (mm), with an error of 5% or less by using the equation:

\[ R = 0.85H \]

Using eqn (6), a first approximation of the relative erosivity can be made.

An index also based on the annual precipitation has been developed by Fournier [14, 15] and is of the form

\[ R = \frac{\rho}{P} \]

where \( \rho \) is the maximum mean monthly rainfall and P is the total annual rainfall. Figure 3 illustrates the level of soil erosion in Africa based on Fournier index.

![Fig. 3. An iso-erodent map of Africa based on Fournier index](image)

**4.0 Correlation of Rainfall Factors with Amount of Soil Loss**

The annual rainfall data used in this study covered the period of 30 years, from 1960 - 1990 [16]. In addition rainfall intensity data were obtained by using a continuously recording rain gauge (Dine's...
tropical tilting siphon type) which records on a chart the cumulative rainfall amount as a function of time. Figure 4 shows a typical recording of storm event. The kinetic energy values calculated from eqns (3) and (4) are shown in Table 1.

Fig. 4 A record of rainstorm event

4.1. Computation of El30 index

With reference to Fig. 4, the product of total energy of rainfall and the maximum 30 minutes intensity was computed to give a value for El30 index as illustrated by the calculation below:

Maximum 30 mm rainfall = 19.177 + 2.540 mm = 21.717 mm
Maximum 30 mm intensity, \(I_{30}\) = 21.717 x 2 mm h\(^{-1}\) = 43.434 mm/h = 4.343 cm/h
Total kinetic energy, \(E\) (= total of column 7) = 972.795 J/m\(^2\) = 9.728 MJ/ha
\(R = E_{30}\) index = 42.252 kJ/m\(^2\) x mm/h = 42.252 MJ/ha x cm/h

Hence the equivalent amount of soil loss due to that storm = 42.252 tonne/hectare

4.2 Computation of KEI32 Index

The kinetic energy values for which the rainfall intensities were equal or greater than 25 mm/h were considered as the summation for the total energy (Table 1).

Total KE = (column 7, total of lines 1 & 7) = 641.847 J/m\(^2\) = 6.419 MJ/ha
Sum of \(I_{32}\) = 88.01 mm/h = 8.80 cm/h
\(R\) = KE \(I_{32}\) index = 56.489 kJ/m\(^2\) x mm/h = 56.489 MJ/ha x cm/h

Hence the equivalent amount of soil loss due to that storm = 56.489 tonne/hectare

4.3 Roose 0.85 H Index

This index is relative and is used to compare erosivity hazard levels or to construct erosivity map. The mean annual precipitation for a 30 year period was obtained [16] and the index computed. The Roose index for some locations in Ghana are as follows: Axim: 1991; Tarkwa: 1525; Kumasi: 1235; Komenda: 1217; and Tamale: 851; Accra. 786.
<table>
<thead>
<tr>
<th>CLOCK</th>
<th>TIME</th>
<th>INTERVAL t/min</th>
<th>STORM RANGE (mm)</th>
<th>RAINFALL AMOUNT P (mm)</th>
<th>INTENSITY I (mm/h)</th>
<th>KINETIC ENERGY E (J m(^2)/mm)</th>
<th>TOTAL ENERGY (J m(^2)) (COL 4 X COL 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.10-13.30</td>
<td>20</td>
<td>0.000-19.177</td>
<td>19.177</td>
<td>57.531</td>
<td>27.234</td>
<td>29.578</td>
<td>522.564 (Total) 567.217 (Total)</td>
</tr>
<tr>
<td>14.00-14.10</td>
<td>10</td>
<td>19.177-21.717</td>
<td>2.540</td>
<td>15.531</td>
<td>22.269</td>
<td>28.979</td>
<td>56.564 (Total) 73.607 (Total)</td>
</tr>
<tr>
<td>14.10-16.30</td>
<td>80</td>
<td>21.717-24.130</td>
<td>2.413</td>
<td>1.810</td>
<td>14.119</td>
<td>22.756</td>
<td>34.069 (Total) 54.910 (Total)</td>
</tr>
<tr>
<td>23.20-23.25</td>
<td>5</td>
<td>36.830-39.570</td>
<td>2.540</td>
<td>30.480</td>
<td>24.826</td>
<td>29.382</td>
<td>63.057 (Total) 74.630 (Total)</td>
</tr>
</tbody>
</table>

TOTAL ENERGY (J m\(^2\)) = (COL 4 X COL 6)
4.4. Fournier Index

An erosivity map for Ghana was constructed from Fournier Index with 50 mm as the base line to delineate 5 regions of erosion risk hazards ranging from slight, moderate, less severe, severe to very severe risk as shown in Fig. 5. Western Region falls within erosion hazard zone ranging from moderate to very severe erosion risk, as compared to other regions of Ghana.

![Fig. 5. An erosivity map of Ghana.](image)

5.0 DISCUSSION

Both soil and water can be conserved by protecting the soil from raindrops that would puddle the surface and cause crust to form. Plant materials intercepting raindrop help to maintain a condition that allows water to infiltrate instead of running off and also reducing splash erosion. The mean value of the amount of soil loss due to the storm event shown in Fig. 4 can be estimated to be $49 \pm 7$ mt/ha. If 1 mt/ha of soil loss is equivalent to 0.08 mm depth of soil loss [4], then the particular storm analyzed would cause erosion of the soil to the depth of nearly 4 mm; alternatively, about three such storms would cause a soil loss to a depth of over 1 cm on bare land. This high value of storm erosivity is a reflection of level of environmental degradation of exposed and bare lands or mine spoils. By combining the rainfall factors of intensity, kinetic energy and total amount, and using the compound indices of Hudson and Wischmeier a relationship was established between precipitation, $P$ (mm) and amount of soil loss, $Q$ (mt/ha) from bare and degraded lands. This is illustrated by Fig. 6, and represented by the equation,

$$Q = 1.12P$$ (8)
An eroded soil is degraded chemically, physically and biologically, since the sorting action or water removes a high proportion of the clay and humus from the soil and leaves the less productive coarse sand, gravels and stones behind. Eroded mine spoil is now recognized as a major cause of air and water pollution, since erosion produces dust clouds and muddy waters, and the eroded soil particles carry plant nutrients and other toxic chemicals that contaminate water. Eroded soils have therefore become an environmental problem that must be remedied for the sake of clean air and water.

Reducing erosion would therefore keep streams, ponds and lakes from filling rapidly with sediment and causing flooding. Keeping sediment out of water also avoids the build up of plant nutrients in the water and thereby reducing unwanted growth of algae and other vegetation.

6.0 CONCLUSIONS

The ability to assess numerically the erosivity power of rainfall has practical applications in soil conservation. From the calculations of the indices, the annual erosivity indices are high and appropriate conservation measures must be adopted by encouraging re-vegetation and afforestation of bare and degraded mine spoils, since the major effect of vegetation in reducing erosion is to provide resistance to soil movement, improve aggregation and porosity of the soils, and increase biological action in the soil.

REFERENCES


ABSTRACT

Degradation of tropical forests is a problem facing many developing countries but the cause of degradation varies from one country to another. In Ghana the most recent cause of degradation of the forest resources is surface mining. Being a recent activity there has been little or no research nor has there been any serious discussion on its effect on the forest. There have also been no research nor discussion on methods of rehabilitating the degraded forests. However surface mining is being undertaken in both reserved and unreserved forests in almost all regions of Ghana and the impact of this activity affects the forest climate, soil and structure. There is the urgent need therefore to initiate discussions on both the impact on the forest and methods for rehabilitating degraded forests.

This paper therefore reviews the impact of surface mining on the forest climate, soil and structure. It also reviews processes that can be used to rehabilitate the degraded forest and indicators for determining success or otherwise of the rehabilitation programme. It concludes by proposing for the conduction of research for the establishment of guidelines for rehabilitation of the degraded forests.

INTRODUCTION

The continuous search for food and socio economic development by the increasing population have led to the degradation of the forest resources of Ghana. It is estimated by Hawthorne and Musa (1995) that about half of the reserved forests have been degraded and although there are no estimates for the forest areas outside reserves, it is assumed that over 75% of these areas have been degraded. The degradation has in the past been due to activities of shifting cultivation, logging practices, production of firewood and charcoal, over grazing and fodder collection, and accidental or deliberate burning. Recently however surface mining has become one of these activities. But while most of the other activities affect only the forest structure, surface mining affect the forest structure, soil and the atmosphere. Thus damage by mining is bound to be both extensive and intensive and should therefore be given special and immediate attention if these areas are to return to productivity.

Before any efforts are made at rehabilitating those areas so as to make them productive, there is the need to know the extent to which mining activity has affected the forest. However being a recent activity there has been no research or discussion on its impact on the forests, nor on method by which the forests can be rehabilitated after mining. There is the need to initiate these discussions and research so that mined forests can be rehabilitated as urgently as possible. This paper therefore contributes to this discussion by reviewing the possible impact of mining on the forest and possible methods that can be used to rehabilitate the forests. It also reviews indicators for determining the success or otherwise of a rehabilitation programme.
Impact on Vegetation

Surface mining affects vegetation through its effect on (i) biodiversity; (ii) climate and hydrological cycle; (iii) nutrient cycling and (iv) physiological functions of the vegetation.

Effect on Biodiversity

Mining initially starts by clearing of the forest vegetation on the areas to be mined. This inevitably leads to loss of timber species as well as non timber species which provides variety of products including medicines, chewing sticks, pestles, mortars, construction materials etc. It also destroys the habitat for wildlife and other species such as snails and mushrooms.

Effect on Climate and Hydrological Cycle

Clearing of the forest also means that the forest canopy that covers the soil is also lost and this alters the microclimate in those areas. The alteration of the micro-climate eventually affects the rehabilitation of the degraded site since it will influence the successful establishment of seedlings that will be planted to rehabilitate the site (McChesney et al, 1995).

Destruction of the forest may also accelerate warming of the atmosphere mainly for two reasons: The clearing of the forest vegetation means that CO₂, which should have been used for photosynthesis is still available and is therefore released to the atmosphere and this adds to the greenhouse effect: reduced evapotranspiration from cleared areas permits more radiation energy to be transformed directly into heat. Consequently this will also lead to a net increase in temperature.

Destruction of the forest will impair the regulating effect of the forested watersheds causing floods and water shortage down the river.

The increased run off as a result of the floods and reduced evapotranspiration due to the absence of the forest vegetation, will reduce the quantity of water in the lower hydrological cycle and therefore reduced local rainfall.

Effect on Nutrient Cycle

Numerous studies have demonstrated that about 80%-90% of the essential plant nutrients with the exception of nitrogen and phosphorus, in a tropical forest ecosystem are stored in the vegetation (Jordan, 1985, Ruhiyat, 1989).

Thus clearing of the vegetation will directly export these essential nutrients out of the ecosystem thereby reducing nutrients that can support growth in these ecosystems.

Effects on Physiological Functions

When the mine is operational, harmful gases and substances may be released into the atmosphere. These include sulphur dioxide (SO₂), nitrogen oxides (NOₓ) and heavy metals such as lead, cadmium, zinc and mercury. Sulphur dioxide which is easily transportable penetrates the stomata of leaves and directly penetrates the leaves. There, it dissolves in the cell fluid and becomes an acid. Large amounts of the acid destroy the cells and this causes the leaves to die due to
dehydration and fall off. Even small amounts which do not kill the leaves hinder anabolic capacity and this will cause premature ageing and premature leaf loss. Penetration of sulphur dioxide into the stomata also impairs the closing mechanism of the stomata and this makes the trees an important safeguard against transpiration or water loss. Thus during the dry season the trees may lose large amounts of water which if not resupplied quickly by the trees will lead to the death of the trees.

The gas can also dissolve in water from rainfall or moist leaves and becomes converted to sulphurous acid \( \text{H}_2\text{SO}_3 \), or sulphuric acid \( \text{H}_2\text{SO}_4 \) together with other acids primarily nitric acid which is also formed from the nitrous oxides then makes rainfall acidic. Acid rain damages the wax-like film of the assimilating organs of plants and also penetrate the inside of leaves. There they wash out nutrients carried in heavy metals and disrupt the plants enzyme balance.

The heavy metals also invade the trees either through the surfaces of the leaves or through the roots and disrupt enzymatic processes (Engelberth and Jahn, 1989).

All these either decreases the growth rate of the forest plants or makes many of the plants to be diseased.

**IMPACT ON SOIL PROPERTIES**

(i) *Nutrients*

Surface mining results in the removal of the soil surface substrate. The remaining exposed substrate is deficient in nitrogen, phosphorus, calcium and potassium but with high amounts of nickel, iron and chromium. The soils have a low pH and are also characterized by shortages of organic matter (Buckley, 1988, Cherrier, 1990, Mungkorndin, 1995). Acidification of the soil also results in nutrients such as potassium, calcium, and magnesium being washed out from the upper layers of the soil. Aluminium and iron ions then enter the soil solution and damage the fine roots.

(ii) *Temperature*

Due to lack of cover over the soil, it tends to be drier and diurnal temperatures fluctuate widely.

(iii) *Infiltration rate and run off*

The use of heavy machinery at the mined sites compacts the soil. This reduces penetrability and infiltration rates (Abdulhadi et al, 1981) and this increases run off and soil losses by erosion (Kelman, 1969).

(iv) *Water table*

Deformation of the soil surface also disturbs the hydrologic regime and this makes the water table to rise and these areas are therefore prone to flooding whenever there is any heavy rainfall.
PROCESSES FOR REHABILITATION

Limiting factors

The degraded mine sites can be rehabilitated through natural succession. However the succession may occur at slow rate relative to the time scale of human interests because of persistent physical, chemical and biological barriers (Nepstead, 1992). Some of these barriers as already mentioned may include the following low soil nutrition, non-availability of suitable microhabitats, for plant establishment and low availability of seeds. Thus rehabilitation aims at removing these factors and accelerate the speed and control direction and acceleration of the succession process through active intervention.

Thus to rehabilitate successfully a degraded site using the ecological approach, factors that may limit the rate of change may need to be identified and strategies developed to remove the limitations.

METHODS

1 Restoration of soil properties

The soil conditions can be ameliorated by the following methods

(i) Restoring lost nutrients

Essential nutrients lost can be restored by replacing the topsoil removed during the mining operations. Replacement can be done with the original topsoil which had been put aside for this purpose or with top soil collected from surrounding forests. However since collection of large amounts of soil from the surrounding forests will contribute to the damage of the soil in those areas, it is advisable to set aside the original topsoil for this purpose. When it is also realised that the soil is very deficient in particular nutrients, fertilisers can be applied to improve the status of the particular nutrients.

(ii) Restoring organic matter

Mulch can be mixed in with the soil and also applied to the soil surface to restore the organic matter. Mulch on top of the soil surface can also help to keep the soil moist and cool.

(iii) Reduction of acidity

The acid content of the soils can be reduced by applying lime to the surface of the soils.

2. Restoration of vegetation

The degree to which planted trees can be used to rehabilitate degraded site is influenced by several factors, amongst the most important are species selection, plantation design and management practices.
Species Selection

The choice of species to be used for the rehabilitation can influence both the rate and direction of the rehabilitation process. Therefore species to be selected should preferably:

(i) Be fast growing so as to restore tree cover as rapidly as possible and provide for the maximisation of vegetation cover.

(ii) Be nitrogen fixing so that it can have dramatic effect on soil fertility through their production of readily decomposable nutrient rich litter and turn over of fine roots and nodules.

(iii) Have a potential end use so that local communities living close to the rehabilitated site can utilise the species when matured.

(iv) Be fairly resistant to effects of pollution.

Design

Planting design that needs to be considered is the planting density. The density should be such that it can facilitate the recruitment of other secondary forest species and also help to maintain sufficient cover to ease understorey seedling competition with grasses through shading and to provide sufficient habitat diversity for birds and other dispersal agents.

Management

The planted species should be protected from fire, pests, and diseases. When the species is ready to be harvested they should be harvested in such a way as to ensure that at least part of the canopy is always maintained. Trees which become diseased should be felled but the felling should be done so as carefully to maintain part of the canopy.

Potential Indicators of Success of Rehabilitation

How can one determine that a rehabilitation programme has been successful. Lamb 1988 lists the following as indicators of a success of a rehabilitation programme:

- Stable soil surface.
- Presence of adequate plant cover and growth.
- Appropriate plant species composition and structure.
- Appropriate animal populations.
- Adequate regeneration or reproduction of preferred species.
- Acceptable water quality.

Evaluation of the rehabilitated site in terms of these indicators would determine if the rehabilitation have been successful or not.
CONCLUSION

As demands for better socio-economic development grow, proportion of forest land that will be degraded by surface mining in Ghana will continue to increase. Unfortunately these systems have received little or no research attention. There is therefore the need to promote research, targeted at determining guidelines for rehabilitating these areas given that each country and ecozones offers special challenges and opportunities at rehabilitation efforts.

REFERENCES


THE MANAGEMENT OF A MINERAL DEPOSIT IN A FOREST AREA:
A COMPUTERISED APPROACH

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ABSTRACT

Vegetation is a vital component of the biosphere and landscape and it should always be seen in that setting and as an integral part of the environment. In attempting to assess the viability of exploiting a mineral deposit in a specific study area in a typical developing country, a mineral resource manager may desire to know the types and acreage of forests that may be affected by such an activity.

This paper highlights the potential contributions that Geographical Information Systems (GIS) can make in the various analysis of data sets in the management of a mineral deposit in a forest area. Reserved and rain forests, as well as other vital vegetation that may be affected by the proposed mineral activity are analysed and quantified. GIS is shown to be a potential tool that can assist policy makers in the minerals industry in developing countries so that their decisions as regards the exploitation of a deposit will be more closely targeted hence more environmentally friendly.

INTRODUCTION

Forest management is a subject of major public interest in Ghana. The assessment of the effects that the exploitation of minerals have on other natural resources such as forests and wildlife requires the handling of substantial amount of spatially referenced data sets. In this application area, GIS serves as a unified data base for the analysis, manipulation, displays and storage of the results of the analysis performed.

Forest vegetation is usually the dominant vegetation in high rainfall areas, which are also the prime source of river flows. To destroy the natural forest is to destroy nature's first line of defence against the ravages of the sun, wind and water flow following heavy rainfall.

Using Geographical Information Systems (GIS), a computer-based tool, many governments and investors can undertake elaborate analysis of a whole spectrum of factors that may assuage the harmful effects of a mineral deposit exploitation.

A wide variety of natural resources and phenomena are intimately linked to forest ecology. Examples of these are non-wood forest products availability, retention of areas of scientific and archaeological interest, requirements of forest dwellers, wildlife habitats, watersheds and climate changes. The quality and quantity of these play an important part in determining the quality of our lives (Asabere, 1993).

Forests are not only important economic resource yielding wood products, but also produce benefits of flood mitigation, erosion control and landslide prevention. In addition, they also offer
recreation. As prospecting techniques improve and the economic climate changes, mining operations are being introduced into the remote areas in Ghana to exploit mineral deposits.

Using GIS for land use planning has much to recommend. For example, GIS can be used to construct a range of alternative scenarios for different policies and provides a tool to assist in the assessment of their relative merits (Davidson, 1991). Existing forestry inventory and management activities can both benefit from the flexibility and speed of data handling provided by GIS. Additionally, GIS provides opportunities for extending the range and content of inventory and management activity through the provision of analytical tools relevant to the analysis of forest resource data (Calkins et al., 1977).

A common theme that underlies GIS applications in forestry has been the need to examine the extent to which forestry might compete economically with alternative land use such as mining. The main objective of forest resources analysis is to provide an efficient base for decision making for mineral resources management, to accelerate the updating and processing of land data and to establish a core system for other land-related systems. The advantage of GIS application in forestry management is that it provides relatively objective criteria and methodologies for the selection of land for any other use.

Managers of forests in developing countries have to balance an increasing variety of demands on the resource base for which they are responsible (Carman, 1979). Forests can no longer be considered as infinite source of wood and related products but must be regarded as finite renewable natural resource with complex ecologies. GIS will enable forest managers to combine ecological, environmental, social and economic data sets together with forestry detail to ensure a more efficient mineral resource activity in forest areas (Braken et al., 1990).

Management issues relating to the entire life of a tree crop can be addressed using GIS. For example, GIS can be used to both plan and manage programmes of management activities within a forest unit. (species selection, site preparation, planting, silviculture, timber extraction etc.) optimal layout of forest road networks, calculate volumes and areas of cuttable timber and to plan timber extraction programmes to make effective use of machinery.

Watershed management based on modelling hydrological and chemical impacts of different forest management activities can be achieved through the application of GIS. Wildlife habitat relationships within the forests can be investigated and managed from analysis of wildlife species and habitat distribution data held in the forest inventory. All these aspects of the use of GIS can provide information which can be of value in mineral evaluation decisions.

Geographical Information Systems have the capacity to analyse economic data in a spatial sense. Distortion of economic data due to location can be identified and presented in a graphical form. Such presentation of economic data based on location is an effective tool for communicating with policy makers. Analysis of spatially derived data can be useful in isolating the locational effects of policies and programmes. Thematic maps showing the outcome of policy research and analysis are more readily understood by mineral managers than tabular and statistical presentation of spatially referenced economic data.

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PROBLEMS OF GIS IMPLEMENTATION

All planning activities in connection with land use or environment protection need data about objects in space as they are traditionally shown on maps. But for different planning purposes different data are needed and often the form should be specially adapted. Traditional surveying techniques make it difficult to transfer information on one map into a new map of different scale. The process requires expensive and time consuming manual work, and it is impossible to combine in one drawing data represented on different maps.

A more basic barrier to progress relates to a lack of understanding of the capabilities of automated systems. Many merely regard GIS as computer-based map-editing systems. However, the value of geographic information handling methods is potentially much greater, permitting analyses of the data and the use of the data within physical models (NERC, 1988).

As regards developing countries there is the problem of the lack of compatibility of the currently available microcomputer packages to the conditions in developing countries (Freeland, 1986; Robinson, 1979). The general problem with existing packages is that they have been developed for the North American, Western European or other markets. A GIS that is suitable for country and state planning in Canada will not necessarily be suitable for natural resource management in a developing country, partly because of the difference in scale and partly because of constraints of cost, lack of skilled manpower and the unavailability of hardware and software support in developing countries.

DATA CAPTURE AND ANALYSIS

Forest inventory forms a primary tool for forest resource management. Forest inventory is an exercise carried out to assess the distribution and status of the forest resource. Typically it involves a variety of data collection and analysis methods (for example, field mapping, aerial photography, cartography) which provide data used to update forest maps. Update times ideally should be as short as possible, to allow forest managers access to the most up-to-date data, but the quantity of data, as well as the processing required, means that traditional methods of inventory update are relatively slow. However, the data collected to update the forest inventory can be readily integrated using GIS. This automation offers considerable savings in both time and effort.

The study area encompasses a range of hills, the largest being Wuwuo Hill. Preliminary investigations have revealed (assuming ore thickness of 10 m) the existence that about 147 million tons of iron ore of 52.5% (average 35.3%) iron content in 13 hills.

Production plans estimate that 760,000 tons per year of crude iron will be mined and the deposit will last for twenty years. The ore-body with practically no overburden is ideally suitable for surface mining technology. Figures one and figure two describe the study area and the specific location.
Fig. 1 Study area

Fig. 2 Locational map
The capturing and source information was undertaken on a digitizing tablet as an integral part of the mapping work station. Before digitizing could begin, pre-input editing was undertaken by soil experts and cartographers. Owing to the complexity of the data layers, simplified versions of each map was used.

The software functional modules were employed to create topological layers from the geology, soils and land use data set obtained from the Ghana National Atlas Company. Using the basic polygon overlay functions, various scenarios of the base data were created. These define the likelihood of the effects of the mineral activity on a forest resource and the extent of this effect. Table one below shows some of the primary data layers that were input in the research.

**TABLE 1 : PRIMARY DATA LAYERS**

<table>
<thead>
<tr>
<th>Primary Thematic Data Layers with Data Sources</th>
<th>Thematic Data Layer Title</th>
<th>Data Source</th>
<th>Means of Data Capture</th>
<th>GIS Analytical Function Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation &amp; Land Use</td>
<td>Existing Maps</td>
<td>Digitise, Key-in</td>
<td>Filter, Overlay, Reclassify, Assign</td>
<td></td>
</tr>
<tr>
<td>Rain Forest</td>
<td>Existing Maps</td>
<td>Digitise, Key-in</td>
<td>Filter, Overlay, Reclassify, Window</td>
<td></td>
</tr>
<tr>
<td>Secondary Forest</td>
<td>Existing Maps</td>
<td>Digitise, Attribute</td>
<td>Filter, Overlay, Reclassify, Assign</td>
<td></td>
</tr>
<tr>
<td>Great Soils</td>
<td>Existing Maps</td>
<td>Digitise, Key-in</td>
<td>Filter, Overlay, Reclassify, Window</td>
<td></td>
</tr>
<tr>
<td>Cocoa Areas</td>
<td>Existing Maps</td>
<td>Digitise</td>
<td>Filter, Overlay, Reclassify, Window</td>
<td></td>
</tr>
<tr>
<td>Banana Areas</td>
<td>Existing Maps</td>
<td>Digitise</td>
<td>Overlay, Assign Reclassify</td>
<td></td>
</tr>
</tbody>
</table>

**RESEARCH STRATEGY**

To evaluate the effect of mining on the forest and crops, a series of spatial data layers is manipulated to perform analytical tasks. In order to examine the relationships of mapped characteristics, the GIS software is used to produce statistical summaries of land area covered, for example, by cola, cocoa, bananas, reserve forest, rain forest etc. within the study area. The resulting data files are used in statistical analysis to examine the possible associations between the land area and the landcover (Asabere *et al*., 1992).

Initially the polygons representing cocoa growing areas close to the study site were digitised from the (1:2000000) vegetation map of Ghana along with other identifying topographic detail. The image is then filtered to remove any 'noises' and a digital, topological database is created for GIS analysis. The site image is prepared for spatial overlay with the cocoa image. Knowledge of the types of vegetation covering the land ensured that a qualitative decision could be made about the exploitation of the deposit.
In order to overlay the site image on the cocoa growing areas layer the latter layer had to be reclassed. The combined uses of overlay, windowing, expansion etc. of cocoa growing areas image and the district image produced the final map. Similar operations were performed for the palm plantation, rain forest etc, in the vicinity of the deposit. Various scenarios, using GIS, are developed to analyse, predict and explain the dynamic development of cash crops and plantations damage, and also to depict the distribution of those spatial factors that cause forest and vegetation damage (see figure 3 below).

Fig.3 Forest resources spatial analysis
Table 2 below depicts the areas of the various categories analysed in this research.

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>AREA (Sq. Km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana Farms</td>
<td>900</td>
</tr>
<tr>
<td>Cola Farms</td>
<td>500</td>
</tr>
<tr>
<td>Reserved Forest</td>
<td>700</td>
</tr>
<tr>
<td>Cocoa Farms</td>
<td>300</td>
</tr>
<tr>
<td>Rain Forest</td>
<td>0</td>
</tr>
<tr>
<td>Palm Plantation</td>
<td>0</td>
</tr>
</tbody>
</table>

Full and objective analysis of natural resources and land use planning (Bache et al. 1984, Blunden 1985) is complex and large volumes of detailed, diverse information must be correlated to enable effective decision making. Prediction and forecasting are subjects for sophisticated data modelling. Remotely sensed data is one source of data which might be of use in resource management. For effective management of natural resources and assessment of environmental impact, information has to be accurate, timely, comprehensive, readily retrievable and capable of being subjected to a large and flexible range of analysis and interactive display approaches (MacRae et al., 1983).

**DISCUSSION**

The study has shown that, 300 square kilometres of cocoa farms, 500 square kilometres of cola farms (both cash crops), 700 square kilometres of reserved forest and 900 square kilometres of banana farms would be affected if a decision is taken to exploit the iron ore deposit. Knowing the extent of damage to crops etc. would assist in assessing the amount that would be involved in compensation payouts before the mine begins to operate. Table 3 shows the quantities of crops that can be obtained per season from that tract of land if the extraction of the ore using, surface mining technology never took place. The cost of these cash crops could be imputed against the cash flow of the company before a scientific decision could be arrived at.

After the palm plantation and rain forest images and site image had undergone polygonal spatial analysis, it became clear that the exploitation of the deposit will not affect the palm plantations and rain forest in the study area.

The use of GIS to produce forest inventory, apart from the cartographic benefits, also results in data which are in a form immediately amenable to further analysis; this offers the opportunities for a wide range of investigation not possible for data held only as map hardcopy and thereby provides resource managers with a tool for planning and management. This tool will assist resource managers in their tasks of taking responsible decisions about mineral resources management especially when conflicting interests are at stake (Asabere, 1992).
TABLE 3: VARIOUS CROP YIELD PER ACRE OF LAND

<table>
<thead>
<tr>
<th>CROP</th>
<th>IMPROVED TECHNOLOGY</th>
<th>LOCAL TECHN.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RESEARCH STATION.</td>
<td>FARMER'S FARM</td>
</tr>
<tr>
<td>MAIZE</td>
<td>3000 lbs</td>
<td>1500 lbs</td>
</tr>
<tr>
<td></td>
<td>30 Bags Shelled</td>
<td>15 bags shld</td>
</tr>
<tr>
<td>RICE</td>
<td>4000 lbs</td>
<td>200 lbs</td>
</tr>
<tr>
<td></td>
<td>40 Bags Shelled</td>
<td>20 bags</td>
</tr>
<tr>
<td>GROUNDNUTS</td>
<td>1700 lbs</td>
<td>800 lbs</td>
</tr>
<tr>
<td></td>
<td>17 Bags</td>
<td>8 bags</td>
</tr>
<tr>
<td>PINEAPPLES</td>
<td>20000</td>
<td>15000</td>
</tr>
<tr>
<td></td>
<td>27000 - 30000</td>
<td>15000 - 20000</td>
</tr>
<tr>
<td>COCOA</td>
<td>1134 - 1260 kgs</td>
<td>630 - 756kgs</td>
</tr>
<tr>
<td>63 kgs/bag</td>
<td>18 - 20 bags</td>
<td>10 - 12 bags</td>
</tr>
<tr>
<td>COFFEE</td>
<td>1527 - 1708 kgs</td>
<td>915 kgs</td>
</tr>
<tr>
<td>61 kgs/bag</td>
<td>25 - 28 bags</td>
<td>15 bags</td>
</tr>
<tr>
<td>CASSAVA</td>
<td>10000 - 16000 kgs</td>
<td>7000 - 10000kgs</td>
</tr>
<tr>
<td>96kgs/bag</td>
<td>104 - 166 bags</td>
<td>73 - 104 bags</td>
</tr>
</tbody>
</table>

Experience has shown that resources are not always exploited to secure maximum benefits and important political considerations also have to be recognised. However, geographical analysis can widely be used in the management of resources optimally and this work contributes to the attainment of that objective. It provides the form of data representation that is appropriate to the portrayal of the socio-economic information. This leads to the identification of local area characteristics; that allows regional and local consideration of relevant factors that have a bearing on the management of forest resources.

CONCLUSION

The impacts of surface mining manifests itself on the surroundings. The nakedness of the environment gives the first impression of how destructive the operation can be. Clearing of the site, surface excavation, levelling of hills, deposition of scars in the earth’s crust, mounting of waste dumps, creation of waste ponds and slimes dams, pollution of the atmosphere with dust and obnoxious gases, drying up of waterbodies, all contribute to the destruction of the scenic and aesthetic value of the bio-diversity of the countryside, not mentioning the potential adverse impacts on the socio-economic and socio-cultural aspects of the immediate inhabitants. Absolute regard must be paid to the use of surface mining technology of minerals extraction.

The results of this research demonstrate that GIS can be used to enhance the process of data integration and spatial analysis both in terms of speed and accuracy, compared to traditional methods. Perhaps more importantly, GIS facilitates the process of scientific modelling by allowing forest managers to develop 'What if' scenarios through the integration of data from a variety of
sources for research, planning and management of forest resources in developing countries. For example, it is relatively easy to change any of the criteria for analysis and then observe the outcome of the new scenarios.

REFERENCES


MINING AND THE ENVIRONMENT IN GHANA - AN ECONOMIC CONTROVERSY

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ABSTRACT

The mining industry in Ghana has contributed tremendously to the economic development of individuals and the nation as a whole. These benefits are evident in the creation of direct and indirect employment and the generation of the much needed foreign exchange. The need for more foreign exchange has resulted in the liberalisation of mining laws to promote mining activities in the country. Increased mining activities in recent times has brought to light attendant environmental problems.

The economic benefits and the environmental degradation constitute an economic controversy. This paper reviews the socio-economic benefits and the negative environmental impact of mining in Ghana. Measures to increase the socio-economic benefits and mitigate the environmental degradation are presented. It is concluded that unless special attention is paid to environmental problems, the cost to resolve them will far outweigh the benefits.

INTRODUCTION

Ghana is endowed with numerous mineral resources (Fig. 1). The need for more foreign exchange to enhance the development of much needed infrastructure has made it necessary to increase the exploitation of these mineral resources to cater for the increasing population and the need for better living standards. This compelled the Government in 1980 to appoint a committee on gold mining to, inter alia, investigate the causes of the downward trend in gold production, examine and isolate fundamental policy decisions which Government should take and encourage gold output in the short term and to examine records of abandoned gold mines and prioritise them on the basis of possible reopening and development as part of a long term programme for increased gold production (Anon, 1980). Although this committee was for gold, their findings and recommendations were applicable for the exploitation of the other principal minerals produced in Ghana. Today, the mining industry employs more than 7% of the labour force in the country and is also the premier foreign exchange earner. It contributes about 15% of the nation's foreign exchange earnings, with gold contributing approximately 90% of the total, whilst diamond, bauxite and manganese provide the rest.

The increase in production has been enabled by political stability, good and competitive Mining and Minerals Laws (eg PNDC Law 153) as well as the simplification of tax laws and other incentives like foreign exchange retention account and tax holidays enshrined in the Investment Code which have made Ghana an attractive place for mining investment. These liberal conditions have produced the desired results and there is a real boost in mining operations in Ghana's traditional export minerals like gold, manganese, diamonds and bauxite as well as the industrial minerals like kaolin, clays and salt which are mostly consumed locally.

The increase in mineral production has generated a concomitant increase in environmental degradation which is threatening the mutual coexistence between mining and the other sectors of the economy like tourism and agriculture. This increase has also tremendous social impact on the communities in and around the active mining areas. This paper reviews the socio-economic benefits and the negative environmental impact of these mining activities.
The mining industry in Ghana has suffered from very wide fluctuations in minerals production with a general downward trend after 1960 (Mireku-Gyimah and Suglo, 1993). This brought with it a decline in foreign exchange generation from the industry. The country therefore relied almost entirely on cocoa exports. The decline was mainly due to an uncompetitive investment climate created by a long period of political instability and a general deterioration in the country's physical infrastructure, especially transportation and telecommunications, and unfavourable mineral policy (tax and mining laws) which scared potential investors away from the country and out-of-date technology (Anon, 1980).

In 1983 Ghana embarked on the Economic Recovery Programme (ERP) and took a very bold decision to review the legal framework and create a very congenial investment climate in the mining industry. The measures taken include the promulgation of the Mining and Mineral Law, 1986 (PNDCL 153, 1986) and the simplification of tax laws among other incentives like foreign exchange retention account and tax holidays. In the main, these conditions pertain to large scale mining operations. Recognising the significance of small-scale mining to the economy, the Government regularised small scale mining in 1989 and in the same year passed the Small Scale Gold Mining Law (PNDCL 218), legalising small scale gold mining activity. The basic thrust of this was to recognise the potential of small-scale mining output and to capture the potential into the mainstream economy. The positive economic recovery policies culminated in the birth of the fourth gold boom (Fig. 2). The epochs of the gold booms are: first, 1902 - 1918; second, 1929 - 1943; third, 1949 - 1974; fourth, from 1985 to date. Today, there are 300 registered mining companies in Ghana. Fourteen (14) of these are large-scale producing mines. The remaining are at various prospecting stages. Thus, since 1983, there have been significant rehabilitation, prospecting, exploration and development in the minerals industry resulting in increased mineral production and revenue.
ECONOMIC IMPACT

The mining industry possesses very important economic assets and it is for these reasons that past Governments have tried earnestly to improve this industry. The industry provides employment for the citizen, generate foreign exchange which is much needed for the growing demand for improved living conditions, and generates internal revenue to the state and also produces raw materials for local industries.

Employment

Ghana abounds in different mineral resources. As shown in Fig. 1, minerals can be found in almost every corner of Ghana. For the purpose of this paper the mining industry may be divided into small and large-scale mining. The large scale operations involve the exploitation of all manganese and bauxite and some gold and diamond resources and some quarries of granite and sandstone, which directly employ about 10,000 people. The small-scale operations involve all the industrial minerals, which include kaolin, all types of clay, sand and gravel, as well as placer gold and diamonds. It is estimated that about one million people have been gainfully employed in small scale mining activity all over the country (Kumasi and Klaye, 1996). The industry also gives indirect employment to many artisans, food and foodstuff sellers.

Foreign Exchange Earnings

The nation earns a lot of foreign exchange from the export of minerals. The congenial political condition and the liberal tax regime as well as repatriation of profits, mentioned earlier, have induced an increase in production to the extent that the mining industry has since 1994 become the premier foreign exchange earner by beating cocoa to the second position. In 1994, mineral earned the nation $566.7 million which was about 48% of the total export earnings (Anon, 1995).

Generation of Internal Revenue

The nation obtains additional income from the mining companies from direct taxes (eg. income and profit taxes) as well as royalties. More revenue accrues to the nation (indirectly from the mining industry) from the taxes paid by businesses that the mining industry has given birth to or helped to
grow. Examples of these businesses include food sellers, blacksmiths, carpenters, masons and transport services as well as international companies servicing these numerous large scale mining companies (eg. WAMS ad ICI).

Provision of Raw Materials

The mining industry also produces some of the raw material for many mineral-based domestic industries. These minerals include manganese which is used for the manufacture of batteries by Union Carbide, salt used for the manufacture of pharmaceutical products, kaolin for the manufacture of local powder, mica for the ceramic industry, gold for the local goldsmith and bauxite for the manufacture of beads. Their supplies save the nation a lot of foreign exchange which would have been used to import them to sustain these local industries.

ENVIRONMENTAL IMPACT

The mineral production activities are beset with negative environmental impacts. These impacts are not limited to bio-physical environment alone but extend to the socio-economic and socio-cultural environment as well. The potential impacts range from land degradation, land use conflicts, loss of water quality and total destruction of water sources, dust, noise ground vibration, air pollution to total relocation of communities from one locality to the other.

The environmental impact of mining in Ghana can be traced back to the beginning of mining in Ghana. However the incidence of this effect has become very important with the tremendous widespread increase in the number and size of mining companies.

Social Impact

The rapid growth of the mining industry has encouraged the migration of people seeking jobs to the mining centres: and has helped to retain people in the rural areas. It has an effect of minimising the rural-urban drift and has succeeded in reversing it to urban-rural drift to the extent that some villages are now 'congested'. The provision of jobs for the rural folk has raised their standard of living as a result of increased income.

On the contrary, the vibrant economic activity and the competition for food and other basic commodities has drastically increased the cost of living in the mining areas. In some cases, especially, in the small-scale gold and diamond mining areas, it has affected education as some parents do not have enough money left to pay for school fees. There is an increase in truancy of both teachers and school children as well as juvenile delinquency. Parental control over their children is broken down since their children fend for themselves.

Population increase in the mining areas has brought with it health hazards, increasing crime waves, sexual promiscuity with its attendant spread of communicable diseases such as syphilis, gonorrhoea and AIDS, cultural adulteration of the indigenes etc. There are also reported cases where small-scale mining is carried out under railway lines by small-scale miners resulting in damage to some parts of the lines.

Water Pollution

The sources of water pollution are very varied and can be traced to both large- and small-scale operations. Pollution of water by large-scale operation originates from dredging heap leaching, and
washing and treatment of ore from the processing plants. There is also the pollution of water bodies by small-scale due to the haphazard use of chemicals, especially mercury.

Dredging introduces solid suspensions, acids and mercury into the streams and rivers in which the operations take place. Cyanide and acids escape from the 'control trenches' into the natural drains when such trenches overflow their banks during rainstorms. Washing plants from operations such as manganese and bauxite mining may introduce solid suspensions into natural drains. Small-scale operations which pollute water substantially are mainly alluvial gold and diamond mining. Their mode of operations introduce solid suspensions and mercury into the water courses in which they operate. The mining operations, especially of the small-scale mining, have effectively changed the water courses of some rivers and streams.

Air Pollution and Noise

Air pollution from large-scale mines takes the form of dust in the air resulting from in-pit operations mainly from drilling, blasting, excavation, haulage and crushing of rock material. Gaseous emissions into the atmosphere are commonly from the roasting of ore and also vitiated air from underground mine workings. Gases emitted are mainly the sulphides and oxides of carbon, sulphur and hydrogen as well as some chlorides. Noise from blasting activities and vehicular traffic are a nuisance to neighbouring habitats.

A major source of air pollution in the case of small-scale mining commonly takes the form of solid suspension coming from ore crushing and sieving (sizing). Gold ore from quartz veins and weathered conglomerate of the Upper Birimian and the Tarkwaian rocks are respectively pounded and sieved in enclosed area and sometimes in congested habitats. Also grain mills are sometimes used in milling the ore. This causes very serious air pollution and also contaminates the food mills and poses potential health hazards to the communities.

Ground Degradation

Much of the concern here has been focused on the concurrent and subsequent physical and aesthetic effects that mining operations have on the land - as a basic resource. Both large- and small-scale mines are guilty of serious ground degradation. Large-scale mines use large spans of land for exploitation of ore and as waste dumps. In recent times many farms of cash and food crops have been claimed and pitted for gold. These areas are localised and identifiable. Small-scale mining operations on the other hand, are more widespread and not quite localised. Their operations, as they affect the ground, are very varied. Such operations have resulted in the unnecessary destruction of forests, food and cash crops. Small-scale gold and diamond mining are the most important culprits. The mode of operation destroys the integrity of the natural soil without any deliberate attempt to recondition it for productive food production. Stirring and naked exposure of soil to the vagaries of the weather renders the soil very susceptible to various types of erosion and leaching of plant nutrients, to the extent that it might not sustain crop production for long. It is common to see the extent of this soil erosion, particularly, rill erosion, in the workings. The haphazard placement of overburden material and tailings in mount and ridges between the pits makes the land even more difficult to till for food cropping. Today, the need to acknowledge the importance of good soil management if food production is to be increased and sustained to feed the ever-growing population, which is typical of a developing country like Ghana, cannot be overemphasised.

The present state of the mined lands is also hazardous to the health and safety of nearby inhabitants. People, especially farmers and hunters, can easily fall into these pits and get injured or even drowned as such pits are filled with water. Small-scale mines have in some extreme cases destroyed social ground and schools, eg. in the Akwatia area. They have even been reported cases of destruction of forests at
Sirisu in the Bolgatanga District of the Upper East Region where the forest was destroyed at the rate of 0.2 hectares per day (Anon, 1996). Such destroyed forests are very difficult to retrain. Similar destruction of the land resulting from small-scale mining for shells in the Volta Region are also known.

**ECONOMIC CONTROVERSY**

Mining undoubtedly has brought great wealth to the nation and individuals directly and indirectly, as mentioned previously. It has minimised or even reversed the rural-urban migration in some cases. The purchasing power of the individual has increased and this has improved upon the standard of living of otherwise poor people. It has created permanent or seasonal employment in depressed agricultural areas and imparted new skills to the local population. It has also created demand for transport and other support service industries, such as small-scale engineering (Wels, 1983).

On the contrary population influx to the mining areas has brought about social hazards. There are cultural diversification and conflicts, increasing crime wave and sexual promiscuity and escalating incidence of venereal diseases like gonorrhoea, syphilis and even AIDS. Also, the gross environmental degradation with little attempt to reclaim or rehabilitate the land and the disregard by authorities for the importance of the mining-farming relations, in so far as the two have conflicting claims on land and water resources constitutes a very important controversy.

Although mining constitutes the major foreign exchange earner today, it is necessary to take serious steps now to maintain and preserve the land for posterity after the depletion of such non-renewable natural resources since the land would be so degenerated that it would not be usable for food crop production. Most of the land would be derelict by then. Thus there are conflicting interests between mining, agriculture and other land users.

**REMEDIAL MEASURES**

Regarding the immense potential of mineral resources and the need to obtain sufficient financial resource to satisfy the increasing need to develop and improve upon basic infrastructure for socio-economic development, it is unequivocal that Ghana will continue to promote and increase mineral exploitation. Important, other economically competitive sectors such as agriculture and tourism will also continue to develop and grow. Equally important is space for shelter and recreational facilities. Thus, there is a serious confrontation between mining and other land users. The aim of this section is to highlight some pertinent remedial measures which can be adopted to extract minerals without permanently altering the land values for post-mining uses. Large and small-scale mining require different measures.

**Large-scale Mining**

While the existing legal and institutional framework require the provision of Environmental Impact Assessment by new mining companies and Environmental Action Plans by existing ones (Anon, 1994) to ensure environmentally acceptable mining practices, there is no efficient policing capacity. The Environmental Protection Agency and the Mines Department who are responsible for policing and monitoring of mining activities should be provided with the necessary logistics and incentives to work. Their efforts should be complemented by the District Assemblies, chiefs and other identifiable bodies. To encourage large mines to observe proper environmental issues, some incentive packages, e.g. tax relief, reduced profit tax, or reduced royalty rate may be worked out.

In order to minimise conflicts between local inhabitants and mining companies, there must be a comprehensive and commensurate compensation for agricultural lands and farms and other lands which
have been claimed for mining purposes. Relevant Ministries and Agencies should organise seminars and workshops, at least once a year, to educate mining companies on the need for economically sound and environmentally friendly mining practices.

Small-scale Mining

In Ghana small-scale mining is characterised by one or more people using rudimentary tools to dig for minerals at a level that would otherwise be considered uneconomical for large-scale mechanised mining. It may be done by the casual worker, small groups of persons or co-operative or small company. Most of these people have little or no mining expertise. The mines are so small, individualistic, remote and widespread that it is almost impractical to monitor all such mining operations. This is even worsened by the fact that some of them are still unregistered and illegal.

To minimise the negative environmental impact of small-scale mining operation it is imperative to mount educational campaign to make both miners and people in the localities aware of the damage that is caused. It is also important to educate them on the advantages of more technically efficient mining and extractive practices which can optimise mineral recovery and concurrently minimise environmental degradation. Such educational campaign should be collectively and severally done by all relevant ministries, Minerals Commission, Mines Department, non-governmental organisations (NGO's), District Assemblies, chiefs and prominent locals at festivals and durbars, as well as educational institutions like the Universities.

Undoubtedly finance has been one of the major set-backs for small-scale mining. Financial institutions should be educated and encouraged to extend credits to these miners. Such liquidity solution can promote more environmentally acceptable mining practices. The requisite technical assistance has to be improved through more vigorous commitment of the Small-scale Mining Centres through their warden. Delimitation of ore zones through elaborate exploration may be undertaken by institutions such as the Universities and the Geological Survey Department through sponsorship by Government, NGO's and other organisations such as UNDP and the GTZ. This will minimise the haphazard and indiscriminate pitting and mining which characterise this sector.

The negative social impact can be ameliorated through education by the Ministry of Health, religious bodies, schools, identifiable organisations and respectable personalities in the mining areas. Such education should address sanitation, safe sexual habits and good morals. Conflicts between land users can be minimised if District Assemblies would stop giving out open licenses to miners which entitle them to operate at any place. The Assemblies must communicate and liaise with the Minerals Commission to regulate and rationalise the issuing of licenses.

CONCLUSION

In a liberalised developing economy, such as Ghana's, there is the need to attract local and foreign investment, and this demands that concessions be given, as contained in the investment Code and Minerals and Mining Law 1986 (PNDCL 153).

As a result of political stability and an attractive investment code, Ghana is witnessing an influx of entrepreneurs into the mining sector. There is an expansion in existing mines, reactivation of abandoned mines and increased exploration. The regularisation of small-scale mining has witnessed a rapid growth and proliferation of these mines in the country. Growth and development of mining has brought tremendous socio-economic benefits to individuals and the nation.

However the growth and rapid development of large and small-scale mining are associated with devastating social and environmental problems. If these problems are not tackled quickly and
pragmatically, their effects are likely to negate all the economic gains that accrue from minerals exploited. Various measures need to be adopted to mitigate these negative impacts through education by relevant ministries, state organisations, educational institutions, opinion leaders in mining communities like chiefs, on the need for sound mining practices safe sexual relationship, and moral sanctity. Financial institutions should be encouraged to extend loans to small-scale miners. Also large-scale mining operation should be encouraged to follow the EIA by giving those mines whose operations are environmentally safe some tax packages.

In order to minimise conflict between mining companies and other land users, mining companies must appreciate the significance of these sectors and pay appropriate compensation. Also District Assemblies and the Mineral Commission should work together to regulate the issuing of mining licenses.

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MULTIELEMENT ANALYSIS OF MINERAL ORE SAMPLES USING ENERGY
DISPERSI VE X-RAY FLUORESCENCE ANALYSIS

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ABSTRACT

For effective exploration and exploitation of mineral ore, its elemental composition, chemical states of the elements and other information from the same specimen must be analysed. Non-destructive methods of analysis are preferable and nuclear-related analytical techniques meet this requirement very well.

This paper therefore examines the use of nuclear analytical techniques in elemental analysis of mineral ore samples with emphasis on EDXRF analysis. Neutron Activation Analysis (NAA) is the other technique presently available in Ghana for application in elemental composition analysis. A combination of the above techniques with conventional chemistry allows for the analysis of a wide range of elements.

Results of some analysis of Mn, Au, Bauxite ore and granite in Ghana have been presented. The sensitivity of the EDXRF techniques combined with the rapid turnover in analysis time makes EDXRF and nuclear-related analytical techniques unique and indispensable tool in elemental composition analysis.

INTRODUCTION

Mineral elements of economic importance are usually found disseminated sparsely, and mining therefore has to be in areas where extraction is viable. Therefore during drilling in concession areas it is important to get quick analytical information on the quality and type of ore. Such information cannot be obtained solely from on-line field monitoring systems. This is made more difficult by the fact that mineral deposits do not consist of formations in which concentration values are spread evenly throughout. Parts of the deposit may carry high values, other parts may carry low values. This uneven distribution of the mineral in the ore makes its analysis very difficult. Accurate analytical methods which can generate rapid multi-element analysis of large quantities of analytical data, to take care of this uneven distribution, can support this geological investigations. This can help improve the interpretation of field data. Nuclear Analytical Techniques (NAT) fall into this category of analytical methods. NAT can also be used to control loss of product found in the waste streams and tailings with an added economic advantage, and minimisation of potential detrimental impact. The advantages of NAT include rapidity, high specificity, multi-elemental analysis, simplicity in use and survival in aggressive environment. Another very important advantage is that once a sample is prepared, the method is non-destructive.

The main disadvantages mostly associated with NAT are high initial cost and the analysis being only elemental concentration whereby no information about the chemical environment or matrix is determined. With the high cost the high speed of analysis and the multiplicity of element determination results in lower unit cost per determination and in the long run make NAT cheaper than conventional methods. By manipulation of pH and other chemical conditions the concentrations of the various elemental state could be determined.
The main NAT techniques presently competing with EDXRF in mineral ore exploration are Wavelength Dispersive X-Ray Analysis (WDXRA) and Neutron Activation Analysis (NAA). Clayton also used EDXRF for continuously measuring the concentration of elements in mineral processing plants.

The quality and nature (type) of mineral ore are two very important parameters that determine the method or combination of methods to be used for extraction. Presently, the main analytical methods being used for grading and characterising mineral ores include: fire assay, atomic absorption spectrometry, electro-analytical methods and emission spectrochemical analysis among others. All these methods can only analyse one element at a time, the focus therefore is mostly on the element of economic importance. Analysis of other elements are not carried out on routine basis since it makes the analytical process laborious and time consuming.

Consequently, certain elements of economic values that usually occur as minor constituents in mineral deposits and can be recovered as by-products from mining are missed out. The primary objective of this paper can be spelt out as follows:

1. The multielemental analysis of various mineral ores in Ghana using EDXRF to determine the concentration of the various excitable elements present.
2. To introduce EDXRF and the other Nuclear-related Analytical Techniques available at Ghana Atomic Energy Commission to the mining industry.

EXPERIMENTAL AND RESULTS

Sample Preparation

The mineral ores were collected from the various mines and locations, sun dried, and grounded to very fine powder. "Intermediately thick" and "infinitely thick" samples of each were prepared for EDXRF analysis. The fundamental parameters methods were used for quantitative analysis.

Instrumentation

The EDXRF spectrometer set-up consisted of either annular geometry radicisotope ($^{55}$Fe or $^{109}$Cd) or a Mo x-ray tube (with either Zr or Fe secondary targets) as excitation source. The fluorescent x-rays produced were detected with Canberra Si(Li) detectors having a resolution of 164eV at 6.4 Kev. The analysis was done with either a Canberra 35+ multichannel analyzer linked to a minicomputer or a computer based Accuspec MCA card. Spectra deconvolution was done using AXIL software package.

RESULTS

<table>
<thead>
<tr>
<th>TABLE 1: PRESTEÀ GOLD ORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>% W</td>
</tr>
<tr>
<td>K</td>
</tr>
<tr>
<td>Ca</td>
</tr>
<tr>
<td>Ti</td>
</tr>
<tr>
<td>Mn</td>
</tr>
<tr>
<td>Fe</td>
</tr>
<tr>
<td>As</td>
</tr>
<tr>
<td>Rb</td>
</tr>
<tr>
<td>Sr</td>
</tr>
<tr>
<td>Zr</td>
</tr>
</tbody>
</table>
Other elements identified but not quantified are: Si, P, S, Sc and Sb.

TABLE 2: Mn ORE

<table>
<thead>
<tr>
<th></th>
<th>% W</th>
<th>ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>14.398</td>
<td>± 1.671</td>
</tr>
<tr>
<td>K</td>
<td>0.978</td>
<td>± 0.062</td>
</tr>
<tr>
<td>Ca</td>
<td>0.086</td>
<td>± 0.005</td>
</tr>
<tr>
<td>Sc</td>
<td>0.013</td>
<td>± 0.003</td>
</tr>
<tr>
<td>Ti</td>
<td>0.164</td>
<td>± 0.011</td>
</tr>
<tr>
<td>V</td>
<td>0.017</td>
<td>± 0.001</td>
</tr>
<tr>
<td>Mn</td>
<td>20.611</td>
<td>± 1.670</td>
</tr>
<tr>
<td>Fe</td>
<td>21.140</td>
<td>± 1.531</td>
</tr>
</tbody>
</table>

Average of six analysis.

TABLE 3: KIBI BAUXITE ORE

<table>
<thead>
<tr>
<th></th>
<th>% W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>38.989  + 2.119</td>
</tr>
<tr>
<td>Fe</td>
<td>5.991   ± 0.131</td>
</tr>
<tr>
<td>Mn</td>
<td>330     ± 22</td>
</tr>
<tr>
<td>Sr</td>
<td>59      ± 2</td>
</tr>
<tr>
<td>Zr</td>
<td>161     ± 4</td>
</tr>
</tbody>
</table>

Average of four analysis
Other elements identified but not quantified are: Si, Zn, Ga, As and Nb.

TABLE 4 GRANITE

<table>
<thead>
<tr>
<th></th>
<th>% W</th>
<th>% W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>5.788   + 1.217</td>
<td>0.045   + 0.009</td>
</tr>
<tr>
<td>Si</td>
<td>22.286  + 2.776</td>
<td>0.039   + 0.006</td>
</tr>
<tr>
<td>K</td>
<td>1.439   + 0.019</td>
<td>0.014   + 0.004</td>
</tr>
<tr>
<td>Ca</td>
<td>2.787   + 0.159</td>
<td>0.003   + 0.001</td>
</tr>
<tr>
<td>Ti</td>
<td>0.315   + 0.028</td>
<td>0.018   + 0.002</td>
</tr>
<tr>
<td>Mn</td>
<td>0.029   + 0.040</td>
<td>0.012   + 0.012</td>
</tr>
<tr>
<td>Fe</td>
<td>3.461   + 0.087</td>
<td>0.004   + 0.001</td>
</tr>
</tbody>
</table>

Average of five analysis

DISCUSSIONS

Figure 1 shows the schematic diagram of the EDXRF set-up used to analyse the following Au, Mn, Bauxite and Granite ores. Figure 2 shows the XRF spectrum of Prestea gold ore using tube excitation. Although the matrix of the ores are different the analytical procedure was the same for each sample. The sample preparation procedure was minimal and easy involving only the grinding (with agate mortar and pestle) and pelletizing using SPECAC pelletizing machine hence ensuring negligible contamination.
Principle of X-ray fluorescence analysis

Fig. 1 Schematic diagram of EDXRF setup

Fig. 2 RF spectrum of Prestea gold ore
of samples. The analysis time is about 1000 seconds since sensitivity of the spectrometer to the various elements in geological samples is quite high.

Though EDXRF could be used to identify and quantify element with Z > 12, from the results above elements from Al to Sb present in the samples were analysed. Some of those not quantified were either below detection limit or its concentrations were of no importance to the analysis. Complimenting with NAA, elements with Z >9 could easily be identified and quantified.

Due to the multielement nature of EDXRF information on the major, minor and trace elements in the ores that might be of economic significance are all obtained from each analysis. This is also very important in determining the appropriate mitigation steps to be taken in the environmental practices of the mining industry.

CONCLUSION

EDXRF has been used to analyse ores of Au, Mn, Al and granite. While EDXRF does not provide the sensitivity to trace elements that can be obtained by optical emission spectroscopy, it is nevertheless of great value in general survey work where the target elements are present in higher than trace quantities. As one moves to mining where the elements of interest are at relatively high concentrations and decisions are to be made regarding waste versus ore, EDXRF becomes of greater importance.

Though these nuclear-related techniques are sited at Kwabenya and some distance away from the mining areas, with the general improvement in telecommunication in the country samples could be sent for analysis and the result received within a day or two. The high sensitivity of nuclear-related analytical techniques rapid turnover in analysis time, multi-elemental capabilities, etc makes them an indispensable tool in the mining industry. It can do the same for the industry in Ghana.

REFERENCES


DETERMINATION OF As\textsuperscript{3+} AND As\textsuperscript{5+} IN SOME GHANAIAN GOLD TAILINGS BY DISTILLATION

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Chemistry Department, Ghana atomic Energy Commission, P.O. Box 80, Legon.  
*Department of Chemistry, University of Ghana, Legon.

ABSTRACT

The As\textsuperscript{3+} and As\textsuperscript{5+} in Obuasi gold tailings have been determined by the distillation of the arsenic as the AsC\textsubscript{13}. Results yielded 3,795.1 ± 394.3ppm (45.7%) for the As\textsuperscript{3+} and 3.00 ± 27ppm (36.2%) for the As\textsuperscript{5+}. Total arsenic content of the tailings determined by NAA yielded the value of 8,305 ± 75 ppm.

INTRODUCTION

Ghana since ancient times has been associated with gold production which is increasingly becoming the major export earner of the economy. The result is that arsenic, occurring in ores as the pyrites and arsenopyrites (1), is becoming a major source of pollution (2) in the environment through gold processing in the gold-mining areas. Vegetation around the Obuasi goldmine, the richest in the country, has virtually perished from aerial arsenic pollution in addition to the huge gold tailing deposits that continue to be washed into streams and rivers.

Recent reports also indicate that the arsenic contents of foodstuffs from such major towns as Kumasi (Ghana's second capital), about 50 miles from Obuasi, has reached appreciable levels to raise concern (3). Apart from a recent study conducted by R.J. Bowell and colleagues (4), the few studies carried on Ghanaian goldmines have reported on total arsenic contents of pollutants. It is known that in a mixture of As\textsuperscript{3+} and As\textsuperscript{5+} with conc. HCl, AsC\textsubscript{13} is exclusively formed, since AsC\textsubscript{13} has never been isolated (5). And at a temperature of 108°C the AsC\textsubscript{13} volatilises with practically no interference from the chlorides of the other elements (6). These two factors have been exploited in the determination of the As\textsuperscript{3+} in the tailings.

Aim

This work therefore aims at determining the As\textsuperscript{3+} and As\textsuperscript{5+} in the tailings using a distillation method based on volatility of AsC\textsubscript{13}. In addition this work aims at the determination of the total arsenic content of tailings as an essential and integral part of the speciation studies.

Approach

The As\textsuperscript{5+} is converted into AsC\textsubscript{13}, by reacting the tailings with conc. HCl and distilling it followed by its quantification using iodine titration. After that the same amount of the tailings is reacted with KClO\textsubscript{3} to convert all the As\textsuperscript{3+} into As\textsuperscript{5+}. The latter is then produced back to As\textsuperscript{3+} using hydrazine sulphate and then distilled as the AsC\textsubscript{13}. After quantification by iodine titration, the As\textsuperscript{5+} is obtained by difference. Total As in the tailings was also determined by NAA.

* Person to be contacted in all communications

UST/IDRC '97 Symposium on the Mining Industry and the Environment, UST, Kumasi, Ghana
Fig. 1: Distillation Apparatus for Determining As(+3) and As(+5)

Fig. 2: Gamma Spectra of Irradiated Goldtailings

UST/IDRC '97 Symposium on the Mining Industry and the Environment, UST, Kumasi, Ghana
Determination of As$^{3+}$ and As$^{5+}$ in the Goldtailings by Distillation

Determination of As$^{3+}$

The goldtailing samples were weighed (0.5057g, 0.5026g, 0.5086g) and put into a three-necked 250ml round bottomed flask. 40ml of conc. HC1 was added and stoppered. It was allowed to stand at room temperature (25°C) over night. This was to prevent loss of AsCl$_3$, which was formed (7). The flask was then fitted with distillation condenser, thermometer (0-300°C) and a N$_2$-inlet. The receiver was made to stand in a 500ml beaker filled with ice and NaCl. The condenser then fixed in position. An adapter E connected the end of the condenser to that of the receiver. The receiver was made of glass cylinder fitted with a stop-cock at its upper end which when opened served as an outlet for the nitrogen and HC1.

Operation

C was first opened followed by F. After that K was also opened till the nitrogen gas began to flow at a steady and gentle rate to bubble into the mixture of acid and tailings. Tap water was turned on for water to circulate around the condenser. The flow of heat in the heater was carefully controlled using the know J to keep the temperature below 108°C (8), at which point the AsCl$_3$ distilled into the receiver containing 20ml of water. When volume of the mixture of acid and tailings had been reduced to 20ml, the heat was turned off. After the flask and its contents had sufficiently cooled, flow of nitrogen gas was stopped using the knob K. Flow of water was also stopped by turning off the tap. The rubber tubings connecting the condenser to the tap were as well disconnected. 20ml of deionised water was then introduced into condenser and the latter washed. The washings were then added to the AsCl$_3$, in the receiver. The total volume of the distillate plus washings was measured and then transferred into a 100ml volumetric flask. 20ml aliquot was pipetted into a 100ml conical flask and three drops of phenolphthalein indicator added. Sufficient amount of NaOH was added to neutralise the strong acid solution and then to form the arsenite in solution. Few drops of HC1 was then added to turn the solution slightly acidic. 2gm of sodium bicarbonate added with shaking followed by 3 drops of starch indicator. 0.1N iodine solution was run from a burette in drops (9) with each drop measuring 0.05ml from a previous calibration. The end-point of the reaction was marked by the characteristic dark blue colour of starch iodine reaction.

The blank test was performed by titrating the iodine solution against a mixture of 5ml HNO$_3$, 5ml HC1, 20ml deionised water, 10ml of 6M HC1, 2gm of sodium bicarbonate and 3 drops of starch indicator, all contained in a 100ml conical flask. 2 drops of the iodine solution from the burette was used to reach the end-point. This volume which represented 0.lml of the iodine solution was subtracted from all determinations of samples. Table 1 gives the data on As$^{3+}$ determination by iodine titration.

Determination of As$^{3+}$ plus As$^{5+}$ in the tailings.

0.5147g, 0.5087g, 0.5009g, of the tailings were first weighed into 100ml flat-bottomed flasks. All the As$^{3+}$ in the tailings were then converted into As$^{5+}$ according to the following chemical treatment (10): 5ml of HNO$_3$ and a pinch of KClO$_3$ were added to the content of each flask and heated to dryness. After that 5ml of HC1 was added and again heated to dryness. Then 20ml of 1:1 HC1 was added and boiled for 30 minutes. After cooling it was filtered, 30ml of HC1 added and transferred into the three-necked flask. 0.5g of hydrazine sulphate plus 0.5g of NaBr were added and distilled at 108°C as described above. Addition of the hydrazine sulphate ensured the reduction of all the As$^{5+}$ present back to the As$^{3+}$ to be distilled as the AsCl$_3$. The condenser was again disconnected and washed with 20ml of deionised
water into the filtrate. Total volume of the distillate and washings were measured and the iodine solution titrated against 20ml aliquots of the filtrate. Determination was carried out in triplicate. Table 2 gives the data on As$^{3+}$ + As$^{5+}$ determinations by iodine titration.

**Table 1: Determination of As$^{3+}$ in the Goldtailings**

<table>
<thead>
<tr>
<th>Wt. of Sample (gm)</th>
<th>Total Volume of distillate (ml)</th>
<th>Vol. of 0.1N Iodine Solution (ml)</th>
<th>Total Volume of 0.1N Iodine Solu.</th>
<th>Wt. of As in Sample (gm)</th>
<th>Wt. of As in Sample (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5057</td>
<td>74.3</td>
<td>.05 .05 .05</td>
<td>.19</td>
<td>.00086118</td>
<td>1,704.3*</td>
</tr>
<tr>
<td>0.5026</td>
<td>43.5</td>
<td>.15 .15 .15</td>
<td>.33</td>
<td>.00149688</td>
<td>2,978.3</td>
</tr>
<tr>
<td>0.5086</td>
<td>86.0</td>
<td>.20 .20 .20</td>
<td>.34</td>
<td>.00154224</td>
<td>3,032.3</td>
</tr>
</tbody>
</table>

As$^{3+}$ = 3.005.3 ± 421.3ppm

**Table 2: Determination of As$^{3+}$ and A$^{5+}$ in the Goldtailings**

<table>
<thead>
<tr>
<th>Wt. of Sample (gm)</th>
<th>Total volume of distillate (ml)</th>
<th>Vol. of 0.1N Iodine Solution (ml)</th>
<th>Total Volume of 0.1N Iodine Solution</th>
<th>Wt. of As in Sample (gm)</th>
<th>Wt. of As in Sample (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5147</td>
<td>110</td>
<td>.15 .15 .15</td>
<td>.825</td>
<td>.00037422</td>
<td>7,270.6</td>
</tr>
<tr>
<td>0.5087</td>
<td>95</td>
<td>.20 .20 .20</td>
<td>.76</td>
<td>.00344736</td>
<td>6,882.3</td>
</tr>
<tr>
<td>0.5009</td>
<td>99</td>
<td>.25 .25 .25</td>
<td>.69</td>
<td>.00312984</td>
<td>6,248.4</td>
</tr>
</tbody>
</table>

As(+3)+ As(+5) = 6,800 ± 421.3ppm

* Rejected, since the value is significantly different from the other two (Q-Test)

**CALCULATIONS**

The following equations account for the reactions used in the As$^{3+}$ determination by iodine titration.

$$\text{As}_2\text{O}_3 + 6\text{H}^+ \rightarrow 2\text{As}^{3+} + 3\text{H}_2\text{O} \quad (1)$$

$$\text{As}^{3+} + 3\text{H}_2\text{O} \rightarrow \text{AsO}_3^{3-} + 6\text{H}^+ \quad (2)$$

$$\text{AsO}_3^{3-} + \text{I}_3^- + \text{H}_2\text{O} \rightarrow \text{AsO}_4^{3-} + 3\text{I}^- + 2\text{H}^+ \quad (3)$$

$$\text{H}^+ + \text{HCO}_3^- \rightarrow \text{H}_2\text{O} + \text{CO}_2 \quad (4)$$

Addition of 1, 2, 3 and 4 yield:

$$\text{As}_2\text{O}_3^{3-} + \text{I}_3^- + 2\text{HCO}_3^- \rightarrow \text{As}^{3+} + \text{AsO}_3^{3-} + \text{H}_2\text{O} + 3\text{I}^- + 2\text{CO}_2 \quad (5)$$

From which, $I_3^- = \text{As}_2\text{O}_3$

From $\text{KI}_3 = \text{As}_2\text{O}_3$

1ml of 0.1N iodine solution = 0.004536gm of As

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.34ml of 0.1N iodine solution = 0.0015422gm of As

In 0.5086 gm of tailings we have 0.00154224gm of As

\[ \text{In 1000gm of tailings we have } 1000 \times \frac{0.00154224gm}{0.5086} = 3.0323 \text{ppm} \]

2. EXPERIMENTAL

**Determination of total arsenic in the gold tailings by NAA**

NAA determination of the total arsenic content of the tailings was carried out by irradiating 100mg of the sample for an hour in the reactor at a neutron flux of \( 1 \times 10^{12} \text{n.cm}^{-2} \text{s}^{-1} \) (11). It was subsequently measured in the gamma spectrometer consisting of an N-type high purity germanium detector with resolutions of .85Kev at 122Kev, 1.8Kev at 1.33Kev of Co-60 gamma energy. The detector had a relative efficiency of 25%, whilst the Multichannel Analyzer is computer-based (Silene Emcaplus). SPAN 5.0 gamma spectra software was used. Delay time was 24 hrs and counting time was 600s.

Fig. 2 shows the spectra of 100mg of the sample after an hour's irradiation in a neutron flux of \( 1 \times 10^{14} \text{ ns cm}^{-2} \text{s}^{-1} \). Measuring time was 1000s using a PCA-4KN Multichannel Analyzer at the Institute of Isotope Co. Ltd. Budapest, Hungary.

Delay time was 197 hrs with an activity of \( 2.2537 \times 10^6 \text{ Bq} \). Other elements detected included: Sm-153,41.5 Kev; Au-198, 4118 Kev; La-140, 487.03 Kev; Sb-124, 602.71 Kev; Sb-122, 563.93 Kev; Sc-46, 893.3 Kev; Fe-59, 1099.22 Kev; Sc-46, 1120.5 Kev; Fe-59, 1291.56 Kev; La-140, 1596.6 Kev.

**RESULTS**

The results of the As\(^{3+}\), As\(^{5+}\) as well as the total As concentrations in the goldtailings are given in table 3.

| As\(^{3+}\) | 3,005.3 ± 27 | 36.2 |
| As\(^{5+}\) | 3,795.1 ± 394.3 | 45.7 |
| Total As | 8,305 ± 75 | 100 |

**DISCUSSION AND CONCLUSION**

As\(_3\)Cl\(_3\) is highly volatile and it is this unique property that was exploited to determine the amount of As in the sample. To avoid the possibility of losing it, the sample was not refluxed with conc. HCl prior to distillation in the determination of the As\(^{3+}\) in the tailings, but rather the tailings was allowed to react with the HCl without applying any heat whatever. Meaning that a small fraction of the As\(^{3+}\) in the tailings, possibly, might not have reacted to form the As\(_3\)Cl\(_3\). Heating or refluxing of the tailings with...
HCl prior to distillation will be carried out using finer distillation equipment that will ensure that nothing is lost prior to distillation. From table 3, the sum of As\(^{3+}\) and As\(^{5+}\) concentrations gave 6,800.4 ± 664.3 ppm. This differed by about 1,494.6 ppm from the total As concentration of 8,305 ± 75 ppm, which could be attributed to this.

ACKNOWLEDGEMENT

I wish to express my gratefulness and thanks to Mr. S. Kumi of the Glassblowing Unit, University of Ghana, Legon who made the 250ml three necked round bottomed flask for me.

REFERENCES

INTRODUCTION

The gold ore at Obuasi consists mainly of pyrites and arsenopyrites (1), the roasting of which releases large amounts of As$_2$O$_3$, SO$_2$ etc into the atmosphere. In addition to this arsenic fallout, process water used to be discharged into the Kwabrafo stream from the Pompora Treatment Plant. 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.

But since 1990 an arsenic recovery plant (ARP) has been put in place to remove particulate As$_2$O$_3$. In addition all liquid waste from the PTP are being recycled to minimize discharge into the streams. Inhabitants in the area are encouraged to use bore-hole water for domestic purposes.

Most - studies (2-5) to assess the impact of arsenic pollution, before and after the installation of the ARP, have paid little attention to the sediments of the streams and rivers. But the sediment is an important habitat for aquatic organisms. Metals may accumulate in sediments and from there can influence metal flux into the food chain (5).

In this work, water and sediment from the streams and rivers in the catchment area of Obuasi mines were analysed to ascertain the extent of arsenic pollution. In addition the leaching behaviour of the samples were studied.

EXPERIMENTAL

Sampling

Sediment and water samples were taken from the Kwabrafo-Pompo-Jimi network, which forms part of the mineral concession of the Obuasi mines (see Fig. 1). Sampling was done on different occasions within a period of two years.

Sediments were taken using a Dutch auger sampler. At each location samples were taken from the surface and where possible also from the depth of about 30cm. Water was taken at same location as the sediment, using an improvised sampler of a wide-mouth plastic bottle tied to a rope and weighted to facilitate sinking. Each water sample was acidified with 1ml conc. HNO$_3$. Both sediment and water were put into reconditioned plastic bottles.

Sample treatment

The water samples were filtered over a 0.45µm membrane filter paper. The sediment samples were oven dried at 40°C for 48 hours, ground to break up the lumps and sieved through 85 mesh sieve.

A.A.S. Measurement of the Water

Total As of the filtered water was determined by atomic absorption spectrometry at a wave length of 193.7nm on a Perkin-Elmer 2280 AAS equipped with a hydride generation accessory. All parameters were according to the manufacturers prescription. All determinations were done in triplicate.
Fig. 1: Kwabrafo-Pompo-Jimi Network showing the sampling points

Fig. 2: Mean arsenic levels in the waters from Obuasi mine

Fig. 3: Cumulative leach rate for As in sediment (Leachant: Deionised-dist. H₂O)

Fig. 4: Cumulative leach rate for As in sediment (Leachant: Simulated water)

Fig. 5: Differential leach rate for As in sediment (Leachant: Deionised-distilled water)

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Sediment samples were weighed and wrapped into polyethylene films and the films inserted into polyethylene capsules. The capsules were transferred into a Miniature Neutron Source Reactor (MNSR) by a rabbit system for irradiation. The following conditions were applied for the As determination:

Neutron flux: \( = 5 \times 10^{11} \text{ n cm}^{-2} \text{ s}^{-1} \)

Irradiation time \( t_1 = 1 \text{ h} \)

Cooling time \( t_4 = 46.5 \text{ h} \)

Counting time \( = 600 \text{ s} \)

RESULTS AND DISCUSSION

Considering first the mean As levels in 1992 (Table 1) it can be seen that, as expected, the arsenic concentrations at Points Y, A and B, are relatively low. Here As contamination is probably due to arsenic fallout on the vegetation and rain-washed into the dam. Also contamination could be due to erosion and weathering of rocks and soils.

At the Pompora Treatment Plant i.e Point C where aqueous effluent is discharged into the streams, the As concentration increases dramatically to 20.00mg/litre. From there it decreases sharply to a value of 9.49mg/litre (Point D) and 9.60mg/litre (Point E) and then gradually downstream to a value of 2.00mg/litre (Point P). This decreasing trend is collaborated by values obtained from same location in the same year by the Environmental Laboratory of the mines (Table 1) and also by Amonoo-Neizer et. al. (5). No detectable As was found at Point R on the Pompo stream. This is expected because Point R is a location called Mampamhwe about 14 kilometers east of Obuasi and out of the general wind direction.

Table 1: Mean Concentration of As in the water Samples (SD omitted for clarity)

<table>
<thead>
<tr>
<th>SAMPLING POINTS</th>
<th>This Work 1992</th>
<th>This Work 1993</th>
<th>Mine Lab** 1992</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>7.56</td>
<td>0.40</td>
<td>NA</td>
</tr>
<tr>
<td>A</td>
<td>5.51</td>
<td>0.13</td>
<td>2.00</td>
</tr>
<tr>
<td>B</td>
<td>3.00</td>
<td>4.00</td>
<td>2.30</td>
</tr>
<tr>
<td>C</td>
<td>20.00</td>
<td>N. A.*</td>
<td>35.00</td>
</tr>
<tr>
<td>D</td>
<td>9.46</td>
<td>4.00</td>
<td>13.00</td>
</tr>
<tr>
<td>E</td>
<td>9.60</td>
<td>1.45</td>
<td>9.60</td>
</tr>
<tr>
<td>F</td>
<td>7.29</td>
<td>1.71</td>
<td>7.30</td>
</tr>
<tr>
<td>I</td>
<td>5.64</td>
<td>1.97</td>
<td>6.20</td>
</tr>
<tr>
<td>K</td>
<td>6.41</td>
<td>1.97</td>
<td>6.20</td>
</tr>
<tr>
<td>L</td>
<td>6.67</td>
<td>2.76</td>
<td>6.60</td>
</tr>
<tr>
<td>R</td>
<td>0.01</td>
<td>0.01</td>
<td>-</td>
</tr>
<tr>
<td>M</td>
<td>0.35</td>
<td>0.01</td>
<td>0.23</td>
</tr>
<tr>
<td>N</td>
<td>5.10</td>
<td>1.84</td>
<td>4.90</td>
</tr>
<tr>
<td>O</td>
<td>3.50</td>
<td>1.58</td>
<td>4.10</td>
</tr>
<tr>
<td>P</td>
<td>2.00</td>
<td>0.40</td>
<td>1.50</td>
</tr>
</tbody>
</table>

*No Sampling was done at this point

**Values of the Environmental Lab of the mines
The values for 1993 are even lower than the 1992 set. No wastewater was obtained at point C because the discharge has been curtailed and the water recycled. Consequently the As level has dropped considerably.

Figure 2 compares the As levels for 1992 and 1993 and highlights the disparity between the two sets. The disparity is probably due to the fact that discharges from the PTP into the Kwabrafo stream and which accounted for the high arsenic levels in the water were stopped towards the end of 1992 and the effluent recycled for use in the running operations of the PTP. One should also not forget that the ARP may also have contributed to this trend. The mean arsenic levels in the sediments are given in Table 2, the relative standard deviations are in parenthesis. The arsenic level range from 18.1 mg/kg (Point R) to 2743.0 mg/kg (Point D) with coefficients of variation below 3%. These values are high but compare well with those obtained by Bowell and co-workers (4) for uncontaminated soils overlying unmineralized bedrock and soils contaminated by mine tailings from the study area.

In general the levels of total As in the sediment are far greater than those in the water. This is expected because natural waters possess the ability to cleanse themselves of heavy metals including As. Arsenate and arsenite form insoluble precipitates with Fe, Ca, Al, Pb and Mn compounds found in natural waters. They may also get absorbed or co-precipitated onto clay particles hence increasing the concentration in the sediment (7). In addition the sediment samples worked on are heavily laden with mine tailings. It must be noted that the values for 1992 are not very different from those of 1993, even though no water was discharged into the streams and the ARP is in position. This underlines the importance of paying more attention to the sediment. It appears the sediment would need much longer period to decontaminate than in the case of water.

Both sediment and water are carrying arsenic far in excess of the threshold values of the EPA. At the points where samples were taken from both depths, the surface invariably had the higher concentration. Earlier studies carried out in some mining areas of Ghana gave similar results (4,6). This might be due to the higher solubility of arsenite as compared to arsenate. The former is likely to predominate with increasing depth, where reducing conditions prevail (8).

Table 2: The mean concentration of Arsenic in the sediments.

<table>
<thead>
<tr>
<th>SAMPLING POINTS</th>
<th>MEAN CONCENTRATION 1992 Samples (mg/kg)</th>
<th>MEAN CONCENTRATION 1993 Samples (mg/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>77.4 (1.5)</td>
<td>125.0 (2.1)</td>
</tr>
<tr>
<td>A</td>
<td>225.9 (2.8)</td>
<td>86.5 (1.8)</td>
</tr>
<tr>
<td>B</td>
<td>1602.8 (1.4)</td>
<td>560.0 (2.0)</td>
</tr>
<tr>
<td>B30CM</td>
<td>2589.7 (0.9)</td>
<td>2555.0 (0.9)</td>
</tr>
<tr>
<td>D</td>
<td>2743.0 (0.9)</td>
<td>2627.5 (1.0)</td>
</tr>
<tr>
<td>F</td>
<td>2404.0 (2.0)</td>
<td>2173.2 (1.8)</td>
</tr>
<tr>
<td>F30CM</td>
<td>1891.4 (2.1)</td>
<td>1811.0 (1.9)</td>
</tr>
<tr>
<td>I</td>
<td>854.3 (2.9)</td>
<td>1041.0 (2.9)</td>
</tr>
<tr>
<td>I30CM</td>
<td>596.0 (2.2)</td>
<td>540.0 (2.7)</td>
</tr>
<tr>
<td>K</td>
<td>2261.0 (0.9)</td>
<td>1996.7 (1.8)</td>
</tr>
<tr>
<td>K30CM</td>
<td>1854.0 (1.4)</td>
<td>1765.0 (1.8)</td>
</tr>
<tr>
<td>L</td>
<td>1521.2 (2.0)</td>
<td>1395.5 (1.9)</td>
</tr>
<tr>
<td>L30CM</td>
<td>1154.0 (1.8)</td>
<td>1102.9 (1.4)</td>
</tr>
<tr>
<td>M</td>
<td>744.0 (2.5)</td>
<td>711.6 (1.7)</td>
</tr>
<tr>
<td>M30CM</td>
<td>262.0 (1.9)</td>
<td>95.9 (2.1)</td>
</tr>
<tr>
<td>N</td>
<td>1484.4 (2.2)</td>
<td>2265.6 (1.4)</td>
</tr>
<tr>
<td>R</td>
<td>22.0 (3.0)</td>
<td>18.1 (2.9)</td>
</tr>
</tbody>
</table>

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In conclusion we observe that the sediments and the waters in catchment areas are polluted as a result of the tailings being constantly washed and/or leached into the rivers and other water bodies in the area.

LEACHING EXPERIMENTS

The sediments were leached with the aim of finding out how long it will take for the As concentration to reduce to acceptable levels when no discharge is taking place and the ARP is functioning. Two leaching methods- static and dynamic - were adopted. In each case distilled water (pH 6) and simulated river water containing 3.0ppm Al, 1.0ppm Mn and 1.5ppm Fe were employed leachants.

a) In the STATIC method 2g of the sediment sample was suspended in 100ml leachant. After stirring for 30minutes the suspension was allowed to stand undisturbed at room temperature. 1ml portions of the clear supernatant leachant was taken for total arsenic determination each week. Samples for measurement were filtered over a Milllex-FG50 unit (Millipore, USA)

b) In the DYNAMIC method, 2g of the sediment suspended in 100ml leachant, stirred for 30 minutes and allowed to stand at room temperature. Samples of arsenic determination were taken each week, after which the leachant was decanted from the sediment and replaced with a fresh one.

Total As in the water and in the sediment were determined as previously described. The results are presented in figures 3 to 5. The reproducibilities are in all cases better than 10%. For heterogenous materials like the sediment lower reproducibilities are expected (9) because the system is seldom in equilibrium; many processes, including dissolution, exchange, diffusion etc., may be taking place to different extents at the same time.

Since the leachant was not renewed in the static method the concentration of arsenic in the solution increased with time. The leach rate i.e the amount of As leached as a function of time is depicted in fig 3. Initially, a relatively high rate (between 11.00 and 48.60 ppb/wk) was registered but this decreased rapidly in subsequent weeks to very low levels (0.1 - 3.30 ppb/wk). The cumulative percentage amount of arsenic leached in distilled water, i.e. the fraction of the total arsenic leached are given in table 3. After about 20 weeks the fraction of As that has leached out of the sediment is very small, below 0.5% of the initial amount.

Table 3: Mean cumulative fraction of As leached from surface sediments. (Leachant: deionised - distilled water).

<table>
<thead>
<tr>
<th>Time (Weeks)</th>
<th>1</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
<th>18</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
</tr>
</thead>
<tbody>
<tr>
<td>% As leached</td>
<td>0.093</td>
<td>0.118</td>
<td>0.131</td>
<td>0.166</td>
<td>0.186</td>
<td>0.213</td>
<td>0.229</td>
<td>0.244</td>
<td>0.256</td>
<td>0.264</td>
<td>0.272</td>
<td>0.274</td>
<td>0.273</td>
<td>0.272</td>
</tr>
</tbody>
</table>

The cumulative leach rate in simulated river water shows a similar trend as in the case of the distilled water (fig.4). However the rate appear greatly suppressed. The initial rate at point F. for example, is 32.30 ppb/wk, decreasing to 0.05ppb/wk by the sixth week, as compared to 48.60 and 1.10 ppb/wk for the same period in distilled water. In the method by which the leachant was renewed periodically the rate of leaching is expressed as the differential leach rate. Fig. 5 shows the variation of the differential leach rate with time. Here the rate is relatively higher than the cumulative rate and it decreases much slower with time. The fraction leached after several weeks was, however, insignificantly small. These results are not quite unexpected. Arsenic is known to have low leachability as a result of the strong absorptive capability of sediments and soils for it. It may be leached from coarse textured soil, if the soil is low in reactive Al and Fe, however it is quite immobile in fine-textured soil i.e with high clay content (10). Also since arsenic forms compounds of varying degrees of solubility with elements such as Fe, Ca, Mn and is
absorbed or occluded by hydrous oxides of Fe and Al, their presence would tend to suppress the leaching (6).

In conclusion we note that the rate of leaching of the arsenic from the sediment is extremely low and decreases also with time. It is therefore not likely the ecosystem in the catchment area can redeem itself within reasonable period of time, even if all discharges from the PTP were stopped and no further action taken. To restore the health of the streams in the area it might be necessary to resort to dredging. But the problem would be the disposal of this contaminated waste.

REFERENCES

LOCAL SULPHOOXIDIZING BACTERIA FOR ENVIRONMENTALLY FRIENDLY GOLDMINING.

C. Clement, R. Asmah, M. E. Addy, K.M. Bosompe* and B.D. Akanmori*

Department of Biochemistry, University of Ghana, Noguchi Memorial Institute for Medical Research Legon*.

SUMMARY

Using gold bearing underground ore as well as processing material as sources of sulphooxidizing bacteria, laboratory cultures of a mixture of the three principal bacteria (Thiococcus ferrooxidans, T. thlooxidans and leptospirillum ferrooxidans) and other isolates were established. Use of 9K, synthetic medium containing Ammonium sulphate, Potassium chloride, Potassium phosphate. Magnesium sulphate septahydrate, Calcium nitrate, Iron sulphate septahydrate, and Sulphuric acid for growing the sulphooxidizing bacteria resulted in the formation of smaller quantities of precipitate compared to the use of the commercially available formulae when iron II sulphate was supplied as the energy source.

INTRODUCTION

Gold is the single most important mineral in the mining industry in Ghana. It has overtaken cocoa the traditional foreign exchange earner and its production is still rising. Currently there are more than fifty (50) mining leases operating in the country, not to mention the small scale operators. The extraction process has however a significant impact on the environment because of the consequent release of toxic chemicals into the environment. Soils, water sources, vegetation and the atmosphere currently show slightly higher than safe levels of mercury, arsenic, zinc, cyanide and emissions of sulphur dioxide etc. While assessing thoroughly the impact on the environment, alternate methods of extraction should be pursued.

Gold occurrence in Ghana is concentrated on the Proterozoic rock formations found mainly in the Southwestern part of the country. This rock formation, referred to as the Birimian, forms the eastern portion of the West African Precambrian Guinea Shield. The Birimian subdivisions are the lower unit (metasedimentary rocks) and the upper unit (metavolcanic rocks).

The most predominant of these is the Ashanti belt which bears five major gold producing mines including the Obuasi mine. The Ashanti gold belt stretches a distance of about 195km to the SW of Obuasi and continues for 65km to the NE. The Ashanti gold deposit occurs at Obuasi. The deposit is the, richest in the West African sub-region. As far back as September 1986 the mine produced about six hundred tonnes of gold with a reported average ore grade of about 22.5g/t (Kesse, 1985). Production for the year 1990 was 420,000 oz. (Obermurn et al 1991). The gold occurs as the native metal normally with arsenopyrite, pyrrhotite and pyrite, these gold-sulphides are disseminated in metasediments and metavolcanics. Some gold is associated with tetrahedrite and sphalerite that abound in the quartz veins. Oxidised ore also occurs within 30m from the surface in some places. Detailed geology and genesis of gold in the Birimian of Ghana and the Obuasi ore have been reported by several workers. e.g., Junner (1932), Kesse (1985), Adjimah (1988), Amanor and Gyapong (1988) and Cozens (1988).

Conventionally the gold-sulphide ore is mined by deep shaft and surface mining and extracted by a chemical process. The ore is milled into fine powder, reacted with cyanide salts (e.g. NaCN), water and aerated to form gold cyanide. The resulting solution is concentrated by a filtration process and passage through a series of thickeners. The gold is recovered from the gold-rich slurry by the addition of zinc metal (Zn). The gold is purified by electrolysis, the anode is impure gold and the cathode is pure gold.
coated with graphite. A substantial quantity of gold is lost through the extraction process to the tailings and it is not an economical way of obtaining gold from very low grade gold sulphide ores.

The biogeochemical process of bioleaching has an advantage over the conventional process due to its low cost, in treating millions of tonnes of otherwise uneconomic low-grade ores and effluent from the extraction process. This technique is used to obtain gold from tailings of mainly ore bodies of gold-sulphides among others. It is an environmentally friendly technique, since there is very little or net release of toxic chemicals into the surrounding. The biological process requires that the microbes are grown under optimum conditions, thus deriving their energy by the oxidation of the gold-sulphide crystals in which the native metal is embedded. The benefit of the bioleaching process is two-fold; the reduction of the use and release of toxic chemicals to the surrounding and adaptation of less expensive machinery that will encourage greater exploitation of gold under environmentally less damaging conditions.

AIM

The overall aim of the research is to develop indigenous sulphooxidizing bacteria for gold mining, a technology recognised as being more environmentally friendly than some other technologies.

METHODOLOGY

Isolation and culture of local strains

1. Samples were collected from mine effluent, tailing dumps etc. and subcultured to obtain single colonies. These clones were established in the laboratory. Pure cultures of the strains were prepared overnight in Erlenmeyer flasks fitted with airlift tubes. The cultures were monitored by a synthetic substrate coded 9K. To check on their leaching capabilities, the cultures were incubated for 24hrs with equal quantities of identical gold-sulphide ore or tailing samples (50g/flask) milled into fine powder. Gold was recovered by solvent extraction using methylisobutylketone (MIBK). The concentration of gold was estimated by AAS.

2. The colonies were identified by microscopic techniques (see appendices A and B) and the gold leaching capabilities of the specific strains measured by preparing overnight cultures for incubating gold-sulphide ore and tailing samples as previously stated. Growth of these strains under the parameters of pH, ionic concentration and quantity of substrate will be varied and measured to establish the optimal conditions for the maximum performance of these strains.

BIOMETICAL LEACHING, AGC EXPERIENCE

The Ashanti Goldfields Company (AGC) is a pioneer in this field in Ghana, having established a bio-leaching plant and adapted isolates imported from South Africa to successfully extract the metal. Currently its bioleaching facility called the Sulphide Treatment Plant (STP) processes about 10% of the total mine ore production and produces about 30-40% of its gold.

The STP uses a huge volume of water, about 3.6 million gallons/day (16,000 m³/day) required and the distance where it is obtained is expensive and challenging. Tremendous savings would be made if this water can be re-cycled. Presently it is not possible to recycle the wastewater back into the Bioleaching Plant because of the extreme sensitivity of the bacteria isolates being used, to the cyanide. Levels as low as 5 parts per billion (ppb) of thiocyanide (SCN) adversely affect their optimal growth and consequently sulpho-oxidizing action. Isolates which are less sensitive to cyanide could lead to some amount of recycling of the water.

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These organisms function best at acidic pH. The downstream processing to recover the gold therefore involves the addition of a certain amount of basic compounds to increase the pH. In addition to temperature-tolerant strains, additional savings could be made if strains of bacteria which operate at pHs higher than what obtains at the STP could be engineered.

CONCLUSIONS

These results show that we have established the methodology for the isolation and purification of the three original bacteria (T. ferrooxidans, T. thiooxidans and L. ferrooxidans) used in bioleaching. The usefulness of this result is that pure cultures of the sulphooxidizing bacteria could be maintained while investigations are carried out to ascertain the most effective combination of these pure cultures for the bioleaching of each type of ore available at the mine site. With this information, different combinations of the various bacteria will be used to inoculate the tanks, depending on the type of ore, rather than the current practice of using the same combination of the three bacteria for all types of ore.

The isolation of local sulphooxidizing bacteria from the underground mine water is most exciting. This is because it could lead to isolation of local bacteria with better efficiency of biooxidation of the AGC underground ore. It also suggests that additional organisms in the ore could change the efficiency of the bioleaching process depending on the source of the ore.

REFERENCES


APPENDIX A

Top figure: 1) Irregularly shaped colonies of *T. ferrooxidans*
2) Star shaped colonies of *L. ferrooxidans*
(Specimen comes from underground ore)

Bottom figure: (1&2) are the same colony types (specimen comes from some reactor tank)

APPENDIX B

(a) Shows the curved rod cell of *L. ferrooxidans*.
(b) Shows the straight rod cell of *T. ferrooxidans*.
DEVELOPMENT AND APPLICATION OF SELENIUM ION SELECTIVE ELECTRODE IN THE ANALYSIS OF SELENIUM IN SAMPLES FROM THE ENVIRONS OF OBUASI

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Department of Chemistry University of Cape Coast, Cape Coast, Ghana

ABSTRACT

1,2-diaminoethane and o-phenylenediamine in 2-nitrophenyl octyl ether (NPOE) solvent mediator have been used to fabricate PVC membrane selenium ion-selective electrodes. The electrode based on 1,2-diaminoethane was applied to the determination of selenium in samples from Kwabrafo a suburb of Obuasi with the following results. Tomatoes (5.49 ppm); garden eggs (4.70 ppm); maize (5.13 ppm); plantain (1.580 ppm); cocoyam leaves (0.758 ppm); mango fruit (1.738 ppm); orange (0.869 ppm); pawpaw (0.948 ppm); River Kwabrafo (5.45 ppm); river sediment (1.169 ppm). The selenium concentration in these samples are higher than the recommended values.

INTRODUCTION

Selenium has a dual role. It serves as an essential element at low concentrations on one hand and as a toxic substance at higher levels (1). This dual roles of selenium has generated interest in its study. The primary source of selenium is volcanic activity (1, 2) and mining activity in arsenopyrites ores (3). The gold ore found in Obuasi is reported to be made up of both pyrites (FeS$_2$) and arsenopyrites (FeAsS) (4). The mining activity in Obuasi is therefore expected to release selenium into the environment.

Selenium is required by the body in small amounts. In diet of animals, its concentration is around 0.04 ppm (5). It is beneficial to 0.1 ppm and toxic above 4 ppm (1,5). Selenium in soils varies from about 0.1 ppm in deficient areas to as much as 1,200 ppm$^2$. Intake of high levels of selenium results in chronic selenium poisoning which is known as selenosis. It is therefore important that levels of selenium in the environment are well determined since plants and streams in the selenium rich environment will carry high levels of selenium. The current methods of selenium determination include UV/VIS spectrophotometry, spectrofluorimetry and hydride generation atomic absorption spectrometry. These methods though are very sensitive for Se$^4+$ the equipment involved are expensive.

It is the aim of this paper to fabricate a selenium ion PVC membrane electrode based on 1,2-diaminoethane and o-phenylenediamine using 2-nitrophenyl octyl ether (NPOE) as solvent mediator and apply it to the determination of selenium in samples from the environments of Obuasi, a mining town in Ghana.

Experimental

Reagents/Chemicals

Analytical grade chemicals were used whenever possible. All solutions were prepared in double distilled water. Chlorides of interferant ions were used except lead where the nitrate was used. Selenium dioxide was used as a source of selenium (iv) ions and was obtained together with the chlorides and the nitrate from BDH Chemicals Ltd., Poole, England. PVC and 2-nitrophenyloctyl ether (NPOE) were obtained from Sigma Chemical Company, St. Louis, USA.

Technical grade ionophores were used and were obtained from BDH Chemicals Ltd, Poole, England. The formula of the ionophores are shown in figure 1.
Membrane Preparation.

The membrane component (1-3% w/w ionophore, 0% w/w PVC powder, and 66-69% w/w plasticizer) totalling about 300 mg were dissolved in 5-10 ml of freshly distilled tetrahydrofuran (THF). The mixture was stirred continuously for about 15-20 minutes using a magnetic stirrer until an oily mixture was obtained. The resulting mixture was cast into a 24 mm (inner diameter) glass ring resting on a glass plate. After leaving overnight for the solvent to evaporate, discs of 7 mm diameter of the resulting membrane were cut and peeled from the glass plate. The membrane discs were glued to pvc tubes. The membranes attached to the tubes were soaked in 10^-3 M selenium (IV) solution for 24-26 hours. The pvc tube together with the membrane was fixed on to a discarded glass electrode as shown in figure 2.

Determination of Selectivity Coefficient (k^\text{Vet}_{\text{Sn,III}})

The selectivity coefficient was determined for the selenium electrode with respect to the following ions(B) using the mixed solution method (6): Li^+, Na^+, K^+, Mg^{2+}, Ca^{2+}, Ba^{2+}, Ni^{2+}, Cd^{2+}, Co^{2+}, Fe^{3+}, Pb^{2+} and Cu^{2+}.
**Determination of Operational pH range**

The operational pH range of the electrode was determined by varying the pH of 10⁻³M selenium(IV) solution with hydrochloric acid and sodium hydroxide solution. The change in potential was plotted against the pH. The pH range where there was no change in potential was recorded as operational or working pH range.

**Electrode Calibration**

The electrochemical cell used was as follows:

Ag, AgCl, 10⁻³M; selenium(IV) sensor sample  
Hg₂Cl₂, Hg; KC₁(Sat)

solution membrane solution

The electrodes were calibrated by spiking standard selenium (IV) solution to cover a range of 10⁻⁷ - 10⁻¹ M in 100mL distilled water. A graph of millivolts against the log activity of selenium (log a₅₂) was plotted from which the slope and linear concentration range were calculated. Measurements were made at temperatures between 28 and 29°C. The activities of the metal ions were based on activity coefficient data calculated from the modified form of the Debye-Hückel equation which is applicable to any ion (7, 8). All emf measurements were made with a Pacitronic 870mV digital pH meter (Messgerate, Dresden, Germany).

**Preparation of selenium (IV) standard solution**

1.0M standard selenium solution was prepared by dissolving 110.96g of selenium dioxide (analytical reagent grade) in a minimum volume of 5% v/v HNO₃ solution. The mixture was then diluted to 1 litre with double distilled water. Various working standard selenium solutions spanning the concentration range, 10⁻⁷ -10⁻¹ M, were prepared by diluting the selenium (IV) standard solution with doubly distilled water.

**RECOVERY**

Selenium (IV) recovery was done by direct potentiometric method. A calibration curve for selenium (IV) was obtained by spiking 0.1, 0.5, 1.0 and 1.5cm³ of 10⁻⁴M standard selenium (IV) solution corresponding to 0.5, 2.5, 5.0 and 7.5 (x 10⁻⁴M) selenium (IV) ions in 20cm³ of distilled water.

The millivolt of 0.75 cm³ of solution of 10⁻⁴M standard selenium (IV) solution in 20 cm³ distilled water corresponding to 4.00 x 10⁻⁶M selenium (IV) ions was recorded and its concentration obtained from the calibration curve by extrapolation.

**Digestion of Samples**

To 2g soil, 1g biomaterial and 10cm³ of preconcentrated river water sample was added 15 to 20 cm³ of (3+1) HNO₃ + HClO₃ mixture solution. This was heated gently at first, and then to dryness. The residue was dissolved in 5cm³ of 25%; v/v HCl solution followed by further evaporation almost to dryness. The residue was then diluted with distilled water, filtered and made up to 100cm³. One litre of the river water was concentrated to 500ml by evaporation and was referred to as preconcentrated river water.
RESULTS AND DISCUSSION

Performance Characteristic of electrodes

The electrode based on 2% o-phenylenediamine has nernstian slope of 15 and linear concentration range of $10^{-3} - 10^{-1}$M while the electrode based on 2% 1, 2-diaminoethane has nernstian slope of 14.3 and linear concentration range of $10^{-3} - 10^{-1}$. The performance characteristic of the two electrodes is comparable. The calibration curves are shown in figure 3.

Reproducibility and stability of electrode calibration

The reproducibility of the electrode was determined by recording the calibration curve a number of times. Figure 4 shows the calibration of the selenium (iv) electrode based on 1,2-diaminoethane. The electrode is very reproducible as can be seen in figure 4. The electrode was calibrated over a period of nineteen (19) days. The electrode performance was similar over the period as shown in figure 5. The electrode stability was also examined. Figure 6 shows that the electrode response is stable over a wide range of time.

Effect of pH

The working pH ranged from 3.3 to 10.6 for the electrode based on 1,2-diaminoethane and from 2.9 to 10.7 for the o-phenylenediamine electrode as shown in figure 4. The latter electrode has a slightly wider pH range.

Selectivity Studies

The effect of interference by other ions was studied by determining the selectivity coefficient of the selenium (iv) electrode with respect to other ions. The results are shown in Table 1. The selectivity coefficient values are all less than unity indicating that these other ions do not interfere with the selenium (iv) electrode.

Table 1: Selectivity coefficient values of various cations obtained with electrodes based on 1,2-diaminoethane and o-phenylenediamine using the mixed solution method.

<table>
<thead>
<tr>
<th>Interferant ion</th>
<th>$K_{pot}^{M}$</th>
<th>$K_{pot}^{S_4}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$K^+$</td>
<td>3.0 x 10^{-1}</td>
<td>9.0 x 10^{-1}</td>
</tr>
<tr>
<td>$Na^+$</td>
<td>2.5 x 10^{-1}</td>
<td>9.0 x 10^{-1}</td>
</tr>
<tr>
<td>$Cu^{2+}$</td>
<td>7.2 x 10^{-4}</td>
<td>7.2 x 10^{-4}</td>
</tr>
<tr>
<td>$Mg^{2+}$</td>
<td>9.0 x 10^{-4}</td>
<td>9.0 x 10^{-4}</td>
</tr>
<tr>
<td>$Ni^{2+}$</td>
<td>2.5 x 10^{-5}</td>
<td>2.5 x 10^{-5}</td>
</tr>
<tr>
<td>$Fe^{3+}$</td>
<td>7.5 x 10^{-6}</td>
<td>7.5 x 10^{-6}</td>
</tr>
<tr>
<td>$Pb^{2+}$</td>
<td>4.9 x 10^{-5}</td>
<td>4.9 x 10^{-5}</td>
</tr>
<tr>
<td>$Li^+$</td>
<td>3.8 x 10^{-4}</td>
<td>3.8 x 10^{-4}</td>
</tr>
<tr>
<td>$Co^{2+}$</td>
<td>8.9 x 10^{-4}</td>
<td>8.9 x 10^{-4}</td>
</tr>
<tr>
<td>$Cd^{2+}$</td>
<td>1.0 x 10^{-5}</td>
<td>1.0 x 10^{-5}</td>
</tr>
<tr>
<td>$Zn^{2+}$</td>
<td>6.1 x 10^{-5}</td>
<td>6.1 x 10^{-5}</td>
</tr>
<tr>
<td>$K^+$</td>
<td>2.0 x 10^{-5}</td>
<td>2.0 x 10^{-5}</td>
</tr>
<tr>
<td>$Na^+$</td>
<td>3.0 x 10^{-1}</td>
<td>9.0 x 10^{-1}</td>
</tr>
</tbody>
</table>
Fig. 3: Calibration plots for Se (IV) ion selective Electrode based on (1) o-phenylenediamine (2) 1, 2-diaminoethane

Fig. 4: Reproducibility of Electrode Calibration unit using 1,2- Diaminoethane Electrode of NPOE
Fig. 5: Calibration Curves Using 1 X 2- Diaminoethane base Electrode at varied days

Fig. 6: Stability of 1, 2- Diaminoethane based Se (IV) ISE

Fig. 7: Effect of pH on the Se (IV) ISE Response: (1) phenylenediamine (2) 1, 2- Diaminoethane
In general, the results show that there was negligible interference by the inorganic cations investigated for any of the electrodes.

Recovery Studies

The recovery of selenium (iv) was determined using the two electrodes. The results are shown in Table 2. The recovery studies showed that both electrodes could be used to determine selenium in solution.

Table 2: Recovery of Selenium (iv) ions from standard solutions

<table>
<thead>
<tr>
<th>Standard Se (iv) added</th>
<th>1,2-Diaminoethane</th>
<th>o-phenylenediamine</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4.00 x 10^{-4}</td>
<td>4.00 x 10^{-4}</td>
</tr>
<tr>
<td>Amount of Se (iv) recovered</td>
<td>3.80 x 10^{-4}</td>
<td>4.00 x 10^{-4}</td>
</tr>
<tr>
<td></td>
<td>4.00 x 10^{-4}</td>
<td>4.30 x 10^{-4}</td>
</tr>
<tr>
<td></td>
<td>3.70 x 10^{-4}</td>
<td>4.20 x 10^{-4}</td>
</tr>
<tr>
<td>Average Recovery</td>
<td>95.8</td>
<td>99.4</td>
</tr>
<tr>
<td>SD</td>
<td>2.6</td>
<td>1.7</td>
</tr>
<tr>
<td>Confidence level</td>
<td>95.5</td>
<td>90.6</td>
</tr>
</tbody>
</table>

The confidence level of 1,2-diaminoethane is slightly better than that of the o-phenylenediamine electrode. For this reason and for the fact that it also has a better working pH range, the 1,2-diaminoethane electrode was used to determine Se(iv) in environmental samples.

Analysis of Environmental Samples

1,2-diaminoethane based electrode was used to determine selenium in tomatoes, garden eggs, plantain, cocoyam leaves, orange, river water, maize, river sediment and pawpaw. The results are shown in Table 3. The concentration of selenium in environmental samples such as tomatoes, garden eggs, maize, plantain, mango, cocoyam leaves, orange, pawpaw, kwabrafo river water, and river sediment (table 3) varied from 0.758 to 5.49ppm. The selenium ion in the environment varies from environment to environment depending largely on the type of soil and pH. In alkaline soils, selenium is readily absorbed by plants while in acidic soils, it is not easily available since it forms a selenite which is not easily absorbed by plants (1,2).

The acceptable standard value for selenium ion in water and soil is reported (9, 10) to be as follows: portable water (< 10 ppm), seleniferous soils (up to 500 ppm), river water(10-350 part per trillion). The acceptable standard values for selenium in food stuffs and plants are reported (11-15) as follows: land plants (non accumulators) 0.03ppm, edible vegetables 0.001-0.5ppm, mammal muscle 0.42-1.9ppm, mammal bone 1-9ppm, marine algae 0.04-0.1ppm, marine fish 0.17ppm.

The results for the selenium concentration in the samples from Obuasi are high as compared to the acceptable values. This can only be attributed to the mining activity in the area. This confirms the observation made by earlier workers (16, 17) who determined selenium ion in environmental samples from Obuasi using spectropotometric method.
Table 3: Selenium Concentration (dry wt) in Environmental Samples from Obuasi

<table>
<thead>
<tr>
<th>Sample</th>
<th>Selenium concentration (dry wt)(ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomatoes</td>
<td>5.49</td>
</tr>
<tr>
<td>Garden eggs</td>
<td>4.70</td>
</tr>
<tr>
<td>Maize</td>
<td>5.13</td>
</tr>
<tr>
<td>Plantain</td>
<td>1.580</td>
</tr>
<tr>
<td>Cocoyam Leaves</td>
<td>0.758</td>
</tr>
<tr>
<td>Mango Fruit</td>
<td>1.738</td>
</tr>
<tr>
<td>Orange</td>
<td>0.869</td>
</tr>
<tr>
<td>Pawpaw</td>
<td>0.948</td>
</tr>
<tr>
<td>River Kwabrafo (after effluent)</td>
<td>5.45</td>
</tr>
<tr>
<td>River Kwabrafo (upstream before effluent)</td>
<td>0.869</td>
</tr>
<tr>
<td>River Kwabrafo sediment (after effluent)</td>
<td>1.169</td>
</tr>
</tbody>
</table>

CONCLUSION

1,2-diaminoethane and o-phenylenediamine have proved to be a good ionophore for selenium in selenium (iv) ion selective electrode using 2-nitrophenyl octyl ether as a solvent mediator. The electrode based on 1,2-diaminoethane has been successfully used to analyse for selenium in environmental samples from Obuasi, a mining town in the Ashanti Region of Ghana. The selenium (iv) ion concentration in plants, foodstuff, fruits and river water and sediment are high compared to recommended values.

ACKNOWLEDGEMENT

The research grant by The Third World Academy of Sciences towards this research is gratefully acknowledged.

REFERENCES


*Author to whom all correspondence be addressed*
ENVIRONMENTAL ACCEPTABLE RECLAMATION PROCEDURES FOR MINE SPOILS

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Department of Physics, University of Cape Coast, Cape Coast, Ghana

ABSTRACT

Mine spoils are refuse from both shaft and surface mining. Spoils consist of rocks and soil materials in all degrees of coarseness and fineness. Some contain heavy metals in toxic concentrations and pyrite that oxidizes to toxic sulphur acid, causing destruction of established vegetation.

To avoid serious environmental damage the spoils must be smoothed and vegetated. Almost all mine spoils are deficient in nitrogen and phosphorous, and some require lime to enhance plant growth. Since spoil environment is not ideal growth medium and legumes seeded on mine spoils need more than the normal rhizobium inoculation, mulching is generally helpful. Many species of grasses, legumes, trees and shrubs, vines and brambles tolerate acid spoils in the humid tropics and should be used whenever feasible. It is recommended that a soil conservation service be established to manage and monitor mine spoils on national scale and a tax must be imposed on all operations to support the service.

1. INTRODUCTION

Areas drastically disturbed by mining are an environmental menace because they are a source of large quantities of sediment, strong acid and toxic seepage and toxic heavy metals such as cadmium (Cd), copper (Cu), lead (Pb) and zinc (Zn) (1). In addition the acid mine water may contain toxic quantities of Cu, aluminium (Al) and magnesium (Mg). The extraction of precious metal accomplished by an amalgamation process have introduced tons of mercury (Hg) into the environment. Hg is a toxic metal which is bioaccumulated in living tissues with no known biological function (2). Heavy metal pollution of agricultural soils is one of the most severe ecological problems in mining areas.

Mines spoils are refuse from both shaft and surface mining and the general topography indicates that mine spoils have steep slope and are unstable when they become saturated with water. In general are compacted, excessively stony, are deficient in silt and clay and could therefore hold little water and hence of low fertility. It is a requirement in many countries today that the land utilised by a mining company in the course of its operating life be rehabilitated. In some circumstances, for example uranium mines and some base metal smelters decommissioning is considered a separate issue from rehabilitation. But sites where the surface soils and underlying strata have been cut, filled, intermixed and compacted by heavy machinery it becomes difficult to rehabilitate. The problem associated with the establishment of vegetation results from inferior soil physical condition, draughtiness, wetness, low or unbalanced fertility, excess acidity, alkalinity or salinity and steep erosive slopes.

The task of revegetation is generally expensive per unit area of land but the cost is small compared to the total cost of the mining project. Although mining activities put pressure on ecological resources and direct destruction of fragile species, there are a number of situations in which man-made environments can be beneficial to wildlife in general and specific species in particular. Davis (3) has outlined some ways in which wildlife can adapt to and exploit man-made environment. Kelcey (4) points out that extractive industries often provide suitable conditions and opportunities for many species of plants to colonise, as well as breeding sites for birds which nest in areas devoid of vegetation.

Mining in Ghana is on an increase and will be obtained by disturbing the land, but for sustained development, the spoils must be reclaimed. Mine spoils from shaft mines originate from the interbedded
rocks and soil material. Surface mine spoils come mainly from the overburden, but also contain interbedded rocks and earthly materials from below the surface. Whatever the source, mine spoils degrade the environment and accepted reclamation procedures must be adopted. In this paper methods for investigating site preparation and re-vegetation of mine spoils would be discussed.

2. RECLAMATION

Reclamation of mine spoils have different meanings to different people. In this paper the reclamation of mine spoils includes mechanical means of site preparation, revegetation of mine dump sites and the control of acid waters and toxic materials. Out slope spoils tend to be unstable when the pre-mining slope exceed 20°. In some cases out slopes contain pyritic spoils causing acid drainage. High wall seeps can also act as sources of acid mine drainage. Temporary mechanical techniques to retain mine spoils at the site include the use of sediment basins, terraces, berms and diversion dams. Steep slopes must be graded and the topsoil replaced after mining activities have ceased. The final stage is the establishment of either perennial vegetation, cultivated crops, ponds or lakes over the entire area.

2.1. Techniques and Procedures

Before mining begins, materials that can produce extreme acidity or alkalinity or that contain excessive soluble salts should be identified by laboratory testing of core samples. All such materials should be kept separate during excavation and buried below plant root depth before the final grading of the surface. Safe agricultural use of these areas also means controlling plant uptake of heavy metals (5). This can be accomplished by removal of the polluted soil layer, by treating the polluted soil with lime or other chemical reagents to immobilise or remove the heavy metals, and by covering the polluted soil with a layer of clean, unpolluted soil, sufficiently thick to reduce metal uptake to an acceptable level (6).

Crop plants extract most of their nutrients from the topsoil. Many crop roots penetrate into deeper layers up to two meters but this generally contributes to water supply rather than mineral nutrients which are applied to the top soil.

Temporary vegetation may be used to stabilise the surface until perennial vegetation can be established to hold the soil against water and wind erosion. Therefore the management techniques for improving the productive capability of disturbed soil include top soiling, liming (if acid), fertilising, applying manure or sewage sludge and mulching.

By top soiling we mean the application of a productive surface soil to the final soil grade. Lime and fertilisers are usually applied on the basis of soil test before planting vegetation. Addition of lime to a base unsaturated soil raises the pH and the lime potential, increases the proportion of calcium on the exchange complex and can immobilise by precipitation cation elements such as iron, manganese and aluminium which may be present in a soil to excess.

2.2. Soil Test and Remedial Measures

Measurement of soil properties should occur as part of the detailed analysis of the field investigation. General soil properties of interest include pH, permeability, organic matter content, silt, sand and clay content and cation exchange capacity (CEC). An important characteristic of soil is its capability to retain dissolved iron and compounds. The greater the CEC of a soil, the greater the potential or the more effective the soil is for waste treatment. The CEC of a soil is expressed in terms of milliequivalent and is a function of the organic matter content and the type and amount of clay in the soil. Many of the potentially toxic metals such as (Cd), nickel (Ni), (Zn) and (Cu) are positively charged and their immobilisation and retention by soil is related to the CEC of the soil.
Because of the greater variability of spoils, soils sample should represent a smaller area of the mine spoils. From preliminary investigations the chemical variabilities in spoils were identified to be:

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>2.2 to 7.3</td>
</tr>
<tr>
<td>N</td>
<td>&lt; 0.1 to 0.2 %</td>
</tr>
<tr>
<td>P</td>
<td>6.6 to 64.2 ppm</td>
</tr>
<tr>
<td>K</td>
<td>&lt; 0.1 to 0.8 me/100g spoil</td>
</tr>
<tr>
<td>Ca</td>
<td>1.0 to 17.5 me/ 100g spoil</td>
</tr>
<tr>
<td>Mg</td>
<td>0.3 to 4.8 me/ 100g spoil</td>
</tr>
</tbody>
</table>

The main value of a pH measurement is not that it shows a soil to be acid or alkaline but it gives the information about associated soil properties such as phosphorous availability, base status and so on. Soil pH most markedly affects plant growth through control of nutrient availability (i.e. solubility) of manganese and iron to the root system. Phosphorous availability is also reduced because of formation of calcium phosphates. Marked soil acidification tends to affect the plant adversely through increased availability (often to the point of toxicity) of aluminium and also manganese. Sometimes other metals because of their locally high concentrations replace aluminium and manganese as the dominant phytotoxic components of low pH soil systems. Copper, for example can become available at phytotoxic concentrations in mine spoils (7).

Most agricultural soils have pH value lying between 4 and 8. Most acid soils are usually peaty in nature and often contain high proportion of sulphur or aluminium. The more acid a soil is the more mobile will become such elements as iron, manganese, zinc, copper, and other minor element. Another important soil property depending upon pH status is that of microbial activity. Many micro-organisms and in particular the nitriifiers are inhibited by acidity, others such as Thiobacillus thio-oxidans, require a low pH in order to function effectively. In general low pH increases the bio-availability of heavy metal. The effects of mobilised heavy metal ions on different components of the soil biots are complex.

A unique problem of many mine spoils studied is the presence of pyrite (FeS₂) which oxidises to sulphuric acid when exposed to the atmosphere through the chemical reaction:

$$2\text{FeS}_2 + 7\text{O}_2 + 2\text{H}_2\text{O} = 2\text{FeSO}_4 + 2\text{H}_2\text{SO}_4$$  \hspace{1cm} (1)

The ferrous sulphate is oxidised to ferric sulphate:

$$4\text{FeSO}_4 + \text{O}_2 = 2\text{Fe}_2(\text{SO}_4)_3 + 2\text{H}_2\text{O}$$  \hspace{1cm} (2)

The ferric sulphate then hydrolyses to form colloidal ferric hydroxide and sulphuric acid:

$$\text{Fe}_2(\text{SO}_4)_3 + 6\text{H}_2\text{O} = 2\text{Fe(OH)}_3 + 3\text{H}_2\text{SO}_4$$  \hspace{1cm} (3)

The acid is produced by bacterial action and may kill all vegetation, or the process stops when the condition become so acidic that neither the bacteria nor any other living things can tolerate it (i.e pH between 2 and 3). The acid could be neutralised with lime, but the neutralisation may last for only a few months until more sulphuric acid is formed. The best solution is to bury the spoils that contain pyrite. An alternative but expensive method is to apply lime whenever soil tests indicate the need or to use an acid tolerant vegetation.

Since nearly all spoils are low in organic matter and plant nutrients, they can serve as ideal sites for heavy application of manure and sewage sludge. Most species of grasses, legumes and trees grow better in areas treated with sewage (8). Surface mulching with organic wastes reduces splash erosion, surface puddling and sealing of the soil. Immediately after seeding or planting, mulches can be applied.
immediately to protect the base soil until proper season for seeding or planting. The most common organic mulches which can be used are wood chips, wood fibres, grain straw and grass. The materials should be packed into thickness of 3 to 6 cm over all disturbed soil surfaces.

3. PROCEDURES FOR ESTABLISHING VEGETATION

Re-seeding grasses, planting trees and shrubs on a prepared site are relatively straight forward and simple but preparing the site for seeding and protecting it until vegetation is established requires an adapted technology suitable for local conditions (9). Soil amelioration, selection of plant species, time of seeding or planting, kind and rate of fertiliser and lime applications and maintenance are technical factors which require expert knowledge and professional guidance.

3.1 Site preparation

Site preparation is the most important factor in mine spoil reclamation. In general, the topsoil from the site should be removed and stockpiled during the early stages of the project. This material should be spread over the surface of the exposed areas after mining ceases. Replacing the topsoil is most important when the exposed material is unduly sandy, stony, or clayey, or contains toxic materials. Hard soil surfaces must be scarified and heavily compacted areas must be loosened by ripping with a chisel device.

3.2 Re-vegetation

The general principle of soil-plant management recommended for establishing a sustained vegetation on local mine spoils are the following:

a) conduct soil tests for pH and plant nutrients.
b) where the pH is low, acid tolerant vegetation must be used or heavy application of lime or organic wastes are required. Both practices must be applied where the pH <3.5.
c) the type of forage grasses, legumes, trees, shrubs, vines and brambles have different adaptations, and the species chosen must fit the climate and other economic considerations of the reclaimed spoils.
d) soil samples should be taken from the top 15 cm of the exposed areas and tested for lime requirement and available N, P and exchangeable K. The necessary amount of lime and fertiliser application for the site should be applied and worked into the soil.
e) the topsoil surface must be covered with a mulch of straw, wood chips, etc to hold the soil until it is time to seed the perennial crop.

4. MINING LEGISLATION

In Ghana, permit is required for all aspect of mining, including small-scale surface mining. It is expected that Environmental Impact Assessment (EIA) would be made of each mine site before the projects take off. To ensure sustainable development of the mining sector the following regulations are proposed:

a) Regsulations on surface mining must be enacted to ensure adequate protection of the environment by requiring restoration of mined land to its original use or an approved higher use.
b) Legislative criteria should ensure the reclamation and revegetation of all areas of soil disturbed by mining operations in the past, present and future.
c) District assemblies must be assisted in implementing the regulation and ensuring compliance before granting mining permits by the Mineral Commission.
d) The research and demonstration on improved surface mining technology, including technique for minimising damage to hydraulic system, restoring mined lands and spoils to non-erosive
Towards the realisation of this legislation, each mining company is required to pay into a fund for soil reclamation, 10% of the value of the minerals obtained at the mine. This fund is to be administered by the Mining Reclamation and Enforcement Unit within the appropriate sectoral ministry. In addition technical assistance in reclamation should be provided by Soil Conservation Services.

5. SUMMARY AND CONCLUSION

Mining in Ghana is on an increase, especially surface mining and 'galamsey' operation. To sustain the development, regular and continuous monitoring and managing of the environment is a pre-requisite, especially restoration of mine sites and revegetation of mine spoils. To achieve these objective:

a) adequate technical guidance must be set up for site preparation. For example identification of land which is restorable (e.g. waste dumps, land for stock piles), identification of land which is non-restorable (e.g. deep pits steep faces of waste dumps).

b) identification of applicable reclamation techniques.

c) topsoil must be stockpiled and returned to reclaimed land.

d) chemical tests be conducted to identify toxic substances, plant nutrients, pH levels and requirement of manure, lime and fertilisers.

e) revegetation using grasses and plants which are tolerant to the soil condition. For instance a hyper-accumulator weeds can be introduced. These are plants that selectively absorb and transport metals to their stems and leaves to protect themselves against diseases and chewing insects. Finding some heavy metal tolerant crops whose final products are not contaminated could be one alternative for solving the problem.

f) where practicable, reclamation trials to refine technique must be undertaken.

REFERENCES


PRODUCTION OF SULPHURIC ACID FROM THE FLUE GASES OF PRESTEA AND OBUASI GOLDMINES

F. Jetuah
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ABSTRACT

A pollution control strategy is designed to recover the flue gases of the Obuasi and Prestea Goldmines for productive use. The arsenic and antimony trioxide in the flue gases are condensed in spray towers and separated from the sulphur dioxide. A sulphuric acid plant capacity 40,000 tons per year may be installed. A triple superphosphate fertilizer plant capacity 35,000 tons per year is proposed as a utility plant. Absorption of sulphur dioxide in a lime process for the production of 55,000 tons per year gypsum is also proposed. The paper recommends the enactment of a National Air Pollution Control Law to abate discharge of hazardous materials to the atmosphere.

INTRODUCTION

The mineral ore treated at the Prestea Goldmines of the State Goldmining Corporation contains auriferous and antimony sulphates. The sulphides, classified as cyanicides as well as the product of their oxidation, absorb oxygen from cyanide solution, neutralize the protective alkali and form compounds which are incapable of dissolving gold. In particular, antimony minerals present in the ore complicate the cyanidation process due to the formation of films on the fold particles. Besides the chemical reactivity of these sulphides, low efficiency in gold recovery may be caused by the difficulty in liberating the fine gold with particle size less than 5 microns disseminated in the sulphide minerals. Various methods are therefore employed in practice to destroy the cyanicides before cyanidation (1).

One of such methods in use at the Prestea Goldmines is oxidation roasting of flotation concentrates. Associated with this method there are gigantic air pollution problems which were examined in earlier studies (2, 3). This paper presents a pollution control strategy to recover the flue gases for productive use. Analysis of calcine tailings of the flotation concentrates (4) with grade value of 40.0 Dwt/ton showed that almost all the sulphur, arsenic and antimony was removed.

Table 1: Analysis of Flotation Concentrate and Calcine Tailings of the Prestea Goldmines (4)

<table>
<thead>
<tr>
<th>Element</th>
<th>Flotation Concentrate %</th>
<th>Calcine Tailings %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur</td>
<td>16.8</td>
<td>0.48</td>
</tr>
<tr>
<td>Arsenic</td>
<td>4.3</td>
<td>0.21</td>
</tr>
<tr>
<td>Antimony</td>
<td>1.9</td>
<td>0.34</td>
</tr>
</tbody>
</table>

At a milling rate of 35,000 tons per month, enormous quantities of gases, about 16 tons of sulphur dioxide, (SO₂)4 tons of arsenic trioxide, (As₂O₃) and 2 tons of antimony trioxide, (Sb₂O₃) are produced per day. Owing to lack of facilities for the recovery of these gases, for the past decade or two the gases are discharged to the atmosphere. Arsenic trioxide is a deadly poison to higher and lower animals. The extent to which the flue gases must be cleaned is indicated by the tolerated maximum arsenic content (5), established for the following:-

- Beverages ......  0.1 PPM
- Solid foodstuffs ... 1.0 PPM
- Dyes for foodstuffs ... 5 PPM
- Healthy human hair .. 0.03 mg/100g of hair
The recommended maximum atmosphere concentration of arsenic in dust fumes or mists during an 8 hour daily exposure (6) is 0.5mg/m³. Arsenic pollution studies (3) carried out at the Obuasi Goldmine Town and surrounding country side showed abnormal arsenic levels in the hair of mine workers town population, food items and water, Table 2.

Table 2: Arsenic Content in Human Hair, Foodstuffs and Water at Obuasi (3)

<table>
<thead>
<tr>
<th>Sample Description</th>
<th>Arsenic Content (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoyam leaves(Obuasi)</td>
<td>4.8 ± 0.22</td>
</tr>
<tr>
<td>Sugar cane (Obuasi)</td>
<td>14.75 ± 0.11</td>
</tr>
<tr>
<td>Orange (Obuasi)</td>
<td>2.29 ± 0.11</td>
</tr>
<tr>
<td>Cassava (Obuasi Market)</td>
<td>2.65 ± 0.0</td>
</tr>
<tr>
<td>Plantain (Obuasi Market)</td>
<td>0.615 ± 0.015</td>
</tr>
<tr>
<td>Obuasi- Kwafrafoso</td>
<td>2.25 ± 0.083</td>
</tr>
<tr>
<td>Dam Water</td>
<td></td>
</tr>
<tr>
<td>Obuasi- Kwabrafoso</td>
<td>1.40 ± 0.015</td>
</tr>
<tr>
<td>Drinking Water (Shaft)</td>
<td>Maximum 78 ±3.2</td>
</tr>
<tr>
<td></td>
<td>Minimum 7.7± 0.9</td>
</tr>
<tr>
<td>Mine Workers (Roastef &amp; Chemical Processing Section)</td>
<td>Maximum 1940± 62</td>
</tr>
<tr>
<td></td>
<td>Minimum 196± 7</td>
</tr>
<tr>
<td>Citizen (not employed at Mine)</td>
<td>26.4 ± 1.5</td>
</tr>
<tr>
<td>Citizen (not employed at Mine)</td>
<td>57.9 ± 2.5</td>
</tr>
<tr>
<td>Citizen (not employed at Mine)</td>
<td>8.8 ± 0.9</td>
</tr>
</tbody>
</table>

Sulphur dioxide is known to be potentially harmful both from the health and economic point of view. The sulphur dioxide discharged to the atmosphere continues to oxides and reacts with other substances to form sulphates thus creating sulphurous smog, a major pollutant. It is well established that sulphur dioxide is harmful to civil works, vegetation and human health causing such illness as bronchitis. Table 3 lists the maximum tolerances of a number of plants to sulphur dioxide for exposure times of 150 hours (7).

Table 3: Experimental Upper Tolerance Concentrations of Plants to Sulphur Dioxide for an Exposure Period of 150 hours (7)

<table>
<thead>
<tr>
<th>Type of Plant</th>
<th>Maximum Concentration Range (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lucerne and Clovers</td>
<td>0.15 - 0.3</td>
</tr>
<tr>
<td>Summer Wheat, Spinach</td>
<td>0.2 - 0.3</td>
</tr>
<tr>
<td>Beans, Lettuces</td>
<td>0.2 - 0.4</td>
</tr>
<tr>
<td>Strawberries, Rose</td>
<td>0.2 - 0.8</td>
</tr>
<tr>
<td>Potatoes, Radishes</td>
<td>0.3 - 0.8</td>
</tr>
<tr>
<td>Beet Sugar, Cauliflower</td>
<td>0.4 - 0.8</td>
</tr>
</tbody>
</table>

In some industrialised countries, the maximum permissible level of sulphur dioxide in the environment believed to be protective of human health are as shown in Table 4. It is also established that the loss of sulphur dioxide in stack gases exceeds the amounts consumed in manufacturing sulphuric acid in industrially developed countries. Figures for 1965 are given in Table 4.
### Table 4: Consumption of Sulphur, Discharge of Sulphur to the Atmosphere and the Maximum Permissible Level of Sulphur Dioxide in Some Developed Countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Sulphur Consumed (Million Tons)</th>
<th>Sulphur Lost (Million Tons)</th>
<th>Max. Permissible Level, Level SO$_2$ mg/m$^3$ Intermittent Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>9</td>
<td>12.2</td>
<td>4.4</td>
</tr>
<tr>
<td>USSR</td>
<td>6</td>
<td>8.9</td>
<td>8.5</td>
</tr>
<tr>
<td>Great Britain</td>
<td>2</td>
<td>3.2</td>
<td>-</td>
</tr>
<tr>
<td>West Germany</td>
<td>1.2</td>
<td>1.7</td>
<td>0.75</td>
</tr>
</tbody>
</table>

Besides the flue gases, the roaster plant discharges to the atmosphere significant quantities of fine dust, the bulk of which may be discoloured quartz. The danger posed by these particular materials arises from the inhaling of dust particles especially in the size range 0.5 - 3 microns. Also the dust may be laden with considerable amount of gold initially disseminated in the sulphide minerals.

**POLLUTION CONTROL**

Considering the foregoing effects of the flue gases on the environment, treatment of the roaster waste product at Prestea Goldmines is imperative.

The neglect of the quantity of the environment is more alarming at the Ashanti Goldfields Corporation (AGC), one of the richest goldmines in the world. The AGC, treating similar auriferous sulphide ores, operates a large roaster plant. In recognition of the serious environmental pollution prevailing in some manufacturing industries, especially at Prestea and Obuasi (AGC), the Environmental Protection Council was established a decade ago to provide the requisite framework to promote pollution control practices. However, in the absence of a national ambient air quality standards and air pollution control law, the mining industries have not made any serious attempts at pollution control. As a result, important parameters that are required in monitoring the plant operations as regards pollution levels are nonexistent. Such parameters as flue gas temperature, flow rate, composition of flue gas, particle-size distribution and composition of furnace dusts are important economic indicators of the effectiveness of the gold recovery process as well as the sizing and cost of an effluent treatment plant. Analytical study of these parameters is necessary for a planned programme of pollution abatement at the mines.

For quite some time now, the mines have depended on tall-stack dispersion as the control method. This method is not efficient as it does not reduce the overall pollutant but merely spreads the noxious gases and dusts in the surrounding areas. Also there is no reliable method for the calculation of the pollutant content at ground level as a function of the stack height discharge rate of gases, vapours and dusts, air turbulence and velocity and mass diffusion. Empirical formulae are therefore used to determine the necessary stack height (8). For example, the maximum concentration of the pollutant at breathing height of 1.8m above ground level C$_m$ mg/m$^3$ is given by the formula

\[
C_m = \frac{235 \, G_m}{2.5 \, W_0 \, H^2}
\]

Where $G_m$ is the amount of the pollutant being discharged to the atmosphere, g/sec

$H$ is the stack height, meters

$W_0$ - wind velocity at 10m above ground, m/sec.
The formula can be used for determining permissible discharge of a pollutant at a given stack height. Thus, if $H = 100$ meters, the permissible maximum level PML of $SO_2$, $0.5 \text{ mg/m}^3$ will be reached if the $SO_2$ discharge is 15 tons/day. An increase in pollutant discharge will require higher stack height. For instance modern super size heat power plants have Gm values as 1500 tons/day, $SO_2$. Dependence on tall stacks alone as a means of abating pollution will not be practicable owing to the obvious constructional limitations.

A solution to this problem may be found through the application of appropriate process technology to reduce the concentration of the furnace gases and dusts before discharge to the atmosphere. In which case, the tall stack serves as additional precautionary measure.

It is therefore proposed that the gas cleaning should involve the separation and recovery of arsenic and antimony trioxides from the sulphur dioxide and the latter sent for sulphuric acid production as shown in the flow sheet.

**GAS CLEANING PROCESS**

In an oxidising atmosphere, the sulphides of arsenic and antimony are oxidised to the trioxide according to the reactions:

4 FeAsS + 10 $O_2$ = 2As$_2$O$_3$ + 2Fe$O_3$ + 4 $SO_2$

2 As$_2$S$_3$ + 9 $O_2$ = 2As$_2$O$_3$ + 6 $SO_2$

2 Sb$_2$S$_3$ + 9 $O_2$ = 2Sb$_2$O$_3$ + 6 $SO_2$

The arsenic and antimony trioxides are volatile. Significant sublimation of arsenic trioxide, As$_2$O$_3$ begins at 120°C and antimony trioxide Sb$_2$O$_3$ at 450°C. At 500°C the vapour pressure of arsenic trioxide reaches 1 atm. Upon cooling, these oxides condense forming crystals which are separated from the sulphur dioxide. In the manufacture of sulphuric acid by the contact method, the sulphur dioxide must be totally purified from dusts and other compounds, arsenic and antimony trioxides which are catalytic poisons for the vanadium pentoxide trioxides. Also the $SO_2$ is purified from sulphuric acid mist which forms as a result of reaction of $SO_3$ with water vapour during the gas cooling.

In practice, the roasting temperature is between 700°C and 800°C. The oxidation occurs at 400°C, increases considerably at 450 - 500°C almost all the arsenic trioxide sublimes. It is difficult to obtain all the As$_2$O$_3$ and Sb$_2$O$_3$ in the gas or vapour phase since in contact with other oxidisers, the trioxides partially either oxidise to the pentoxides or form stable chemical compounds, arsenates and antimonates which remain in the calcine. The initial roasting is therefore conducted at low temperature. The furnace gases, vapours and dusts are fed into a dust pre-precipitator chamber where the coarse dust particles are removed and sent to the strakes to recover any free gold present. From the precipitator chamber the lighter particles are drawn off to cyclones where they are separated and passed to the strakes. The cleaned gases are cooled to a temperature 250 - 300°C by injecting cool air or by heat exchanger. From the coolers the gases are scrubbed with cooled 40% $H_2SO_4$ in a spray tower. The arsenic and antimony trioxides condense and are partly removed together with escaped fine dust particles and some amounts of sulphates that are formed. At an exit temperature, 50 - 70°C, the cooled gases from the first spray tower, enter the second spray tower where scrubbing and further cooling to 40°C are done by 15 - 20% $H_2SO_4$. The bulk of the arsenic and the antimony trioxide vapours is condensed and removed. Next the cleaned gases with traces of arsenic, antimony trioxide, water vapour and $H_2SO_4$ mist are scrubbed with 20% $H_2SO_4$ in a venturi scrubbed where the gases are cooled to 30°C. Condensations of the vapours occurs on the fine particles (solids and droplets) which escaped the second spray tower but now act as condensation nuclei. Also deposition of the particles occur on the surface of the scrubbing liquid droplets. Agglomeration of the particles takes place and the particles are collected subsequently by inertial impaction.
To achieve effective and final purification of the gases from arsenic and antimony impurities, the gases from the venturi scrubber are sent to the humidification tower with paced ceramic rings. The packing is irrigated by cooled 1% H2SO4. Condensation of vapours and agglomeration of particles covered by condensed water vapour take place facilitating collection in electrostatic mist precipitator. The gases after the electrostatic mist precipitator do not practically contain dusts, arsenic and antimony trioxides, but the content of H2SO4 mist should not exceed 0.005g/m3. The sulphuric acid used as scrubbing liquid in all units is separated from the particulate matter, cooled and recycled. The arsenic and antimony/trioxides are stored in and packaged for exports and local use. Arsenic trioxide is widely used in wood preservation, weed killers and insecticides. In 1978, according to the external trade statistics Ghana imported 29.8 tons of arsenic classified as arsenates/arsenite costing $40,956.00. Compounds of antimony are used as drugs in the treatment of schistosomiasis (bilharziasis), a disease widespread in the Volta Basin. In particular, antimony trioxide is the starting material for the production of organic antimony compounds for medical purposes.

PRODUCTION OF SULPHURIC ACID

The sulphur dioxide from the electrostatic mist precipitator is dried in a drying tower and heated up to about 420°C. It is then oxidised to sulphur trioxide in pentoxide catalyst. The sulphur trioxide is absorbed in a circulating strong acid. For a 99% sulphur dioxide removal efficiency, an ammonia scrubber tail gas system may be recommended (9, 10). The ammonical salts can be reacted with sulphuric acid to produce ammonium sulphate. However, Cameron et al point out that there is no theoretical limit to the amount of SO2 that can be recovered and recycled; it depends on the rate of recirculation of acid between the absorber and air-drying towers (11). It is claimed that this system can readily attain or exceed the 99% efficiency that is required to meet U.S. pollution control standards.

Similar pollution control installation at Obuasi could recover the sulphur dioxide of the roasting plant which has about thrice as much capacity as the Prestea plant. A sulphuric acid plant, capacity about 40,000 tons a year may be sited at Obuasi to convert the sulphur dioxide from both goldmines. The sulphuric acid plant will set the pace for chemical industry development in this country.

The acid requirement of motor car and transport industry as well as the proposed alum plant (12) would be met. Table 5 gives the import statistics of sulphuric acid and some sulphates (13). Also Flurapatite could be imported from the Republic of Togo to produce about 35,000 tons of Triple Superphosphate fertiliser.

The capital cost of the sulphuric acid plant, excluding the plant cost of the gas cleaning may be high relative to its production capacity. Table 6 shows the estimated effect of scale of production on production cost and transfer price assuming 100% capacity utilisation (11). It is also likely that the sulphuric acid plant will cost more than a sulphur burning plant considering the capital intensive gas cleaning unit. However, credit must be allowed for the gold, arsenic and antimony trioxides as well as the sulphur dioxide. Without changing the basic plant design, the production capacity of the sulphuric acid plant could be supplemented by burning elemental sulphur.

PRODUCTION OF GYPSUM

The other alternative and less capital intensive process of recovery of the sulphur dioxide that may be proposed is the ICI-Howden Cyclic lime process (7). A lime slurry is circulated through a wooden grid absorption tower and calcium sulphite is formed, which then oxidises to the sulphate with the oxygen from the flue gases. The removal of SO3 in lime slurry was plagued with fouling and plugging of the scrubbing equipment and pipes as a result of precipitation of the calcium sulphate on the internal surfaces of the equipment.
Table 5: Import Statistics on Sulphuric Acid, Alum and Gypsum

<table>
<thead>
<tr>
<th>YEAR</th>
<th>SULPHURIC ACID tons</th>
<th>GYPSUM tons</th>
<th>ALUM tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>1416</td>
<td>11100</td>
<td>7531</td>
</tr>
<tr>
<td>1971</td>
<td>1741</td>
<td>18908</td>
<td>4629</td>
</tr>
<tr>
<td>1972</td>
<td>209</td>
<td>6051</td>
<td>5511</td>
</tr>
<tr>
<td>1973</td>
<td>1273</td>
<td>9943</td>
<td>28061</td>
</tr>
<tr>
<td>1974</td>
<td>881</td>
<td>17223</td>
<td>6878</td>
</tr>
<tr>
<td>1975</td>
<td>296</td>
<td>16328</td>
<td>1336</td>
</tr>
<tr>
<td>1976</td>
<td>339</td>
<td>16431</td>
<td>5899</td>
</tr>
<tr>
<td>1977</td>
<td>641</td>
<td>15807</td>
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<td>1978</td>
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<td>1979</td>
<td>513</td>
<td>11235</td>
<td>1871</td>
</tr>
<tr>
<td>1980</td>
<td>524</td>
<td>11240</td>
<td>1800</td>
</tr>
</tbody>
</table>

Table 6. Plant and Production Costs of Sulphuric Acid Plants

<table>
<thead>
<tr>
<th>Capacity, tons of H₂SO₄/day</th>
<th>Developed Country</th>
<th>Developing Country</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plant Cost M.</td>
<td>Production Cost/ton</td>
</tr>
<tr>
<td>600</td>
<td>10.0</td>
<td>26.74</td>
</tr>
<tr>
<td>1200</td>
<td>14.6</td>
<td>23.48</td>
</tr>
<tr>
<td>1800</td>
<td>19.4</td>
<td>22.69</td>
</tr>
</tbody>
</table>

Consequently the calcium-based flue gas desulfurization system was subjected to extensive studies to produce more effective designs. The results of these investigations have been summarised by T.V. DeVitt et al (14). Scale-free operation can be accomplished by two basic modes of desulfurization operation: co-precipitation of calcium sulphite and calcium sulphate and control of supersaturation. Another innovative approach to improving lime/limestone systems is the use of chemical additives in the slurry to reduce scaling, increase sulphur dioxide removal and improve reagent utilisation. The Japan Engineering Company and the Mitsubishi Heavy Industries have patented a process which is similar in principle to the ICI-Howden Cyclic lime process but which produces high purity gypsum (7). The Nauli limestone and the more reactive absorbent, lime a by-product of L'Air Liquid Acetylene plant could be used in the sulphur dioxide recovery plant. It is estimated that about 55,000 tons of Gypsum could be produced annually.

In conclusion, it must be emphasised that serious consideration of the proposed strategies of pollution control at the operating goldmines in this country will not only promote active and conscientious drive to maintain a cleaner and healthier environment but will also channel the waste gases into productive use.
RECOMMENDATION/CONCLUSION

A planned programme of action is urgently required to tackle the serious pollution problems in the mining industries. In this regard, the following recommendation are made:

1. Since the waste gases at the operating goldmines contain toxic compounds like arsenic and antimony trioxide, and chemical pollutants like sulphur dioxide, the Environmental Protection Council in collaboration with other institutions in this country including the AGC and Prestea Goldmines should set up a team to work out an Air Quality Standard in the mining industry areas.

2. A pollution control law is needed to regulate industrial operations and practices.

3. The mining industries should invest in research and development, (R&D) to update their effluent disposal practices. This paper observed earlier the lack of basic data for effective analysis, process design and control of the level of discharge of waste gases in the goldmines.

4. The economics of the proposed gas cleaning process should be assessed to determine the extent to which the gas cleaning should be carried out.

5. The Department of Community Health of the Ministry of Health should conduct a study to find out the extent of damage done to human and animal health, vegetation and aquatic life.

REFERENCES


4. Correspondence with the Consulting Metallurgist. State Gold Mining Corporation.


SPECIATION OF ARSENIC IN SOME BIOLOGICAL SAMPLES FROM OBUASI AND ITS SURROUNDING VILLAGES

P.A. Sarkodie, D. Nyamah and E. H. Amonoo-Neizer

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

ABSTRACT

Samples of Pteris vitatae (fern), Musa sapientum (plantain), Colocasia esculenta (coco-yam), leaves of Colocasia esculenta, Manihot esculentum (cassava), leaves of Manihot esculentum, Capsicum frutescens (pepper) and Elaeis guineensis (palm fruits) were collected from fourteen sites in and around Obuasi which is the major mining town in Ghana.

Sampling were done monthly from January to December, 1993, and were analysed for arsenic (V) and arsenic (III). Speciation was done using the molybdenum blue and ion-exchange methods. The maximum mean arsenic (V) concentrations were 32.3 ± 5.4 mg/kg and 31.3 ± 5.4 mg/kg dry weight by the molybdenum blue and ion-exchange methods, respectively. These were recorded in fern. The minimum mean arsenic (V) concentration was 0.07 ± 0.06 mg/kg dry weight in both methods and was recorded in palm fruits. The maximum mean arsenic (III) concentration was 7.3 ± 1.7 mg/kg dry weight in both methods. Kwabrafoso, which is about 0.3km from the Pompora Treatment Plant (PTP) recorded the highest arsenic (V) and arsenic (III) values whilst Ampunyase which is 17.5km from PTP recorded the lowest arsenic (V) and arsenic (III) values.

1.0 INTRODUCTION

The Ghana government’s policy of privatising the mining sector purported to increase her foreign exchange earnings has brought to the fore several splinter mining groups most of whose activities are neither monitored nor regularised. In that light, one cannot underscore the fact that the environment has been tampered with in no mean magnitude.

Even though some of these mining companies like AGC, Canadian Bogoso, Tarkwa Goldfields and the rest have established themselves over the years, their activities have also inflicted quite a remarkable damage on the environment.

At Obuasi, the major gold mining town in Ghana, a cursory look at the environment clearly depicts of the severe damage inflicted on the vegetation, particularly, the area behind the treatment plant of AGC, Pompora Treatment Plant (PTP). Arsenic, one of the major pollutants associated with the roasting of gold, has been responsible for that depressive growth of the vegetation around PTP. Arsenic in the form of arsenic (III) oxide is one of the major gaseous emissions from the chimney of the treatment plant.

Apart from its depressive growth on the vegetation (1), arsenic in the form of arsine gas for example, is reported to first combine with the haemoglobin in the blood corpuscles in some manner, and soon thereafter haemolysis of the cell occurs resulting in the destruction of the cell and solution of the haemoglobin in the serum in humans (2). Death is reported to have occurred frequently from pulmonary edema resulting in either primary irritation or secondary failure of blood circulation as a result of arsenic poisoning (3). Though arsenic is generally found to be toxic, the extent of toxicity actually depends on the arsenic species taken into the body. It has been reported that the arsenic (III) or arsenite which forms complexes with sulphur containing proteins, thereby inactivating them tends to be more toxic than arsenic (V) or arsenate (4). From the foregoing in talking about arsenic toxicology, it would be more purposeful to ascertain into the arsenic species rather than talking about it in general. Therefore the aim of the research was to speciate arsenic, more importantly, the inorganic arsenic

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species in the plant samples. That is, to find out whether or not the plant or food samples have been contaminated with the more toxic arsenic (III) or not. The arsenic (V), arsenic (III) and total arsenic concentrations could then be compared with the WHO recommended maximum arsenic levels in foodstuffs of 1.0 mg/kg (5). Furthermore, though other researchers have worked into arsenic contamination in and around Obuasi, emphasis has been placed on total arsenic than the arsenic species.

Finally, the operations of AGC keeps on varying from time to time. For example, for the past few years the Company has embarked upon surface mining and has also installed an arsenic recovery plant to reduce arsenic discharge. Therefore, research works could be mounted concurrently with such changes in the mode of operation of the Company. This way, results which were obtained before and after the installation of the arsenic recovery plant could be effectively compared and very useful recommendations made.

2.0 EXPERIMENTAL METHOD

2.1 Samples and sampling sites

The samples that were worked on were either chosen because of their medicinal use or as food. These were: Pteris vititae (fern), Musa sapientum (plantain), Colocasia esculenta (coco-yam tuber and leaves), Manihot esculentum (cassava tuber and leaves), Capsicum frutescens (pepper), and Elaeis guinensis (palm fruits).

In all, fourteen sampling sites ranging from 0.30 - 17.50km from the treatment plant were selected. The sites numbered 1, 2, ...,14 were Kwabrafoaso, Wawase, Kokoteasua, Nyamso, Dadwen, Pomposo, Diawuso, Odumase, Hia, Ayease, Domeabra, Akrofuom, Suhyenso and Ampuyase in that order. These sites were also selected taking into consideration their relatively varying positions from PTP, the direction of flue gases from the chimney of the treatment plant and effluent from the treatment plant.

2.2 Experimental procedure

Wavelength of maximum absorption was determined from standard arsenic (V) solutions on a SPEKOL 11 spectrophotometer at 815nm and a calibration curve for different arsenic (V) concentrations was drawn using the molybdenum colorimetric method (6). 1.0 kg dried fine powder obtained from each sample by a 100 mesh sieve was digested with 4.0M HCl solution on a water bath. Phosphate removal was done on each digestate using the zirconium method. 1.0cm³ of each phosphate-free digestate was then subjected to the molybdenum-blue reaction and arsenic (V) concentrations were determined using the calibration curve. Total arsenic in the form of arsenic (V) was determined using the Nyamah and Torgbor (7) method after all arsenic (III) had been oxidised to arsenic (V) with 10% hydrogen peroxide. Arsenic (III) was therefore found by difference. Total arsenic in samples were also determined using AAS.

Arsenic (V) was also stripped off a Dowex 50W-*8 (exchange capacity 5.0meq/g dry resins) cation exchanger using ammonium ethanoate/ethanoic acid buffer at flow rate of 1.8 - 2.0cm³ per minute. This method by Pacey and Ford (8) adopted the Henry and Thorpe (9) suggestion of maintaining the pH of the eluant between 4 and 10. Arsenic (III) was again determined by difference.
3.0 DISCUSSIONS AND RESULTS

3.1 Results

Arsenic (V) and arsenic (III) concentrations obtained by both the molybdenum blue and ion-exchange methods did not show any significant differences at 0.05 level of significance. Hence, the discussion is going to be based on arsenic concentrations obtained by the molybdenum blue method (Tables I and II).

3.2 Discussions

The maximum mean arsenic (V) concentration of 32.28 ± 5.44 mg/kg dry weight was recorded in fern at Kwabrafoaso which is 0.3km from PTP. The minimum mean arsenic (V) concentration of 0.07 ± 0.06 mg/kg dry weight (range 0.00 – 0.01) was however recorded in palm fruits at Ampunyase which is 17.50 km from PTP.

Generally, for a particular sample such as cocoyam leaves, the maximum arsenic concentration, 2.20 ± 0.76 (range 1.30 - 3.20) mg/kg dry weight was recorded at Kwabrafoaso and decreased gradually to 0.97 ± 0.51 (range 0.30 - 1.40) mg/kg dry weight at Hia located between the north and the northwestern end of PTP which is not quite close to the direction of flue gases from PTP. On the other hand, areas off the direction of wind direction of the flue gases located between the north-eastern and south-western end of PTP such as Pomposo and Domeabra recorded very low levels of arsenic (V) concentrations. For example, whereas at Hia arsenic (V) concentration in plantain was 1.09 ± 0.38 (range 0.60 - 1.38) mg/kg dry weight, at Domeabra the mean arsenic (V) concentration in plantain was 0.52 ± 0.22 (range 0.20 – 0.70) mg/kg dry weight. At the far southern end of PTP such as Suhyenso and Ampunyase which were no where near the direction of the flue gases from PTP, very low arsenic (V) concentrations were recorded. For example, whereas at Kokoteasua which is just 1.85 km from PTP and in the direction of flue gases recorded arsenic (V) concentration of 1.68 ± 0.45 (range 1.10 - 2.00) mg/kg dry weight in cassava, at Ampunyase, cassava recorded a mean arsenic (V) concentration of 0.19 ± 0.12 (range 0.10 - 0.20) mg/kg dry weight. The same trend pervaded in all the samples.

Mean arsenic (III) concentrations in the plant samples showed similar trend. Samples from sites which were very close to PTP and in the wind direction of flue gases from PTP recorded comparatively high mean arsenic (III) concentrations. For example, at Kwabrafoaso mean arsenic(III) concentration in cassava leaves was 0.78 ± 0.23 (range 0.50 - 1.00) mg/kg dry weight which decreased steadily to 0.21 ± 0.11 (range 0.10 - 0.30) mg/kg dry weight at Hia and decreasing finally to a very low level of 0.0 mg/kg dry weight at Ampunyase. This trend occurred in all the samples at all the fourteen sites.

Finally, within the year, concentrations of arsenic species increased from January to a peak in September/October when the rainfall was highest and coming down again in November or December when the rainfall had subsided. At Kwabrafoaso for example, the mean arsenic (V) concentration in cocoyam in January was 1.2 mg/kg dry weight which rose to a maximum of 3.4 mg/kg dry weight in October and coming down to 3.1 mg/kg dry weight in December. Similarly, at the same place the mean arsenic (III) concentration in January in cocoyam was 0.3 mg/kg dry weight which rose to a maximum of 1.0 mg/kg dry weight in October and finally coming down to 0.8 mg/kg dry weight in December.
Table I: Concentration of Arsenic (V) mg/kg dry weight in samples from Obuasi and its environs

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>FERN</th>
<th>PLANTAIN</th>
<th>COCOYAM LEAVES</th>
<th>COCOYAM</th>
<th>CASSAVA LEAVES</th>
<th>CASSAVA</th>
<th>PEPPER</th>
<th>PALM FRUITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32.28 ± 5.44</td>
<td>3.08 ± 1.00</td>
<td>2.10 ± 0.78</td>
<td>2.20 ± 0.76</td>
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<td>1.82 ± 0.69</td>
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<tr>
<td>2</td>
<td>32.14 ± 5.44</td>
<td>3.05 ± 0.98</td>
<td>2.05 ± 0.78</td>
<td>2.14 ± 0.74</td>
<td>2.18 ± 0.67</td>
<td>2.31 ± 0.65</td>
<td>1.71 ± 0.68</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>14.42 ± 2.14</td>
<td>2.17 ± 0.41</td>
<td>1.40 ± 1.41</td>
<td>1.68 ± 0.46</td>
<td>1.68 ± 0.45</td>
<td>2.02 ± 0.43</td>
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<tr>
<td>4</td>
<td>12.33 ± 1.26</td>
<td>1.79 ± 0.34</td>
<td>1.38 ± 0.43</td>
<td>1.53 ± 0.48</td>
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<tr>
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<td>2.23 ± 0.45</td>
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<td>0.62 ± 0.36</td>
<td>0.73 ± 0.37</td>
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<td>2.38 ± 0.44</td>
<td>0.94 ± 0.30</td>
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<td>8</td>
<td>2.15 ± 0.39</td>
<td>0.98 ± 0.35</td>
<td>0.60 ± 0.32</td>
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<td>0.19 ± 0.12</td>
<td>0.28 ± 0.13</td>
<td>0.10 ± 0.08</td>
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Table II: Concentration of Arsenic (III) mg/kg dry weight in samples from Obuasi and its environs

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>FERN</th>
<th>PLANTAIN</th>
<th>COCOYAM LEAVES</th>
<th>COCOYAM LEAVES</th>
<th>CASSAVA LEAVES</th>
<th>CASSAVA FRUITS</th>
<th>PEPPER FRUITS</th>
<th>PALM FRUITS</th>
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<td>1</td>
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<td>3</td>
<td>3.99±0.73</td>
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<td>8</td>
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<td>9</td>
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</tr>
<tr>
<td>10</td>
<td>0.38±0.13</td>
<td>0.21±0.14</td>
<td>0.08±0.06</td>
<td>0.12±0.10</td>
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<tr>
<td>12</td>
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<td>13</td>
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<td>0.09±0.08</td>
<td>0.03±0.04</td>
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</table>
Fig. 1: Seasonal variation of As (V) concentration at Kwabrafoso

Fig. 2: Seasonal variation of As (III) concentration at Kwabrafoso
4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

In the light of the analysis made, the following conclusions were drawn from the research: levels of arsenic concentrations were dependent on the nature of plant samples and the extent of arsenic concentrations also depended on the type of plant or food sample. The orders were: leafy samples > plantain > food tubers > fruit samples and fern > plantain > cassava leaves > cocoyam leaves > cassava (food tuber) > cocoyam (food tuber) > pepper > palm fruits.

Concentrations of arsenic species increased in both the direction of flue gases from the treatment plant and intensity of rainfall. However, concentration decreased with increasing distance from the treatment plant.

Apart from fern and occasionally cassava leaves all the other samples recorded concentrations of arsenic species less than the WHO recommended maximum level of 1.0mg/kg in areas beyond 5.0km from PTP. Again, with the exception of fern all the other samples recorded the most toxic arsenic [arsenic (III)] concentrations less man 1.0mg/kg. Additionally, arsenic (V) concentrations were below the WHO recommended maximum level of 1.0mg/kg (except fern) in samples located at 4.38km and beyond PTP.

Arsenic species concentrations determined from the research were far below those obtained by Acheampong et.al (10) who worked on similar samples before the installation of the arsenic recovery plant within the premises of AGC. This goes to say that AGC has at least reduced arsenic (including the arsenic species) concentrations at Obuasi and its surrounding villages.

4.2 Recommendations

From the discussions and conclusions the following recommendations have be put forward:

Foodstuffs produced within the immediate periphery of PTP such as Kwabrafoso, Wawase and Kokoteasua contain high levels of toxic arsenic species and consumers should desist from them. Again, people who use fern for medicinal purposes risk taking in more arsenic species.

Finally, though the AGC had reduced arsenic by the installation of the recycling plant, more efforts should be made to reduce the other forms of pollution such as the discharge of particulate into the atmosphere during the crushing and grinding of the gold ore and those from the operations of the surface mining. Moreover the re-cycling of the effluent to the Kwabrafo stream and the slime dams which normally cause spillovers during heavy downpours could go a long way to reduce arsenic concentrations in the biological samples in the environs.

REFERENCES


UST/ADRC '97 Symposium on the Mining Industry and the Environment, UST, Kumasi, Ghana


PART IV: CLOSING ADDRESSES
REPORT FROM THE RAPPORTEUR GENERAL

E. Adei
Department Of Chemistry U.S.T., Kumasi

A. Advocates for the Mines

1. It is the largest gross foreign exchange earner in Ghana. It contributed about 40% of the country's total foreign exchange revenue since 1992 compared to 20% in the 1980's. It has overtaken cocoa as the largest foreign exchange earner - US $ 612.4 million as against US $ 508 million for cocoa.

2. It employs more than 7% of the labour force in the country - employs about 20,000 workers in the large scale mining sector. About one million people have been employed in the small mining concerns scattered all over the country.

3. The industry provides social services to the local communities in their areas of operation, these services include roads, schools, scholarship schemes, portable water, clinics, electricity etc. Thus it has led to considerable improvement in the living conditions of the local communities.

4. The mining industry has assisted the country to restructure the economy under the Economic Recovery Program.

5. It contributes substantially to the Gross Domestic Product (G.D.P).

6. The mining industry alone has contributed to increase investment to the tune of about US $ 2 billion.

7. The mining industry has the further potential of contributing more to the foreign exchange earnings if all the 300 registered mining companies become operational. At the moment only about fourteen are in production.

8. The mining industry has led to the springing up of auxiliary businesses which include food sellers, blacksmiths, carpenters, mechanic shops, transport companies, analabs, etc. It is expected that the increase in mining operations will encourage other international and local private companies to be set up in Ghana to provide support services such as the manufacture of mine consumables, assay laboratories, custom milling, drilling, etc.

9. The mining industry provides raw materials for mineral based domestic industries e.g. manganese for Eveready company Ltd., kaolin for manufacture of local powder, mica for the ceramic industry, gold for local goldsmiths etc.

10. The mining industry generates considerable internal revenue from direct taxes as well as royalties.

11. The government being aware of the immense contribution made by the mining industry to the national economy has enacted various legislation to mitigate against the negative impact on the environment. Some of these are Mining and Minerals law of 1986 PNDCL 153, Environmental
Protection Agency act of 1994 (act 490). Other regulatory mechanisms have also been put in place namely National Environmental Action Plan, NEP, Assessment of potential impact project etc.

12. Apart from the fact that the large scale mining concerns have endeavoured to operate within these legal and policy frameworks they have also taken bold initiatives in adopting environmentally sound and friendly methods of operation and safety precautions to mitigate the negative impacts of their operations on the environment.

RECOMMENDATIONS

1. Policy makers should provide the necessary framework for reviewing the regulatory measures to ensure environmentally sound and sustainable mining operations.

2. Efficient and environmentally friendly methods of operation should be adopted by the industry.

3. The industry should collaborate with researchers in monitoring, identifying and reducing the negative impacts of their operations on the environment.

4. Efficient monitoring mechanism should be put in place.

5. Regulatory laws on reclamation and revegetation if not already in existence should be enacted and strictly enforced.

6. Proper environment management practices should be adopted.

7. Promotion of environmental awareness among all mine employees and small scale mine operators.

8. Small scale miners should be exposed to and encouraged to adopt the small scale extraction techniques which do not involve the use of mercury. These methods apart from being environmentally friendly is more efficient and less costly.

B. Advocates for the People

The land is not ours. The earth is the Lords.

1. The mining sector has been identified as the single largest earner/contributor to the economy of Ghana since the export earnings from gold alone was US $ 612.4 million in 1996 as against US $ 508.6 million from cocoa export which hitherto was the major earner. However the mining sector's operations has done a lot more harm to the ecosystem than cocoa which is renewable.

2. The environmental impact of the mining industry can be seen in the following areas:

a. Social Impact

The rapid growth of the mining industries has encouraged the migration of people seeking jobs in the mining centers, creating slums with accompanying health hazards, crime, sexual promiscuity, etc., There is also considerable cultural alteration of the indigenous people.
b. Water Pollution

Most mining companies use chemicals e.g. cyanide, this together with heavy metals which results from their operations are discharged into the streams and rivers, thus polluting the source of drinking water, aquatic food of the local mining communities. The harmful effect of mercury used by small scale miners cannot be over emphasized. The consequent health effects stretch our over-burdened health system.

c. Air Pollution

Air pollution is the most difficult form of pollution to control because once it starts the pollutants quickly spread and the individual choices here are limited compared with water pollution. The main air pollutants are arsenic, sulphur dioxide and particulate matter.

d. Noise Pollution

The noise comes from blasting, drilling, excavation, crushing of rocks, haulage trucks and sirens. This could be a nuisance to the local communities.

e. Land Degradation

The impact of surface mining manifest itself clearly on its immediate surroundings. The surface soil which supports vegetation is degraded, the land becomes exposed to the elements of the weather, and consequently become barren. In some instances there is complete relocation or resettlement of mining communities. This leads to further exploitation of virgin lands. It is therefore imperative that steps are taken to arrest these negative impacts of the mining industry at the “baby” stages or nip them in the bud or else the cost in resolving them will far outweigh the benefits the industry contributes to the economy.

RECOMMENDATIONS

1. Education of miners on the advantages of using more technically efficient mining, planning and management practices to minimize harmful environment effects.

2. Programs which deal with soil rehabilitation and revegetation should be given serious attention.

3. Collaborative work between mining industry and researchers, and seminars involving all stakeholders from time to time will go a long way to help to minimize the harmful environment.

4. The necessary logistics and incentives should be given to EPA, the mines department and research institutes for effective policing and monitoring of the mining industry.

5. Enactment of legislation with punishment that will deter galamsey and illegal mining operators from degrading or polluting the environment.

6. Evaluating (quantitatively) the vegetation and minerals to enable cost benefit analysis to be done.

7. Collection of data on weather elements e.g. rainfall, and correlation of these elements on the soil.

8. Mining techniques using microorganisms worth pursuing.
CLOSING ADDRESS

P. Bradford
President Of The Ghana Chamber Of Mines.

Mr. Chairman, thank you for your kind words.

Mr. Chairman, distinguished colleagues, and friends of the mining community, members of the media, ladies and gentlemen, on behalf of the Ghana Chamber of Mines and on my own behalf, I wish to thank the Organizers for their initiative and for inviting me to deliver the closing address of a Symposium which has given mining such a worthwhile exposure to the general public soon after the recent workshop on land policy which was hosted by the Ministry of Lands and Forestry.

The general purpose of the Symposium, we are told, is to educate the general public on mining and measures which mining operators are expected to put in place to manage the mining environment with a minimum of environmental damage. Towards this end, a number of informed papers have been presented with a lot of recommendations for consideration by the Mining Companies. I have no doubt that at the end of the symposium we shall all be proud to declare that this has been a job very well done for the benefit of all of us in this ever-growing industry.

Mr. Chairman, permit me, however, to say a few words about the Ghana Chamber of Mines and what it can do.

The founding fathers of the Chamber set up the offices of the West African Chamber of Mines at Southern Street, High Holborn, London, in 1903 - with the principal objective of advancing and protecting the mining interests of the shareholders, particularly, the consolidating and discussing of all questions, the collating and collecting of statistics and general information relative to mining and other matters which were, from time to time, considered desirable and submitted to the West African Chamber of Mines.

The West African Chamber of Mines was composed of Directors of the Mining Companies in London who, among other functions, had power to promote or oppose any legislative measures or petition government or political and administrative bodies in the colony on any matters which directly affected mining interests.

Towards the end of the second decade, the London Council of the West African Chamber of Mines was dissolved and the interests of the Gold Coast Chamber of Mines were managed by the London Chamber of Commerce. The first constitution or the Local Council (West African Section) of the London Chamber of Commerce was incorporated in February 1921.

On 6th June 1928, the Gold Coast Chamber of Mines was incorporated as a Private Company and operated at Tarkwa in the Western Region. On 14th February 1964, the Chamber was converted under the Companies Code, 1963 (Act 179) into a Company Limited by guarantee. In 1967, the registered office of the Chamber moved to Accra.

The Chamber has a total membership of 10 gold producing members, 19 gold prospecting associate members, one gold and diamond marketing member, one each of diamonds, bauxite and manganese; two affiliate members in laboratory services, six affiliate members in mine construction, three associate members in exploration and research, two associate regulatory agency members, two affiliate members in explosives and one in limestone production. The total membership of the Chamber is 61.
It is noteworthy that last year, the Chamber Members produced 1,550,814 ounces of gold and earned US $681.5 million. Diamond production of 714.341 carats earned US $14.4 million. Bauxite exports totalled 473.218 tonnes which yielded US $8.4 million while manganese production of 455.624 tonnes earned US $8.5 million. So for last year the Chamber Members earned a total of US $712,856,461. This represents an increase of 8.6% over last year's earnings of US$656,604,396.

Indeed, the Service Industries Sub-Committee of the Chamber bring together all the Member Companies in the Service Industries such as Mine Construction, Contract Mining, Laboratory Services, Mine Equipment/Accessories Supplies, and two manufacture of some mine consumables. These provide the gateway to the linkages necessary for future full integration of the Sector into the local economy.

Today, the Ghana Chamber of Mines continues to be a private sector employers' association representing Companies and Organizations directly concerned in the mining and minerals industry in Ghana. Its activities are funded entirely by its Member Companies which are largely responsible for producing almost all of Ghana's minerals. The Chamber pursues its objects by joint action at industry level in areas where it is considered economically advantageous, prudent and desirable for members to co-operate and act in concert. It represents the mining industry's collective views to government and public authorities on matters related to the judicious development and exploitation of the nation's mineral resources. It also promotes the national and international interests in the mining industry through the provision of information and educational material.

The Chamber operates through a Council and an extensive committee system which enables the specialist expertise and the intellectual capital within the Member Companies to be tapped. The existing committees are on technical mine management, mineral processing, personnel administration, security, health and safety and the environment.

The Chamber attaches great importance to health and safety in the working environment and the larger community. It represents the industry's views on environmental policies to the Minerals Commission, the Mines Department and the Ministry of the Environment, Science and Technology. Through its Sub-Committee on the Environment, the Chamber seeks to advance the practice of environmental sciences within the mining and mineral processing industries. Further, it seeks to promote the industry's expertise in environmental management to the community.

Every year, safety competitions are organized among the mines in order to stimulate safety awareness. Besides, all Chamber Members have been encouraged to develop a health and safety policy which involves the entire workforce to deal with environmental problems at the workplace and in the mining communities. No doubt, the development of Ghana's human resources is at the very core of the country's prosperity; and so, the continued enhancement of safety awareness is undoubtedly the most important vehicle for reinforcing that core to benefit the workforce and the mining communities.

In this regard, permit me to further outdoor the focus of the Chamber on environmental matters in the coming years. The thrust of this focus is a multi-faceted initiative to enforce environmental standards and promote healthy relations with mining communities and the general public whose perceptions about Mining Companies as destroyers and money seekers should be corrected to appreciate the role of mining in the economy of the nation and the benefits derivable therefrom by the mining communities in particular.

In going so, the Chamber's initiative does recognize pressures from the public about environmental issues; from the communities about land use and from the workforce over pay. These pressures are certainly bound to come especially in areas where there are intensive mining activities using technologies that are relatively new. As you may remember, mining has in the past been carried out
from underground and there have been minimal protests, if at all. Now most mining activity is on the surface at centres such as Tarkwa, Bogosu and Obuasi whose populations have grown over the years to the city size. It is natural that protests will emanate from what can be seen without much effort as compared with what cannot be seen underground to which they are not exposed. That is the origin of the protests.

Unfortunately, the industry cannot afford to do without surface mining with attendant ugly sights and the inconveniences it tends to create. In surface mining the near surface ore bodies are best economically mined by excavation rather than drilling a shaft. The Chamber is aware that it can operate optically only when it has been able to obtain the full co-operation of the host communities which suffer displacement, relocation and sometimes loss of traditional jobs to the mines that take their place.

In this connection, the Chamber is launching bold actions on two fronts in 1997-environmental outreach and an educational programme that will explain the benefit of mining to the country, what the Companies are doing for host communities and minimizing environmental damage. The programme will seek to promote the awareness that mining necessarily involves a trade-off between wealth creation and some environmental damage and that the wealth created is worth the environmental damage.

The Chamber, as part of its outreach programme, will introduce a new Environmental policy which will be supported by guidelines or a code of ethics with which all Member Companies will be obliged to comply. It will represent one way of demonstrating the Chamber’s commitment and also becoming more transparent to help people understand the mining industry in a clear perspective. Highlights or the policy which is at the drafting stage are as follows:

a. Every mining and exploration Company to strictly abide by the mining laws and guidelines of the Republic of Ghana;
b. Incorporation of the guidelines on sustainable development of the World Commission on Environment and Development, not just to meet the needs of the growing population but also the demands of the environment;
c. Preservation of cultural, physical and social heritage items;
d. Self-regulation as the most efficient form of controlling mining operations;
e. Interaction on environmental issues, by all concerned parties so that resolutions adopted would be acceptable.

The ultimate goal of the code is self-regulation which, from all indications, is achievable. In this connection, note is taken of the welcome fact that most of the major mining and exploration Companies in Ghana have parent Companies in the United States, Canada, Australia and South Africa where there is a great deal of respect for the environment. Those who manage these Companies are used to operating under high environmental standards. They try to keep close relationships with the local communities where they operate to know and meet their needs wherever they can. Further, the Chamber expects to receive the continued co-operation and support of the Minerals Commission, Mines Department and the Environmental Protection Agency on matters related to responsible environmental management by the Mining Companies. In this regard, the Chamber expects to see an environmental monitoring arrangement which will involve, say, the Mines Department only. A multifaceted monitoring system for the mining industry, it is feared, might not produce the desired results in a situation where harmonized mono mechanism under the existing Mining Regulations has not been proved wanting. Clearly, this is an area which should be developed further with the co-operation of the Environmental Protection Agency and the Minerals Commission.

One of the major issues of concern to the Chamber is in the area of concessions granted in forests. Several exploration Companies have been granted such concessions but now government refuses to
issue new ones and renew those that have expired. Fortunately, government has come out with a set of draft guidelines for monitoring the operations in the forests and the expectation is that agreement will be reached soon to enable at least some of the affected Companies to resume exploration activities. In this connection, it is important to look at the Chamber's proposal on forests which invites the authorities to survey and classify all forest areas to determine those that are intact which would not be mined at all; and those with a lower classification which would exist where mining could only be done with special permission from government after an assessment. Besides, deforested areas could be mined under the original terms of the concession. Above all, the Chamber has no doubt that there will be transparency and consistency in deciding where can be mined.

On the thorny issue of community relations, the Chamber is always transparent in handling related matters such as compensation and relocation. In this regard, it has to be made clear that the quantum of compensation will vary from mine to mine as circumstances dictate. For instance, Ghanaian Australian Goldfields Limited spent the equivalent of US $10 million on relocation and compensation because the area was sparsely populated. On the other hand, it is believed that Gold Fields Ghana Limited may be paying between US $10 million and US$20 million in compensation and relocation costs at its Tarkwa mine. Besides, the Chamber encourages its members to adopt a policy of continuous dialogue between the Companies and District Assemblies, District Environmental Authorities and Chiefs.

Further, the Chamber hopes to ease tensions with host communities by the continued adoption of more efficient land use practices. To this end, the Chamber will encourage land use planning to have orderly and sequential use of land. Farming, forestry and mining can be done on the same land sequentially, since land can be reclaimed for other uses when a mine's life expires. But this concept will have to be developed further by tapping the resources of all interested parties at the appropriate time.

Another matter of concern to the industry is illegal artisanal mining about which a Chamber paper will be presented in due course. As will be demonstrated the Chamber favours a policy that will effectively regulate illegal mining rather than stopping it by force. The Chamber at this stage, proposes that alternative employment opportunities should be provided for these employable young men and women who appear to have been "pressed" into galamsey because they have no choice. Because they do not make much money anyway they lend themselves to opportunities that will also give them vocational training. It is the expectation of the Chamber that this matter will be taken up by the authorities alongside the existing provision in the Mining Regulation for the tributer system which should be further developed for efficient management.

Mr. Chairman, I have tried to outline the vision of the chamber in the foreseeable future to achieve a peaceful and transparent mining industry that will be ready to respond effectively to the demands of the environment and to achieve harmonious relations with the host communities as well as more efficient land use practices.

I thank you for the attention.
APPENDICES

APPENDIX A

TIMETABLE

NATIONAL SYMPOSIUM ON MINING INDUSTRY AND THE ENVIRONMENT
MONDAY 14TH AND TUESDAY 15TH APRIL, 1997

PROGRAMME - MONDAY 14TH APRIL, 1997

OPENING SESSION

CHAIRMAN: Hon. J.A. AFFUL
Minister of Environment, Science & Technology

9.00 INTRODUCTION OF CHAIRMAN: Dr. David Nyamah
Secretary, Organising Committee of Symposium

9.05 CHAIRMAN'S REMARKS: Hon. J.A. Afful

9.15 WELCOME ADDRESS: Prof. E.H. Amonoo-Neizer
Vice-Chancellor of U.S.T. & Chairman, Organising Committee of Symposium

9.35 KEYNOTE ADDRESS: Hon Kwame Peprah
Minister of Mines & Energy

10.00 CHAIRMAN'S CLOSING REMARKS: Hon. J.A. Afful

10.10 VOTE OF THANKS: Dr. Derick Carboo
Member, Organising Committee of Symposium

10.15 BREAK

PLENARY/SCIENTIFIC LECTURES

CHAIRMAN: Prof. A. A. OTENG-YEBOAH

10.45 The Role of the Mining Industry in the Economy of Ghana
E. Adadey

11.15 Current Environmental Practice in the Mining Industry
Goitkhold Agra

11.45 Analyzing Rainfall Factors to Estimate Soil Loss from Degraded Lands and Mine spoils
A. Ayensu

12.15 LUNCH BREAK
PLENARY/SCIENTIFIC LECTURES
CHAIRMAN: PROF. K. TUFUOR

14.00 The Protection of the Ghanaian Mining Environment: The Role of Legislation
Larsey Mensah

14.30 Current Environmental Practices at Iduapriem Goldmine
Ben Addo

14.55 Mining and the Environment - The Economic Controversy
S. Al-Hassan, D. Mireku-Gyimah and R.S. Suglo

15.20 SNACK

SCIENTIFIC LECTURES
CHAIRMAN: PROF. A. AYENSU

15.45 Multielement Analysis of Mineral Ore Samples using Energy Dispersive X-ray
Fluorescence Analysis
I.J. Kwame Aboh, S. Akoto Bamford, G.K. Tetteh and F.G. Ofosu

16.10 Measurement of As(+3) and As(+5) Content of some Ghanaian Gold Tailings
Khalid Ahmad

16.35 Arsenic Pollution in Streams and Sediments in the Obuasi Area
Derick Carboo and Y. Serfor-Armah

17.00 Development and Application of Selenium Ion Selective Electrode in the Analysis of
Selenium in Samples from the Environs of Obuasi
J. Kambo-Dorsa and V.P.Y. Gadzekpo

18.00 COCKTAIL RECEPTION

TUESDAY 15TH APRIL 1997

PLENARY/SCIENTIFIC LECTURES
CHAIRMAN: DR. A. OFOSU-ASIEDU

8.30 Mining Degradation of Forest-Land Resources and Rehabilitation
K. Tufuor

9.00 Revegetation of Destroyed Forests
A. A. Oteng-Yeboah

UST/IDRC '97 Symposium on the Mining Industry and the Environment, UST, Kumasi, Ghana
9.30 Environmental Acceptable Reclamation Procedures for Mine Spoils
A. Ayensu and K. Anane Fenin

9.55 Production of Sulphuric Acid from the Flue Gases of Prestea and Obuasi Goldmines
Francis Jetuah

10.20 BREAK

PLENARY/SCIENTIFIC LECTURES

CHAIRMAN: PROF. V.P.Y. GADZEKPO

10.45 Addressing the Galamsey Problem: The View from the Ghana Chamber of Mines
G.T. Lewis

11.10 The Impact of Surface Mining on Forest Structure and Environment
Dominic Blay Jr and C. Adu-Anning

11.35 The Management of a Mineral Deposit in a Forest Area: A Computerized Approach
Ralph Kingston Asahere

12.00 LUNCH BREAK

SCIENTIFIC LECTURES

CHAIRMAN: PROF. F. K. OPPONG-BOACHIE

14.00 Environmental Studies Related to Gold-mining in Ghana: A Review
S. Akoto Bamford, I.J. Kwama Aboh, and F.G. Ofosu

14.25 Speciation of Arsenic in some Biological Samples from Obuasi and its Surrounding Villages
P. Abum Sarkodie, D. Nyamah and E.H. Amonoo-Neizer

14.50 Local Sulphooxidising Bacteria for Environmentally Friendly gold Mining

3.15 BREAK

CLOSING SESSION

CHAIRMAN: DR. K. SRAKU-LARTEY

3.40 REPORT FROM RAPPORTEUR GENERAL: Dr. E. Adei

4.00 CLOSING ADDRESS: Mr. Peter Bradford, President, Ghana Chamber of Mines

4.30 VOTE OF THANKS: Dr. David Nyamah
APPENDIX B

ORGANISING COMMITTEE

Chairman: Prof. E.H. Amonoo-Neizer, Vice-Chancellor of U.S.T. and Director, U.S.T./IDRC Environmental Research Group

Secretary: Dr. David Nyamah, Co-ordinator UST/IDRC Environmental Research Group

Members: Prof. A. Oteng-Yeboah, Botany Department, University of Ghana, Legon

Prof. F.K. Oppong-Boachie, Chemistry Department, UST, Kumasi

Dr Derick Carboo, Chemistry Department, University of Ghana, Legon

Dr. Evans Adei, Chemistry Department, UST, Kumasi

Dr. S. Osafo-Acquaah, Chemistry Department, UST, Kumasi

Mr. W.K. Bannerman, Chemistry Department, UST, Kumasi

Dr. Dominic Blay Jr, Forestry Research Institute of Ghana, Kumasi

Mr. C. Adu-Anning, Forestry Research Institute of Ghana, Kumasi

Dr. S. Akoto Bamford, Ghana Atomic Energy Commission, Kwabenya

Dr. A.K. Brimah, Chemistry Department, University of Ghana, Legon

Mr. Yaw Serfor-Armah, Ghana Atomic Energy Commission, Kwabenya

APPENDIX C

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