KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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DEPARTMENT OF ECONOMICS AND INDUSTRIAL MANAGEMENT

SOLID WASTE MANAGEMENT IN THE MINING INDUSTRY IN GHANA

A CASE STUDY OF ASHANTI GOLDFIELDS COMPANY LIMITED

OBUASI, GHANA

A THESIS PRESENTED TO THE BOARD OF SCHOOL OF GRADUATE STUDIES, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF ARTS (ECONOMICS) DEGREE

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ABSTRACT

Ghana is endowed with abundant natural resources, which have played a very important role in the agricultural and industrial efforts of the country. These resources served as the springboard for the country's industrial development after the attainment of independence and they remain the fundamental endowment from which the nation's people derive their livelihood. In the process of exploiting these resources to meet the legitimate socio-economic needs and aspirations of her people, however, adequate care has often not been taken to guard against the destruction of the environment. Mining is one of the main sectors that contribute significantly to the nation's development but its activities are usually associated with a number of problems such as land devastation, soil degradation, and water and air quality changes.

Attempts are made in this study to identify how the solid waste from mining is managed in Ghana, with particular reference to the Ashanti Goldfields Company Limited, one of the largest gold mining companies in the world, as the case study. The study identifies the world's standards for managing solid waste from mining. The waste management methods of some major gold producing countries in the world such as South Africa, the United States of America, Denmark, India, and the Great Britain are also identified. Ghana's mining regulations are also identified and compared to those of the world standards. In addition, the AGC's solid waste management methods are also identified and compared with these standards to see whether the company's waste management methods conform to those of the world standards or not.

The reasons for comparing the AGC's waste management methods to those of world standards is first, to determine whether the AGC adopts the world's standards or those of Ghana's Mining Laws of managing mining waste in the country. The second reason is to know whether Ghana's mining Laws also conform to those of world standards. On the basis of this, conclusions can be drawn as to whether the AGC is doing the right thing by adopting the world standards or not.

Information from the study is gathered through the use of interviews, questionnaires, and extensive observation at the study area. The study revealed that although the company's waste management methods conform to some of the world conventions, a greater percentage of these conventions are either partially adhered to or completely ignored.

In view of this, it has been suggested that the government of Ghana and all the agencies concerned with environmental safety be actively involved in enforcing and ensuring that the AGC Limited, and for that matter mining companies in the country manage their wastes in accordance with the world standards. A call has also been made for the review of Ghana's mining regulations which does not address current concerns on waste management so that it can be abreast and consistent with those of the world standards. Perhaps, this can serve as a yardstick and a basis of effective monitoring of the activities of the mining firms to ensure sufficient air, soil and water quality in the country.

DEDICATION

To my wife, Lilian, and the kids, Dennis, Andrews, and Jennifer.

DECLARATION

I declare that I have personally, under supervision, undertaken the study herein submitted.

DATE.....5/10/2004.....

.....

WILLIAMS KWASI BOACHIE

I declare that I have supervised the student in undertaking the study submitted herein.

DATE 12/10/04.....

.....

DR OSEI A. KUFFOUR

(SUPERVISOR)

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I haven't the slightest doubt that errors and obscurities remain. These are my responsibility alone.

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CHAPTER ONE

INTRODUCTION

1.1 GENERAL OVERVIEW

Mining is one of the main sectors that contribute significantly to the nation's development. The gold mining industry has led the overall recovery in the mining sector since the inception of the E.R.P./S.A.P. and the institution of the relevant policy reforms for the mining industry. The industry has also attracted much of the foreign investment flows into the national economy especially from 1988 onwards. Indeed the mining sector has now become the most important foreign exchange earner for the country having displaced cocoa to a second position (Songsore, et al 1994). Mining activities in and around Obuasi in the Ashanti region of Ghana have played a significant role in the nation's development, and above all, the revival of economic life in and around Obuasi and to some extent the country in general.

The extraction and other industrial processes under gold mining activities generally involve the conversion of raw materials from the earth (gold ore) and resources into semi-finished and/or finished products (gold). The 'residues' formed in the process usually become waste, and if not managed properly, such wastes can become pollutants if discharged into the environment.

There are three main types of wastes that are generated from various economic activities. These are solid, liquid and gaseous wastes. All these forms of wastes are produced from activities such as the extractive (or agricultural) sector, the processing (or industrial/manufacturing) sector and the commercial (which may include domestic or municipal wastes) sector.

This study, however, focuses on the analysis of solid wastes from the extractive industry, with special emphasis on the gold mining sector. Unless otherwise stated, wastes mentioned in this study refer to solid wastes from the mining sector.

1.2 STATEMENT OF THE PROBLEM

In the process of exploiting gold and other minerals for socio-economic development, adequate care has often not been taken to guard against the destruction of the environment. Mining in Ghana is usually associated with a number of problems such as land devastation, soil degradation, and water and air quality changes. The use of cyanide as the main chemical for processing eventually leads to the pollution of rivers and water bodies. The roasting process also results in the discharge of large quantities of arsenic into the atmosphere. The health and safety hazards of miners and residents of mining areas are numerous and may include accidental rock falls, mine fires, haulage accidents, shaft accidents, chemicals discharge into rivers and streams, gas poisoning, high temperature and humidity effects, and various occupational diseases besides the soil degradation and landscape transformation.

The cyanide spillage in the Asuman and Huni rivers at Abekoase and Huniso near Tarkwa by Goldfields Ghana Limited (GGL) in October 2001 is an instance of concern. Four months after the incident the company agreed to pay a compensation of one billion cedis to the communities affected, but the communities rejected the amount as being meager (People's Daily Graphic, March 28th 2002.)

It is in the light of these problems that there is much cause for concern, particularly, in the mining and concentrated area of Obuasi, Ghana. Over the years, the quantity and diversity of mining wastes have increased, however, there are hardly any waste recycling or proper management practices in the country. Of late issues with mine waste has become a major problem and in a growing list of communities around the world, it has reached crisis proportions (Saigo, et al, 1995).

It is in view of the above issues and problems that this study attempts to undertake in-depth analysis of solid waste management methods of the mining industry in Ghana, using AGC, Obuasi as a case study.

1.3 OBJECTIVES OF THE STUDY

The general objective of the study is to identify and analyze the methods by which the mining industries in Ghana manage their solid wastes. Specifically, the study aims to achieve the following objectives:

a. To review current international and government policies on the operations of the mining industry, particularly on issues relating to the management of the solid wastes from their operations.
b. To identify the solid waste disposal and management systems of the mining industry in Ghana, using AGC as a case study.
c. Based on the findings above, the social, economic and environmental implications of the mine solid waste management systems in Ghana would be evaluated, and where necessary, make realistic and implementable short and long term recommendations for ensuring an efficient and successful waste management systems in the mining sector would be made.

1.4. HYPOTHESES OF THE STUDY

This study does not involve a vigorous hypothesis testing either parametrically or non-parametrically. An assertion is made that the mining companies in Ghana, specifically the AGC, do not manage their solid wastes according to government policies and international standard. Government guidelines concerning waste management are listed and the management strategies of the AGC are checked against these guidelines. A similar check is also done with international benchmarks.

A subjective conclusion is drawn on the basis of conformity of AGC's waste management strategies to these benchmarks. If the study reveals, for example, that the AGC's solid waste management methods fall short to the international benchmarks, being the effective and most efficient means of managing mining wastes, then a conclusion is drawn on that basis.

1.5. JUSTIFICATION AND SIGNIFICANCE OF THE STUDY

The research is necessary for the sustainable economic development of Ghana. The disposal of solid wastes from the mines, an inevitable by-product of socio–economic development, eventually affects surface and ground water bodies as well as directly affecting other biological organisms such as vegetation, biodiversity and forests. In order to have a sound and pristine environment for a smooth developmental take-off, there is the need for efficient and appropriate regulatory and supervisory system of waste management systems for households, agricultural, mining, other industrial organizations and commercial activities.

It is in this light that this research work attempts to study the various existing methods of waste management in the mining sector and it is hoped that the study would be able to suggest alternative and efficient solid waste management methods in the country. This will not only ensure increased productivity in the face of efficient waste management, but also in terms of adopting measures that will help to improve human health and environmental quality.

Although much work has been done in this area by the Environmental Protection Council (1988), Council for Scientific and Industrial Research (1987), Acquah, P.C. (1988), Songsore et al (1994), and the Chemistry Departments of KNUST (1988) and UCC (1971-86), there is the need to fill this gap by finding out, if there is any, the shortcomings of the existing wastes management methods and suggest other methods to revamp the current methods and show concern for the environment and human health, especially during this period of Ghana's investment drive.

1.6. SCOPE AND LIMITATIONS OF THE STUDY

As with most research works, a whole lot of difficulties are encountered in the study. The study could have covered about three or four mines but funds, manpower and time constraints, limit the scope of the study in terms of data collection and the depth of the analysis made. Because of these problems this is a highly restricted sample in terms of number and coverage, as Obuasi is selected as a case study.

Furthermore, there are several wastes residues created by mining industries but this study is devoted solely to solid wastes; liquid and gaseous wastes are not included in this study.

In spite of these drawbacks, it is hoped that the study will contribute greatly to the need for effective and efficient waste management for many industries in the country.

1.7. CHOICE OF THE STUDY AREA

The study is conducted on the Ashanti Goldfields Company Limited (A.G.C), Obuasi, in the Adansi West District in the Ashanti Region of Ghana. The choice of the study area is based on the fact that the topography, climate and vegetation of the study area favour the production of several agricultural crops. Therefore, if the solid wastes from the mining operations are not managed properly most of the land, soils, streams, aquatic life and the vegetation would adversely be affected in such a way that their effect may hamper the production of many agricultural crops.

Furthermore, the mining industry is fast becoming the leading foreign exchange earning sector with gold providing over 80% of these earnings (World Bank, Ghana 2000 and Beyond, 1993). Mining, agriculture and forestry are the major growth activities on which the future of the Adansi West district depends. These are all natural resource-based activities. Among these, mining stands out, not only as an exhaustible activity but also the one that carries potentially the most serious environmental consequences. According to Steer (1991) the challenge is to accelerate development without ruining the natural resource base and undermining future prospect.

This implies potential for growth trade-offs among the three sectors identified above in fashioning out an accelerated growth strategy for the district. Specifically, Obuasi lies almost at the center of the Adansi West district (see **Appendix D1, page 99**), and it is therefore necessary to study the environment-economy linkages of the AGC since mining is known to carry environmental consequences in the long run.

A careful analysis of the waste management methods of the company is therefore, necessary because if the mining waste were mismanaged, most of the land, soil, water and vegetation and the people living around the area would be adversely affected. The area consists of a number of mining departments sufficient enough to provide much information on the management of waste.

Again, the area is selected for the study because the conditions there are almost similar to the other mining areas in Ghana, and so the findings can perhaps be projected onto the national level.

1.8. ORGANIZATION OF WORK

The dissertation is divided into chapters. After the introductory chapter, the second chapter is devoted to the review of the literature. It outlines a brief overview of world and international environmental policies, as well as mine waste management systems of some countries in the world. This chapter also provides a checklist of waste management methods against which the findings of the study will be measured. The chapter ends with the Conceptual Framework of the study: the materials balance model of waste generation and management.

Chapter three of the study is also devoted to a brief method of the study and a brief profile of the study area. Chapter four, the main body of the work, discusses the findings and their implications for socio-economic development of Ghana. The last chapter summarizes the findings and attempts to suggest alternative and efficient solid waste management methods in the country to alleviate the problems.

CHAPTER TWO

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORKK

2.1 GENERAL OVERVIEW

Environmental protection has been recognized today as an important factor to improve the quality of life and to enhance the economic independence of a country. Safe disposal of wastes with possible recycling is essential prerequisites for the protection of the environment. Governments of developing countries are becoming increasingly conscious of the need for proper waste management.

Generally, most industrial, commercial, agricultural and household activities essential to the development of a country generate a wide variety of wastes. In the normal sense, these wastes have to be pretreated before disposal or recycled so that they do not adversely affect the environment. The chemical nature of these wastes is diverse depending upon the type of industrial activity, and there is no single method of treatment that is prescribed. Special methods have to be developed to treat the wastes from a particular type of industry.

Solid waste disposal and management is vital to the development of a country and it is, therefore, not surprising that it has attracted the attention of many writers. Statistics currently available show that good sanitary practices have the potential benefits of enhancing the health of the people. A readily available supply of safe water and the sanitary disposal of wastes, for instance, are known to be among the essential ingredients of a healthy productive life. This study, therefore, is an attempt on the analysis of solid waste management methods of the mining industry in Ghana, using AGC as a case study.

A World Health Organization (WHO) expert committee on environmental sanitation in 1954, rated the proper management of mining, medical wastes and other forms of wastes as among the basis for ensuring a safe environment for any community.

The Environmental Protection Agency in Ghana (1994) maintained that excess of different metals could prove toxic to most plants and animals. To support this fact Table 2.1 reveals how the concentrations of certain elements (heavy metals) can be toxic to living organisms.

Table 2.1 Levels of Concentrations at which common heavy metals can be Toxic to living organism (mg/1) .

Description	Cu	Zn	Pb	Cd	Cr	Ni	Fe	Mn	Al	Hg
Toxicity in solution to plants (1)	0.02	1.3	1.7	2.1	3.8	0.18	9.3	0.05	0.9	6.6
Toxicity in solution to fish (2)	0.02	1.3	1.7	2.1	120	30.0	250	100	1.5	0.06
Maximum concentration in drinking water (3)	1.5	15.0	0.1	0.01	0.05	-	1.0	0.5	-	0.001
Maximum concentration in water for farm animal (4)	0.5	25.0	0.1	0.05	1.0	-	-	-	5.0	0.01
Maximum concentration in irrigation water (5)	0.2	2.0	5.0	0.01	0.1	0.2	5.0	0.2	5.0	-

(1) Concentration reducing growth (of roots of Lolium perenne) to 50% will vary with species
(2) Concentration reducing rainbow trout (Salmo gairdneri) to 50% after 48 hours.
(3) WHO (1971) recommendation
(4) EPA (1972) recommendations. Toxicities can be reduced by several factors, notably by the presence of calcium, phosphates, carbonates, hydroxides, organic matter and clay minerals.
Source: Ghana Environmental Action Plan Vol. 2 (1994) P. 67.

The elements on Table 2.1 are usually common in most mine wastes. Each of them has a range and degree of toxicity to human and plants (**Appendix E, page 101**).

The chemical constituents in mine wastes create various health problems for humans and also impact on aquatic organisms. In the case of chemical constituents, studies have shown that the health aspects arise from the different impact, which the constituents have on human body. There are

- Constituents, which exert acute and/or toxicity upon consumption. The human body is able to tolerate a certain level only beyond which it cannot. Examples are metals, nitrates and cyanides. Higher concentration of cyanide than the WHO (1984) drinking water guideline

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value has been found in the waters of Jimi River in the Offin Basin (WRRI, 1988). Osafo (1988) found the same situation in the Ankobra basin. The sources were effluents from gold mining operations.

- Constituents, which are carcinogenic or mutagenic and cannot be tolerated at any level. Examples are some pesticides and arsenic. In the gold mining areas, waters receiving mining effluents contain certain levels of arsenic beyond the WHO (1984) guideline value for safe drinking water.

- Constituents which are necessary for human health. Examples are iron, fluoride and iodine. Deficiency for these can be detrimental to health, but higher concentrations than optimum can also be detrimental. Some of the consequences of deficiency for these effluents are tooth decay or rejection of suppliers. Amusu (1974) has showed that about 30% of the groundwater suppliers have high iron concentration beyond the WHO (1984) guideline values, and these have resulted in rejection with consequent loss of investments.

It is therefore, evident that most wastes from mining and other manufacturing industries contain hazardous and toxic chemicals that require much attention and care. It is noteworthy that it is still not possible to quote definite toxicity concentrations of individual metals because of the many factors involved. This is because there are usually several metals involved and the interactions between them may multiply the potential problems. For example, combinations of metals in solution such as nickel and zinc, copper and zinc, and copper and cadmium are more toxic than their individual toxicity would suggest. Alternatively, the presence of phosphates or calcium can reduce the toxicity of lead, zinc and copper.

2.2 THEORETICAL FRAMEWORK

2.2.1 THE NEED FOR PROPER WASTE MANAGEMENT

The definition of wastes as being hazardous or not varies from one country to another. One of the most widely used definitions, is contained in the United States Resources Conservation and Recovery Act (1976). According to the Act, wastes are toxic and/or hazardous if they cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or

incapacity reversible, illness, or pose a substantial present or potential hazard to human health or the environment when improperly created, stored, transported, disposed of, or otherwise managed. The definition above gives us a detailed insight about wastes and their associated problems: that is

- It defines wastes as toxic or harzadous
- It tells us the extent of toxicity or hazardous nature of wastes
- It tells us the causes and the processes through which wastes could cause harm; and
- It also tells us those that are affected:
  i. humans- health, illness, accidents, death, fatality, and mortality
  ii. non humans- plants, animals, water bodies and acquifers, soils and landscapes, and aesthetics in general.
  iii. other activities affected include agriculture, fishing, hunting, and recreational activities.

It should also be noted from the above definition that wastes may either be harzadous or toxic if they cause or significantly contribute to:

- an increase in mortality
- an increase reversible or irreversible illness (human health)
- an increase in environmental destruction which also affects the quality of human life
- actual or potential threat to other living organisms and the environment in general

It can also be seen from the above definition that wastes whether hazardous or toxic can cause or contribute to the above problems in society if they are:

- improperly created
- improperly stored
- improperly transported
- improperly disposed
- improperly managed

It is in the light of these problems caused by improper waste management that there is much cause for concern, particularly, in the mining and concentrated area of Obuasi, Ghana. Over the years, the quantity and diversity of mining wastes have increased; however, there are hardly any waste

recycling or proper management practices in the country. Mine waste has become a major problem and in a growing list of communities around the world, it has reached crisis proportions. To minimize the negative effects of poor waste management, there is the need to identify a framework to serve as a basis against which mining companies should behave towards the environment.

2.2.2 MATERIAL BALANCE MODEL OF WASTE MANAGEMENT

Based on material balance model the physical environment of mankind has three life sustaining functions:

1. as a source of input to productive activities to sustain human life and welfare (quantitative input)
2. as a source of input into assimilation of less useful materials associated with productive resources (physical inputs); and
3. as an amenity of nature enjoyed directly by humans including air quality, water quality, etc (qualitative input).

These three functions are closely interrelated: productive activities yield both good and bad "things". Good things are used by humans for comfort and welfare. Bad things are returned back into nature as waste or residue.

2.2.2.1 USED UP NATURAL RESOURCES

Depending upon the nature of the natural resources, the process of productive activity to enhance human welfare tends either to exhaust or depletes the resource. The first environmental problem society encounters is **exhaustion or depletion.**

In the process of creating "goods" to enhance human welfare, "bads" are also created. These 'bads' are called wastes or residuals. The wastes that are generated are thrown back into the environment. Depending on the nature of the wastes, nature may absorb them completely and turn them into useful products or may just contain them in their original form (biodegradable or non biodegradable). The ability of natural environment to absorb wastes one way or the other is its assimilative function. Waste generation occurs in three phases- at the primary stage of extraction, secondary stage of processing and final stage of consumption. Each stage of human activity creates wastes, which must be disposed of in some way.

The second problem society faces is **waste disposal** and **cost on waste management.** The cost to society (public or private) is usually called **pollution prevention costs** or **abatement costs**. For example a farm may find it necessary to treat its waste before releasing it into the environment, thus rendering it harmless to the environment. This is seen as the costs incurred by the private firm to prevent pollution. But if society (public or private) is unable to accept the proper disposal costs and the waste is dumped into the environment to some critical level, the environment may not be able to assimilate the waste any further. In such a situation, **Environmental Degradation** or **pollution** occurs. The quality of environmental amenities (i.e. air, water, etc) degenerates. The problem at this stage is to determine **optimal pollution** level or the **cost of pollution** in monetary terms).

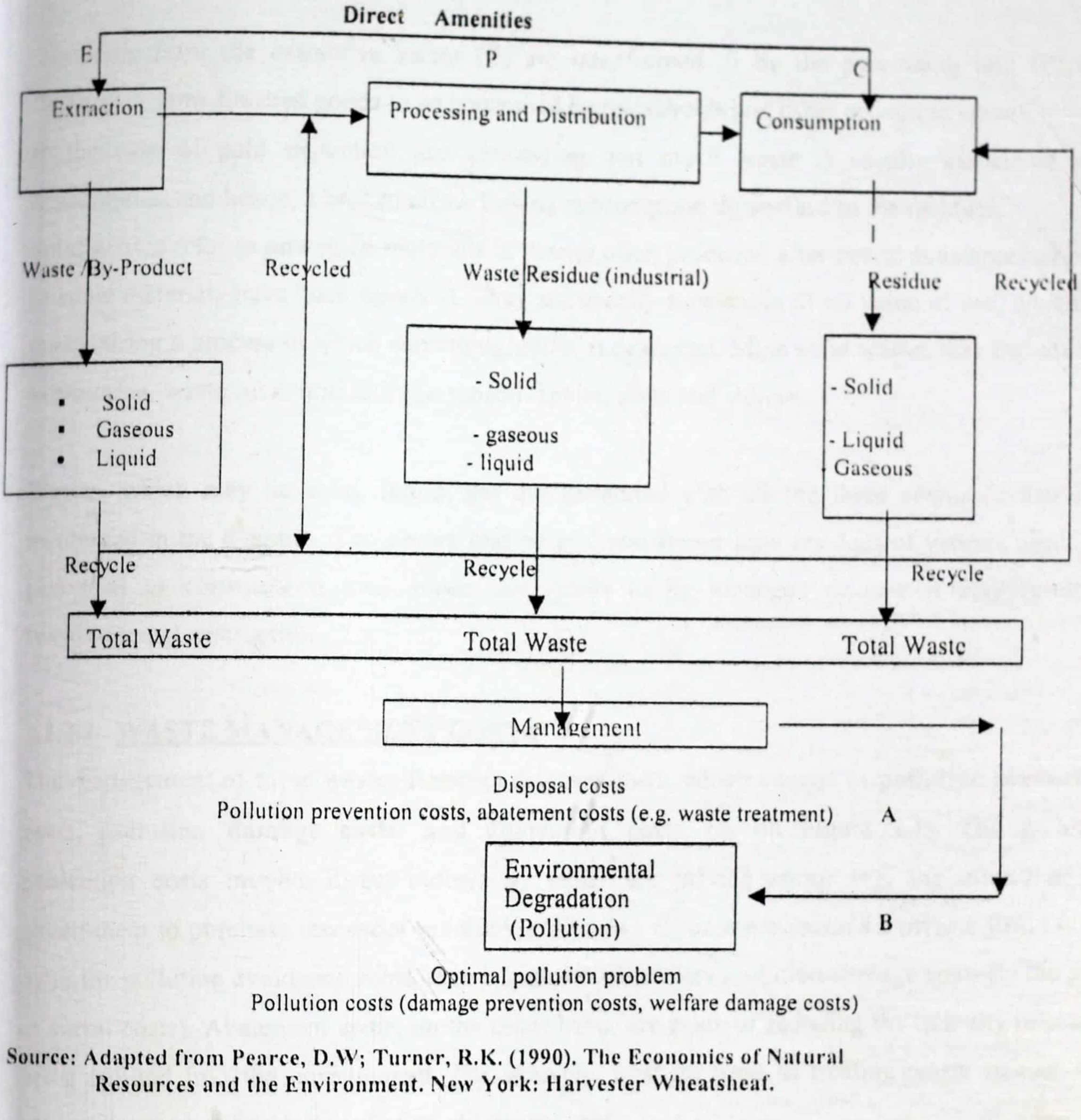
Pollution costs involve **damage avoidance costs** (defensive or remedial expenditures) and **welfare damage** of pollution or externality costs (here, society accepts the consequences of pollution in terms of health, visibility, noise, etc).

Figure 2.1 illustrates the materials balance model of waste management and costs. It shows the three main activities where wastes can be generated: Extraction (E), Processing, Manufacturing and Distribution (P) and Consumption (C).

The **extractive** activity in figure 2.1 comprises the input and amenities that we derive from the environment. This consists of activities such as hunting, gathering, recreational, and medicinal inputs that we derive directly from the environment. It also includes all private firms that take inputs direct from the environment and convert them into outputs. The primary inputs from the natural environment to the production sector are materials, in the form of fuels, non-fuel minerals, and wood; fluids (e.g., water and petroleum); and gases of various types (eg, natural gas and oxygen). All goods and services are derived from materials with the application of energy inputs. It also includes the exploration of minerals and other natural resources, the extraction of these resources and harvesting them to ensure utility maximization and economic growth.

The **processing** and **manufacturing** stage adds value to the resources that are extracted from the extractive industry to facilitate their distribution and consumption.

Figure 2.1. THE MATERIAL BALANCE MODEL OF WASTE GENERATION AND MANAGEMENT



Source: Adapted from Pearce, D.W; Turner, R.K. (1990). The Economics of Natural Resources and the Environment. New York: Harvester Wheatsheaf.

The next activity is **consumption**, that is, the using up of the goods and services that are manufactured and distributed by the processing stage. It includes all of the private households to whom the vast collection of final goods and services are distributed. One could argue that consumers sometimes use inputs directly from nature, like the extractors; many households for

example, get their water supplies directly from groundwater aquifers, rather than water distribution companies. Figure 2.1, shows the link (direct amenities) between the extraction and consumption activities.

Materials from the extractive sector (E) are transformed or by the processing unit (P) into finished or semi-finished goods to be consumed by households and other economic units(C).
In the case of gold extraction and processing, not much waste is usually associated with consumption and hence, a broken arrow linking consumption downward to the residues.
Solid wastes refer to unwanted materials or matter often produced after useful substances or parts of some materials have been removed. They are usually substances of no value or use, which are made during a process in which something useful is produced. Mine solid wastes may include soil overburden, waste rock, mill tailings, topsoil, spoils, slags and slurrys.

Wastes, which may be solid, liquid, gas are generated with all the three economic activities mentioned in the diagram. The arrows that point down shows how residues of various forms are generated to constitute a total waste that needs to be managed or else it may result in environmental destruction.

2.2.2.2 WASTE MANAGEMENT COSTS

The management of these wastes involves disposal costs, which consist of **pollution prevention costs, pollution damage costs, and abatement costs**, (**A** on Figure 2.1). The pollution prevention costs involve direct outlays by either the private sector (eg. the miner) or the government to purchase resources to inhibit pollution. If for some reasons a private firm fails to incur the pollution avoidance costs, then it imposes on society pollution damage costs (in the form of social costs). Abatement costs, on the other hand, are costs of reducing the quantity of wastes being emitted into the environment. For example, cost incurred in treating waste so that they become less toxic is an instance of an abatement cost.

If on the other hand, the wastes generated are not well managed and the environment is not able to assimilate the waste any further, then we have a situation of environmental degradation or pollution which may also involve damage prevention costs and welfare damage costs. (B on

Figure 2.1). With the welfare damage costs, society accepts the consequences of pollution in terms of health effects, visual degradation, noise levels, etc.

Welfare damage costs, therefore, represents the impacts produced by environmental pollution on people and on elements of the ecosystem through disruption of ecological linkages, species extinction, and so forth. Figure 2.1 also reveals that part of wastes generated from the three activities can be recycled before the remaining wastes enter the waste stream. It is evident from Figure 2.1 that with each of the economic activities waste is generated either in the form of a by-product or residue.

2.2.2.3 The Assimilative Capacity of the Environment

The environment has a capability to take wastes and to convert them back into harmless or ecologically useful products. This is the environment's assimilative capacity (**A**) and it is the second major economic function of natural environments. So long as waste is dispose of waste in quantities (and qualities) that are commensurate with the environment's assimilative capacity, then we have

$$W = A$$

The circular economic system will function just like a natural system; although it will still draw down the stocks of exhaustible resources. The system will therefore have a finite life determined by the availability of the exhaustible natural resources and other considerations. If wastes are disposed in such a way that the capability of the natural environment to absorb the waste is damaged, then

$$W > A,$$

and the economic function of the environment as a waste sink is impaired. The assimilative capacity of the environment is thus a resource, which is finite. So long as the rate of assimilation is not exceeded, the environment will absorb wastes and essentially return them to the economic system. If all polluting activity today is dropped, within a short time, the sink and drain would clear and a pristine environment would re-emerge.

To foster rapid economic growth and development, however, industrialization has accelerated and worldwide population levels have increased multifold since the World War II. Therefore, nature's

sink gets clogged, reducing its ability to absorb and break down pollutants. Rather than the environment absorbing pollutants, the pollutants change the environment. Pollutants may change the composition of gas in the atmosphere, thereby altering the earth's temperature and climate. Major lakes and oceans may be so radically altered as to destroy aquatic life and most plant life. This may require decades to regenerate. Toxic wastes with half-lives of several generations may lie in wait in deteriorating containers to unleash their destruction on future generations.

2.2.2.4 MANAGEMENT POLICY POINTS

The above model indicates three policy action points in terms of waste generation and management. Policies can be initiated at the primary activity point (extraction point) not only to reduce the rate of extraction in order to prevent exhaustion or depletion but also to reduce waste **generation** or encourage waste management. This is the **source level management**.

Society (public and private) must incur waste disposal cost in the form of pollution prevention costs or pollution damage prevention costs. Otherwise society must accommodate the waste and suffer external damage costs. Similar policy measures must be taken at the processing and consumption levels.

With respect to mineral extraction and processing, pollution prevention costs may involve expenditures on pre-treatment of some of the wastes before they are disposed of. Several examples will be provided in the text. This cost is incurred **ex ante** because the waste matter is treated before it enters the environment. Pollution damage refers to all the negative impacts that users of the environment experience as a result of the degradation of the environment. These negative impacts are of many types and will of course vary from one environmental asset to another. Pollution damage cost is **ex post.** The waste matter is not treated but dumped raw into the environment. This is the **pollution level management**.

At this stage the environment has been exposed to harmful materials and the effects must be mitigated by determining a remedial expenditures e.g. clean up programmes or other expenditures to avoid contact or exposure. For example, if the water in a mining area is polluted by toxic material from mining activities, the mining company may incur the mitigative costs of importing uncontaminated water for consumption by the local communities or may resettle the inhabitants

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of the locality elsewhere where water is not polluted. In such a situation, resettlement expenditures become the remedial costs. In this case, we have the **damage level management**.

If pollution is not prevented at point **A (see Figure 2.1, page 13)** or avoided at point **B**, then society must accept welfare losses or damages. For example, in a mining area society may accommodate unfilled excavations, removal of topsoil without rehabilitation, unsealed mine shafts, etc. The physical degraphlets may pose considerable hazards to individuals in the locality. Such damages can be measured in money terms. A visit to a mining area reveals physical damages to the environment. The most tangible pollution damage takes the form of observable deterioration of both physical assets and of living things, including human beings. However, the full welfare costs of pollution damage are difficult to estimate exactly.

From the above discussion a generalized cost equation can be formulated for Waste Disposal Costs **(WDC) :**

Waste Disposal Cost = Pollution Prevention Costs + Pollution Avoidance Cost + Pollution Damage Cost

$$WDC = PPC(A) + (PAC + PDC)(B)$$

Where **A** and **B** are referred to the parts in figure 2.1.

In general **PPC (A)** involves direct outlays by either the private sector (e.g. the miner) or the government to purchase resources to inhibit pollution. Since this tends to increase operation cost or initial investment cost, or both, private operators may not have any incentive to incur these costs. Such costs eat into private profits. Firms would find it expedient to dispose of raw waste into the environment for natural treatment. This is cost free to the miner because the environment's assimilative capacity has no market price. It is a free good. However, untreated waste dumped into the environment for natural treatments does have **real pollution costs**. If the firm fails to incur the pollution avoidance costs then it imposes on society **pollution damage costs** (social costs). Most private firms, left to them, would avoid both pollution prevention costs and pollution avoidance costs so that society bears all the social costs. Herein lies the role of a

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public contribution to ensure that part of the **W.D.C.** is borne by the private sector that generates wastes.

2.2.2.5 OPTIMAL POLLUTION LEVEL

The basic principle here is the **polluter pays-principle** and not the **suffer-pays principle**. Society that suffers from disposed mine wastes should not be left to bear the costs in the form of **PDC**. The government must ensure that the mining companies bear at least a greater proportion of the waste disposal costs in the form of **PPC + PAC.** This implies that some of the costs will still be borne by society in the form of **PDC**. Hardly any economic activity (production and consumption) can be completely free from **Pollution Damage Cost.**

Both first and second laws of thermodynamics make it impossible for absolute pollution free economic activity. Not all wastes can be eliminated hence **PDC** is always positive. Optimal pollution does not mean zero pollution from economic perspective, unlike the way physical or the biological sciences conceive of the problem of pollution free environment. So long as society engages in economic activities there will always be some level of pollution. However, the economic level of pollution is defined as that level where Marginal Net Benefit (**MNB**) in the economic activity (private or public) equal Marginal Social Costs (**MSC**) both explicit and implicit and environmental costs inclusive. At the level where (**MNB = MSC**) pollution externality is no more Pareto relevant.

Figure 2.2 illustrates a set of conventionally shaped marginal net benefit and marginal social cost curves labeled **MNB** and **MSC** respectively. Marginal benefits have a threshold at pollution level **A** whereas the maximum uncontrolled pollution level is at **B**

The optimal level of pollution is at point **C** where the **MNB** curve equates the **MSC** curve at value **Pe**. Allocative efficiency requires that in allocating resources among uses, the marginal social costs and benefits of a resource be equalized within and across uses. That is, it requires that individual and societal economic decisions be based on social costs and benefits, not just private ones. Figure 2.2 shows that society accepts some level of pollution up to point **C** where **MSC = MNB**.

Efficient pollution level means that pollution level at which marginal net benefits are equal to marginal social costs. There is a trade-off inherent in the pollution phenomenon: high waste production exposes society or some part of it, to greater costs stemming from environmental damage. On the other hand, lower waste generation involve society in greater costs in the form of resources devoted to abatement activities, or lower level economic activities. At the pollution level **C**, total societal costs are equal to the benefits that society enjoys as a result of the economic activity, which generates the pollution.

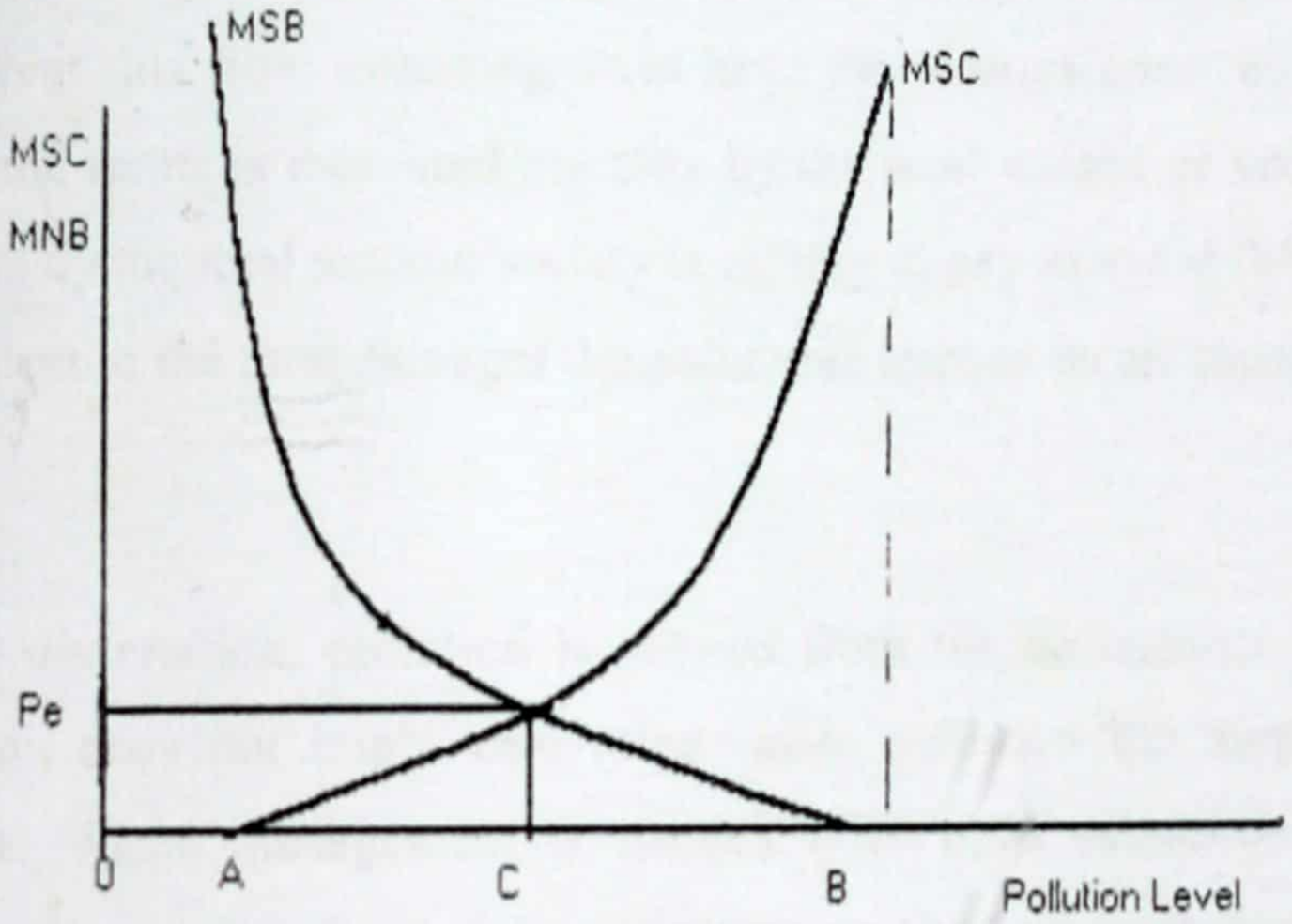

Figure 2.2 The Concept of Optimal pollution

Clearly, no environmental management policy can ensure zero pollution. Such a policy would not be optimal because it would imply sub-optimal economic activity and welfare loss to society.

In the mining sector, policy guidelines on how mine wastes should be managed especially at point A are done not necessarily to eliminate all waste-pollution but to ensure that mine waste pollution is optimal.

2.2.2.6 POLLUTION CONCEPT

It should be clear from the above that economic concept of pollution is different from physical and biological concept of pollution. Whenever the physical or biological sciences define pollution as accumulation of substances or the disruption of ecosystem as a result of production and consumption activities, economist consider such accumulation of substances as pollution only when their effects on the environment become harmful or undesirable. From economic perspective pollution is a concept that involves individual and group preferences as well as technical, physical and biological science data.

If people discard plastics into the natural environment, it is pollution from the point of view of physical sciences. To the economists it becomes pollution if people are willing to pay something to prevent this from occurring or to have the plastics removed. Thus, the extent of pollution in economic terms is measured not only by the total weight or volume of the accumulated material but also by the total amount society is willing to pay to avoid the damages. This amount should be equivalent to the total damages the pollutants impose on all consumers.

In this dissertation, pollution is viewed from the economists perspective: optimal mine waste pollution does not imply zero mine waste pollution but some level of pollution society can tolerate. Waste management is viewed from both extraction and processing points and not consumption point. Further, this research emphasizes pollution prevention and avoidance costs and shows that pollution costs is still positive and not zero. It also examines how the gold mining companies deal with wastes ex ante – **pollution prevention exercises** as well as ex post **pollution avoidance exercises**. The World Environmental Policy and EPA policy guidelines which serve as a checklist for AGC practices are compared to these two categories of waste management systems. Whether the management policy is based on pure market mechanism (Coasean liability rule), mimic market mechanism (charges, taxes, subsidies, marketable permits/rights), command and controlled mechanism (standards, regulations, moral suasion, or government direct participation) – any of these involves either prevention or avoidance management exercise, or both. Each policy instrument is expected to provide appropriate

incentives for the companies to behave responsibly towards the environment. It is a carrot- and-whip issue.

2.3. THE DEVELOPMENT OF WORLD ENVIRONMENTAL MANAGEMENT POLICY

Within the last three decades or so the concept of 'sustainable' development has become current in international development dialogue and since the Rio Summit in 1992 it is fast becoming a practical guide in development practice.

Owing to the dangers that waste mismanagement poses to mankind, environmentalism has become a growing factor in international relations. Many world leaders saw the concern for environment, health and natural resources as entering a policy stream. A new sense of urgency and common cause about the environment was leading to co-operation in some areas. Ecological degradation in any nation was now understood almost inevitable to impinge on the quality of life in others. According to the Brundtland Commission, sustainable development implies "meeting the needs of the present generation without compromising the needs of the future generations"(WCED, 1987). This position is endorsed by the World Bank in its World Development Report of 1992 on Development and the Environment.

The increased attention to the environment as a foreign policy and national security issue was only the beginning of what would be necessary to avert the problems in the future. A major step in that direction was the 1972 UN Conference on Human Environment in Stockholm, Sweden. This was the first international conference specifically dealing with environmental concerns. Out of the conference was born the UN Environment Programme, a separate department of the United Nations that deals with environmental issues.

In 1982, the third United Nations Conference on the Law of Sea produced a comprehensive convention that addressed many of the issues concerning jurisdiction over ocean waters and use of ocean resources. It was out of the 1982 UN convention that some laid down procedures were structured, amended, ratified and adopted by all the UN member countries to ensure that environmental, nuclear, and chemical contamination against the bankruptcy of soil and water systems were greatly reduced. The UN Conference on Environment in Rio de Janeiro, Brazil in

1992, among other provisions, required that since the effects of wastes are usually dangerous and diverse, management of its disposal is essential (Quarrie, 1993; Gilpin, 1995).

It was, therefore, required at the conference that governments and other organizations, according to their capacities and resources available, and with the co-operation of the UN, should adopt environmentally sound management of wastes. For the purpose of comparison, the world conventions of managing mine waste and Ghana's Mining and Environmental Guidelines are summarized and produced on Table 2.2.

Table 2.2 will also be employed as a benchmark against the solid waste management practices of the AGC Limited to determine whether or not the company's solid waste management practices are in line with world standards.

TABLE 2.2 SUMMARY OF MANAGEMENT OF MINE WASTES (BASED ON UN CONVENTION)

ACTIVITY	CONVENTIONS REQUIREMENT	GHANA'S MINING LAWS & REGULATIONS
1. **EXCAVATION**	• Must use appropriate equipment to minimize size of excavations. • Construct drill pads • Well positioning of drill holes and excavations to avoid environmental disaster • Recycling of drilling fluids • Make sure that uncontaminated water to settle before discharge to natural drainage • Store oil based fluids in steel or appropriate plastic tanks	• Using appropriate equipment to minimize size of excavations. • Construct drill pads • Well positioning of drill holes and excavations to avoid environmental disaster • Recycling of drilling fluids • Allow uncontaminated water to settle before discharge to natural drainage • Store oil based fluids in steel or appropriate plastic tanks
2. **CONSTRUCTION & DEWATERING**	• Bury materials in chemically unreactive rocks to prevent surface and groundwater contamination	• Bury materials in chemically unreactive rocks to prevent surface and groundwater contamination

3. ABANDONMENT	• Inspect all excavations during operations and backfill or seal them • Rehabilitate the site to a condition consistent with pre –existing character of the area • Bury/remove all refuse from exploration sites • Exploration sites rehabilitation be completed within three months of abandonment	• Inspect all excavations during operations and backfill or seal them • Rehabilitate the site to a condition consistent with pre–existing character of the area • Bury/remove all refuse from exploration sites • Exploration sites rehabilitation be completed within months of abandonment
4. TAILINGS DISPOSAL	• Tailings be stored in impoundments two weeks after production • Capacity of impoundment should be sufficient to contain tailings volume • Be deposited by sub aerial deposition to maximize consolidation and decay of degradable contaminants	• Tailings be stored in impoundments after production • Capacity of impoundment should be sufficient to contain tailings volume • Be deposited by sub aerial deposition to maximize consolidation and decay of degradable contaminants
	• Impoundment be located down stream to the processing plant so that run-off and spillage will report to the impoundment • No discharges to natural drainage other than emergency passageway will not be permitted • Routinely monitor phreatic water levels as specified in the EIA or EAP	• Impoundment be located down stream to the processing plant so that run-off and spillage will report to the impoundment • No discharges to natural drainage other than emergency passageway will not be permitted • Routinely monitor phreatic water levels as specified in the EIA or EAP
5. WASTE ROCKS	• Should be disposed six months after operation • Manage any chemically reactive	• Should be disposed immediately after operation • Manage any chemically reactive

	waste rocks to minimize leaching and acid generation	waste rocks to minimize leaching and acid generation
6. WASTE DUMPS OR OVERBURDEN	• Be progressively reclaimed two weeks after production • Topsoil and subsoil be separated and kept in an environmentally friendly manner • May be used for eventual restoration/reclamation	• Be progressively reclaimed after production • Topsoil and subsoil be separated and kept in an environmentally friendly manner • May be used for eventual restoration/reclamation
7. CONTAINER DISPOSAL	• Be stored and maintain precautions to minimize risk of spillage and groundwater quality • Only reuse containers when no environmental hazard would occur	• Be stored and maintain precautions to minimize risk of spillage and groundwater quality • Only reuse containers when no environmental hazard would occur
8. DISCHARGES TO WATER	• Undertake regular in-stream monitoring to ensure water quality • Report the quality and quantity of any unavoidable discharge to natural drainage in the EIA or EAP • Treat contaminated water to a standard to be agreed between the EPC and the company	• Undertake regular in-stream monitoring to ensure water quality • Report the quality and quantity of any unavoidable discharge to natural drainage in the EIA or EAP • Treat contaminated water to a standard to be agreed between the EPC and the company.
9. RECLAMATION	• Reclaim scarred land within three to four weeks after production	• Reclaim scarred land should be done after production to restore land to its original state.

Source: Adapted from Quarrie, Joyce (1994) Earth Summit (1992) " *The UN Conference on Environment and Development*" Held in Rio de Janeiro, Brazil. London: Regency Press; and Ghana's ***Mining and Environmental Guidelines*** (1994) EPC, Floent Publishers, Accra.

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Table 2.2, and **Appendix B** of this study, indicate that the Government of Ghana has in place laws and regulations in line with world standards; and structures to check permanent environmental damage caused by mining companies in Ghana. It should, however be noted that whereas the world conventions specify a time frame by which wastes are collected and managed, Ghana's Mining Regulations **do not specify such time frame**. Following Ghana's mining laws therefore suggests that wastes generated can be on the ground for long period of time, thereby permitting the possibility of polluting the environment. The above reveals that Ghana's mining standards need to be reviewed, allowing time dimensions and enforced to ensure compliance by the mining companies in the country. It is, therefore, believed that if the above polices on environmental regulations are properly enforced, monitored and adhered to by all concerned, a sound environmental stewardship can perhaps be promoted.

For the purpose of this study Ghana's Mining and Environmental Guidelines are summarized and shown in **Appendix B** of this study.

2.4. DEFINITION, NATURE OF MINE WASTES AND THEIR EFFECTS ON THE ENVIRONMENT

The definition of wastes as being hazardous or not varies from one country to another. One of the most widely used definitions is contained in the United States Resources Conservation and Recovery Act (1976), that was considered under Section 2.2.1 of this dissertation

Wastes generated form mining activities may include overburden, waste rock, and mined out land, mill tailings, spoils and rocks (**see Appendix A, page 82**).

The wastes produced vary with the type of mining operation involved. Greater quantities of unprocessed waste and mill tailings, for instance, are generally produced from open-pit operations more than underground operations. In appropriate surface mining operations, the topsoil, sub soil, and overburden are extracted and kept separately for eventual use. The mill tailings are produced after the actual minerals have been recovered from the ore. The topsoil and subsoil are useful for eventual restoration or reclamation of the mined land. If the overburden is non-toxic, it is valuable for the immediate mining operation for covering other wastes and mining scars, or for construction of landscaping features around the site.

Waste rock may be used as fill, as surface stabilizer on tailing embankments, in construction of highways or as an aggregate in street paving. Pollution problems may, however, arise if mineralized material is used. The coarse fraction tailings may be used as an underground fill and this lessens the chances of surface subsidence.

2.4.1 CHARACTERISTICS OF SOLID WASTES FROM MINING

2.4.1.1 Overburden

This is usually a fairly innocuous material and has the potential for rebuilding a reasonable soil, provided that toxic residual metals are not present. Texture and structure may be poor but can be improved by ripping and addition of organic matter. The removal of overburden during mining operations tends to contaminate water bodies and streams during the rainy season. It also causes dust blow and contaminate the air in the atmosphere during harmatan season.

2.4.1.2 Waste rock

This is predominantly composed of boulders and cobbles and has little material of sand, silt and clay dimensions. The rapid loss of any rainwater due to percolation through this open material causes considerable problem in vegetation establishment.

2.4.1.3 Mine Tailings

These generally have small and relatively uniform size of particles, which generally range from fine sand down to clay. Physical factors can vary considerably within any impoundment. Texture gradients can occur both vertically and horizontally, the heterogeneity being affected by the milling and disposal methods. Tailing materials are generally structureless, unstable and liable to erosion. Higher bulk density, compacted surface crusts, low permeability are further physical problems that may arise with tailings.

2.4.1.4 Slags, Spoils, and Slurrys

During the smelting process of an ore to extract gold, metal sulphide and arsenides produced from individual layers can be separated due to differences in their specific gravity. Such layers are

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called **slags.** They are also waste materials produced after mixing chemicals with gold that has been heated (liquefied) to remove unwanted substances from it.

Spoils are a mixture of earth and stones that are dug out during the mining process.

Slurrys are also a mixture of water and small pieces of solids that are usually produced after the refining process. These mine wastes can cause dust blow, contamination of runoff water and sterilization of land. Spoil can also present visual intrusion problems and hence require careful siting and landscaping.

The chemical composition of these wastes is so toxic that much attention needs to be given to their management. This category of mine wastes is the major cause of river/water pollution, destruction of ecosystem and biodiversity because they are highly toxic that their impact on the environment may last for years.

2.4.2 Chemical Composition of mine wastes

The most dangerous aspect of the waste stream described above contains highly toxic and hazardous materials that are injurious to both human health and environmental quality. The chemical composition of waste is highly variable and depends on the nature of the original ore, the minerals extracted, the method of treatment and disposal, climatic conditions and weathering and reactions that follow disposal.

The organic reagents such a flutation reagents, mercury, filtration aids, flocculants and coagulant, grinding aids and smelting and refining reagents commonly used to process minerals and which occur in mine effluents are not hazardous mainly because of the concentration levels which occur in the effluents but also because the chemicals are generally biodegradable. However, it must be emphasized that at higher concentration levels most of these chemicals are very toxic. In addition, residual process agents and chemical complexes formed during processing are a further source of toxic compounds in mine tailings. The main chemical effects, apart from heavy metal pollutants, in mining that can adversely affect the environment include salinity and acidity (alkalinity).

2.4.2.1 Salinity

This is due to the presence of calcium, sodium, and magnesium, mostly as sulphate and chloride, which can accumulate in wastes to concentrations that are toxic to plants. High salinity results from (a) the concentration of naturally occurring salts by recycling of water in tailings dam, and (b) indigenous salts in the original ore which accumulate in the surface of wastes in arid regions. An excess of soluble salts influences the water relationships between plants and their growth medium by increasing the osmotic pressure of the soil solution resulting in reduced availability of water for root absorption.

2.4.2.2 Acidity

Acidity, on the other hand, can arise from (a) weathering of especially iron sulphide minerals in the waste materials (b) acid leaching of ores (c) use of acids or acid salts in other mill processes and (d) mine drainage water. Also alkalinity can arise from

i. Lime used in milling processes and in waste treatment
ii. Ammonia and some ammonium compounds used in leaching
iii. processes,
iv. Sodium cyanide used in gold ore treatment, and
v. Other alkaline salts used in milling processes.

The most toxic chemical used in the treatment of auriferous ore by the company is cyanide. Alkaline cyanide solution is used to dissolve gold from the ore. The dissolved gold is precipitated from the cyanide solution by using powdered zinc. The cyanide solution is then either recycled or discarded. If the spent cyanide solution is not neutralized, it can cause extreme damage to aquatic life, especially. Both man and animals can be seriously, and indeed fatally, affected by pollution, particularly by heavy metal contamination of drinking water. Heavy metals gradually build up in soils, particularly in the surface organic material. Extensive pollution by heavy metals can also affect man by contamination of drinking water or by metals passed through the food chain to crops, vegetables or animals used for human consumption.

Some of the effects on animals and man due to injection of abnormal quantities of various metals commonly associated with industrial practices and also their (metals) effects on plants are summarized in **Appendix E, page 101.**

It can be seen from the above that most mineral wastes are highly toxic, unsafe, hazardous and they also contain immense volume of toxic material. They represent a substantial, if relatively dilute, potential source of pollution if they are carelessly handled.

2.5 SUMMARY OF WASTE MANAGEMENT IN SOME SELECTED COUNTRIES

For the purpose of comparison in this analysis, the UN conventions and the way the wastes are supposed to be managed are labeled in capital letters and summarized in Table 2.3.

TABLE 2.3 SUMMARY OF HOW WASTES ARE TO BE MANAGED (BY UN STANDARDS)

Waste rocks (boulders), mineralized and non-mineralized rocks	A*
Tailings, spoils, slags, and slurrys	B*
Soil overburden, and topsoil	C*
Containers (oil, grease, cyanide, etc)	D*

SOURCE: Extracted and summarized from Quarrie,(1993), Gilpin, (1995).

Table 2.3 summarizes, according to world standards, how mine wastes should be managed. The letters with stars (*) indicate the various acceptable methods of managing mine wastes. For instance, letter **A*** stands for the management of waste rocks to be used as backfilling existing excavations; **B*** for storing tailings, spoils, slags, spoils, etc in impoundments; soil overburden and topsoil in dumps and for reclamation; and so on.

The waste management methods adopted by the selected countries such as South Africa, Great Britain, Denmark, India, and krygystan are summarized and compared with international conventions in Table 2.4.

Table 2.4 shows the various acceptable methods of mine waste management and what other countries are doing in terms of the management of their mine wastes. The ways by which various

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forms of wastes are to be managed by world standards are labeled in capital letters and these were summarized and shown in Table 2.3. It can be deduced from the table that most of these selected countries manage their wastes in accordance with world standards.

TABLE 2.4 : Summary of Waste Management Systems of Some Selected Countries

WASTE	Acceptable Method of Management	USA	BRITAIN	DENMARK	KRYGYSTAN	SOUTH AFRICA
Waste rocks (boulders)	A*	N.A	A*	N.A	A*	A*
Waste Rocks	A*	A*	A*	A*	A*	A*
Tailings	B*	B*	B*	B*	B*	B*
Soil overburden	C*	C*	C*	C*	C*	C*
Topsoil	C*	C*	C*	C*	C*	C*
Spoils	B*	B*	B*	B*	N.A	N.A
Containers	D*	D*	D*	D*	D*	D*
OTHERS[a]	B*	B*	B*	B*	N.A	B*

[a]OTHERS—includes Slags and Slurry
* Indicates the Acceptable Method of Waste Management (by UN standards) as inTable 2.3.
N.A = Information Not Available
Source: Adapted from Quarrie, Joyce (1994) Earth Summit (1992) " *The UN Conference on Environment and Development*" Held in Rio de Janeiro, Brazil. London: Regency Press.

In addition, the information on Table 2.4 could be summarized and grouped under the three levels of solid waste management identified in the conceptual framework, i.e. the source level management, pollution level management, damage level management. Table 2.5 details out the results.

Table 2.5 shows the various levels at which wastes are managed by these selected countries as discussed under Section 2.2 of this study. It is clear from Table 2.5 that countries like Great Britain, the USA, and Denmark adopt the source level management of waste. At the extractive level where the wastes are generated, efficient and effective management methods are employed either to treat the wastes or minimize their negative impact on the environment. In the case of

India, Krygystan and South Africa, although some methods are used to treat wastes at the source level, vigorous mechanisms are put in place to manage the wastes at the pollution and damage levels than at the source level.

Table 2.5 Levels of Waste Management in Selected countries

COUNTRY	SOURCE LEVEL MANAGEMENT	POLLUTION LEVEL MANAGEMENT	DAMAGE LEVEL MANAGEMENT
GREAT BRITAIN		N.A	N.A
USA		N.A	N.A
DENMARK		N.A	N.A
INDIA			
KRYGYSTAN	N.A		
SOUTH AFRICA			

= Level of Waste Management Adopted by that country

N.A = Not Available

Source: Adapted from Quarrie, Joyce (1994) Earth Summit (1992) " *The UN Conference on Environment and Development*" Held in Rio de Janeiro, Brazil. London: Regency Press.

2.6 CONCLUSION

Although there is a wide variation of mine solid waste characteristics and their management between these countries, it is important to note that management systems such as impoundments, tailings pond, and reclamation methods are employed extensively in these countries, and the variation in the refuse densities affects the design of equipment for managing the wastes in each of these countries. The technologies applied in each country must thus, be appropriate to the waste and the socio-economic characteristics prevailing in that country.

CHAPTER THREE

METHOD OF THE STUDY

3,1 GENERAL OVERVIEW

This part of the study is devoted to a brief method of the study. The method of the study includes data collection, population and sample, research questions to be answered and data analysis.

3.2 DATA COLLECTION

There are very few publications on waste management in general, and that of mining waste in particular, especially that which is related to the management of mining waste in Ghana. Hence, this study is worth investigating. The main methods of data collection adopted in this dissertation come from primary and secondary sources.

3.2.1 The Primary Data

From the primary source, a questionnaire directed at the staff and workers of some of the departments of the Ashanti Goldfields Company Limited (AGC), Obuasi, will be administered **(see Appendix C, page 92)**. Also, structured interview schedules are constructed and used to obtain information from them. The following members of the company are selected for the study:

1. The production Managers
2. Head and workers of waste management section
3. Environmental Protection Agency (EPA), Obuasi.
4. Some individuals in the community.

These respondents are selected because preliminary studies and discussions showed that they are in tune and directly or indirectly involved with the issue under investigation. The interview questions are administered to respondents on face – to – face basis. In all the interviews, the questions are read from the interview guide and responses are recorded.

3.2.2 The Secondary Data

The next source of information comes from secondary source. This involves the review of existing literature on the topic from libraries and data from departments and organizations. Data on world conventions and Ghana's mining regulations and guidelines for managing mining waste will be gathered. Information is also obtained from textbooks, magazines (journals), pamphlets and publications like the news media and the Internet.

In addition to these two sources of data, the study also involves extensive observation at the study area, to acquire a first hand information on the solid waste management systems of the company. This is then used as a basis of comparison to world standards to determine compliance or otherwise of the AGC's solid waste management systems to world standards.

3.2.3 The Population and Sample

For the purpose of this study, the study area, consisting of many different production departments, has been divided into three zones: A, B, and C. The total number of workers in these zones is estimated to be 75 and ten employees from each zone are selected by using a stratified random sampling and interviewed.

The reason behind the use of stratified random sampling is due to the fact that it improves representativeness of the sample in addition to allowing for the selection of a manageable sample size. Again the study involves descriptive, qualitative as well as quantitative analyses and, therefore, considering the nature of the study area the stratified random sampling techniques are employed to avoid bias of the findings of the study.

3.3. RESEARCH QUESTIONS TO BE ANSWERED

The study aims at answering the following questions:

- Do mining companies in Ghana, specifically the AGC follow the international acceptable conventions of managing mine solid waste?
- If no why; and if yes, how?

- If yes, does the A.G.C adhere to these regulations?
- Does the Government of Ghana enforce the company's waste disposal and management practices in terms of her mining laws and regulations, if such laws and regulations exist?
- If no why; and if yes, how effective is it?
- If such laws exist in Ghana, do they conform to those of world standards?
- If no, why; and what must be done to ensure full compliance?
- What are the International Conventions and standards for managing mining wastes?
- Does the AGC, Obuasi conform to Ghana's mining laws or those of the world standards?
- If yes, how effective is it?
- If no why not? And what should be done to ensure compliance?

Even though no hypothesis is tested, attempt is made in this study either to refute or confirm these assertions by:

- first, outlining international conventions governing mine waste management as benchmarks
- secondly, the AGC's waste management practices will be provided; and
- a checklist of Ghana's Mining Laws on managing mining wastes will also be provided

This means that a checklist of Ghana's Mining Laws and those of International Conventions and Standards for managing mining wastes will be provided, and the AGC's practices will also be compared with these lists.

The reasons for comparing the AGC's waste management methods to those of world standards is first, to determine whether the AGC adopts the world's standards or those of Ghana's Mining Laws of managing mining waste in the country. The second reason is to know whether Ghana's mining Laws also conform to those of world standards. On the basis of this, conclusions can be drawn as to whether the AGC is doing the right thing by adopting the world standards or not. This will the help to determine what is actually happening in the mining industry in Ghana and what ought to have happened in terms of proper and effective waste disposal and management.

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3.4. DATA ANALYSIS

The study involves qualitative, quantitative and descriptive statistical analyses. Percentages corresponding to the absolute figures are used in the presentation of the findings. In this sense the field data collected for the study is analyzed and evaluated to determine the significant difference between variables such as forms of wastes, their management methods and other health and environmental problems that may be associated with them.

3.5. A BRIEF PROFILE OF THE AREA OF STUDY

3.5.1 PHYSICAL CHARACTERISTICS

3.5.1.1 Location and Size

The Adansi West District is one of the 18 (eighteen) Districts in Ashanti Region of Ghana. It has Obuasi as its capital which is located 64 (sixty-four) kilometres away from Kumasi. The District is located in the southern part of Ashanti Region of Ghana. The District is bounded on the west and north by Amansie East District and in the east by Adansi East District (**See Appendix D2, page100).** Its southern boundary coincides with the regional boundary of Ashanti with River Offin separating it from Central Region. With an area of about 950.00 square kilometres, the district constitutes about 0.39% of the total land area of Ghana.

3.5.1.2 Relief and Drainage

Generally, the district has an undulating terrain with more than half the total area rising up to hills of 500 metres above see level. The highest point is located on the Pompo range at 634 metres near Obuasi. Highland ranges include Dampaia (the most extensive) in the east, Kusa in the northeast, Pompo and Sanso near Obuasi. No area falls below 100 metres above sea level. A number of streams traverse the district (See **Appendix D2, page 100)**. Notable among them is Gyimi with its tributaries flowing from the northeast across the district and emptying into the Offin River in the southwest. Other perennial streams and rivers are Pompo, Subin, Menso, Kwabrafo, Hweasamo, Kyeabo, Ankafo and Nyam, all of which depict dendritic pattern of flow.

3.5.1.3 Climate

The District experiences semi-equatorial climatic conditions with a double maximum rainfall regime. Mean annual rainfall range is between 125 cm and 175 cm (50" 70") with major rains occurring between April and July whilst minor rains occur between September and October. A short dry spell in mid August between the rainy season proceeds a long dry season between November and March.

3.5.1.4 Vegetation

The vegetation is predominantly semi-deciduous forest. The forest consists of large species of hardwood, which are harvested as timber for logging and lumber. There are four (4) major forest reserves in the district, namely Dampaia (34.06km²), Pompo (12.07km²), Kusa scarp (8.02km²) and Supuma shelter belt (24.42km²).

The Ashanti Goldfields Company (AGC) has maintained large tracts of teak plantations known as green belts covering 12.10km² within its concession areas. There is a small reserved area of 0.44km² in Obuasi known as Obuasi catchment, which is almost deforested as a result of surface mining. Large tracts of oil palm and citrus plantations can be found in several parts of the district whilst the frontiers of the reserves are grown with cocoa plantations.

3.5.1.5 Soils and Agriculture Land Use

Soils in the district are predominantly forest ochrosols developed under forest vegetation with rainfall between 90cm and 165cm. They are rich in humus and suitable for agricultural production. The soils in the district support the cultivation of cocoa and a kola nut in the southern parts of the district specifically Yaadome and Gromesa areas. Cashew also thrives in the Sikaman area, ginger in the areas around Ayease, coffee in Bena and Akrofuom. Food crops like cassava, maize, plantain and cocoyam are supported by soils in the forest areas in the south and the north. Vegetables such as pepper and tomatoes are cultivated on large scale in sandy soils around Akrokerri and Dadwen. Oil palm and citrus also thrive well in the soils around Akrokerri, Dompoase and Nkoransa.

3.5.1.6 Geology and Minerals

Rocks in the District are mostly of Tarkwaian (Pre-Cambrian) and Upper Birimian formations in a northeast (NE) – South West (SW) trending belt. They are noted for their rich mineral bearing potentials. Areas around the contacts of the Birimian and Tarkwaian zones known as reefs are noted for gold deposits. The Obuasi mine (Ashanti Goldfields Company) which works on steeply dipping quartz veins over a strike length of 8km, has since 1898 produced almost 600 tons (18 million ounces) of gold from ore averaging about 0.65 ounces per ton.

The Birimian formations are also highly diamondiferous in the south-western part of the district with great potentials for alluvial diamond mining. Isolated incidence of basic intrusive formations can be found in the south-central of the district whilst extensive outcrops of granitic boulder formations are located near Akrokerri and Dompoase in the north-east of the District. These are being exploited for constructional works, i.e. in the building and road industries.

A sand belt stretching from Fomena – Dompoase in the north east run through Old Edubiase to Abadwam and Kwapia in the west and is being exploited for building and constructional works in the district.

3.6. LAND MANAGEMENT

Land management has been mainstreamed in the development planning process. Sound and efficient management of land has tremendous impact on the district's development. This is discernible from the fact that most development efforts of the district manifest spatially.

The single most extensive landowner in the formal sector is the Ashanti Goldfields Company Limited (AGC). The Company's concession in the district totals approximately 36.23 square kilometres. The district capital, Obuasi is totally within the concession of the AGC Ltd, a situation which has very serious consequences for land use development planning and control of settlements and the built environment in the district.

The above scenario brings to the fore, difficulty in obtaining land for spatial planning especially in Obuasi. This situation has resulted in distortion of planning schemes through the activities of landowners culminating in unplanned settlements in the district. Owing to the rather high cost of

land, owners are unable to undertake cadastral survey. Effective development control impacts positively on land use development and the conditions of the built environment. Several factors pose challenges and constraints to effective development control, especially in the urban settlements and its environs. Notable among them is the enforcement of rules and regulations with respect to development control as the Building Inspectorate of the Assembly has only one (1) officer at post.

3.6.1. Efforts Made Towards Land Programmes

The potential of land as the main productive asset in rural development cannot be over-emphasised. The efficient and sound management of land and its usage will therefore have tremendous impact on the district development. This is particularly discernible from the fact that development activities exist in space.

The district land area of about 950 square kilometres is largely held by the Traditional Authorities in trust for their subjects. The single most extensive landowner in the formal sector is the AGC Limited. The company concession in the district totals approximately 36.23 square kilometres. The district capital, Obuasi is totally within the concession of the AGC Limited, a situation that has very serious implications for land use development planning and control of settlements in the district.

There are problems encountered in acquiring land for investment. This is a result of the cumbersome administrative procedures, which frustrate prospective developers to resort to building of houses in unplanned areas. The difficulty of obtaining land for spatial planning purposes, especially in Obuasi hampers settlement planning. Land in the district that are not within AGC concessions, are vested in chiefdom who have unsufructuary rights to land.

In the urban areas of the district, notably Obuasi, land ownership as relates to farming and development bring in its wake boundary disputes. Reluctance of AGC to release land within their concession to developers places extreme pressure on land in Obuasi.

Under the circumstance, unauthorised developments occur. Development control in some selected towns in the district is extremely difficult as a result of lack of support from Traditional Authorities, building inspectors and Environmental health unit of the Assembly. Unauthorised

developments especially, in the urban towns like Obuasi and its environs affects demarcations of roads and public sites. Encroachment on public assess of space in the district is rampant. On the basis of the foregoing, the District Assembly, AGC and Traditional Authorities need to create a land bank, which would be accessible to prospective developers.

3.7. THE AGC AND LAND OWNERSHIP

Land ownership, as it relates to farming and development in the urban areas in the district, poses serious threat to sustainable growth and development. In as much as large tract of land in Obuasi is owned by Ashanti Goldfields Company (AGC), difficulty in obtaining land for long term development projects retards development.

Reluctance of AGC Limited to release land within their concession calls for deeper collaboration between the District Assembly and all stakeholders in land management and development. Under the circumstance, spatial planning processes are affected as well as formal acquisition of sites for public use. Compliance and enforcement of environmental laws is recognised as a prerequisite for sound environmental management but this can only be achieved when effective environmental education and monitoring mechanisms are put in place and sanctions instituted against violators. Environmental problems originate at community levels. Their prevention can best be handled at the Community levels with levels active involvement of Assembly members, unit committees, chiefs and all stakeholders.

3.8. SANITATION PROBLEMS

The Environmental Health and Sanitation Unit of the Assembly is charged with environmental and waste management in the District. The process of exploiting resources in the district to meet basic socio-economic needs has brought in its wake environmental problems like land degradation, air and water pollution.

The district has been zoned into seven (7) Environmental Health areas, namely Obuasi Central, Obuasi West, Obuasi East, Akrofuom, Akrokerri, Fomena and Ampunyase. The Environmental Health Unit is headed by Assistant Chief Environmental Health Officer and supported by staff strength of 92 (ninety-two).

The Environmental Health and Sanitation Unit lack means of transport to undertake effective monitoring of sanitary sites. The supply of motorcycles to each zone to enhance operational work of the Environmental Health workers deserves attention. The total labour force of the Environmental Health unit is woefully inadequate. The resultant effect is that, the few officers are unable to cope effectively with the volume of solid and liquid waste generated by the ever-increasing population.

Sanitary tools and equipment are also inadequate to enhance efficiency of sanitary personnel. At present, tools like shovels, rakes, loading forks, Wellington boots pick axes and wheel barrows are inadequate, bearing in mind the increase in population of the district. There are thirteen (13) designated solid waste collection points in Obuasi and seventeen (17) skips (refuse buckets), which need to be emptied daily but practically the Environmental Health Unit could handle the situation in every three days. This has led to the accumulation of refuse at designated refuse dumping sites.

Consequently, the sites have become breeding spots for flies, pests, mosquitoes, rodents, and reptiles. This can result in the outbreak of epidemic in the district. The Assembly lacks reliable solid waste disposal equipment like skip loaders to enhance daily emptying of refuse buckets. Indiscriminate dumping of solid waste in the district pollutes water sources as refuse is washed into drains which choke them and leads to flooding in communities like Bogobiri, Tutuka, Mensakrom and Gausu.

The Assembly has privatised solid waste management in 16 (sixteen) communities to a waste management firm by name Messrs Arhus Company on a pilot basis. Currently, there are 1,648 (one thousand six hundred forty-eight) waste pans in circulation. Residents pay a monthly service charge of ¢7,500.00 (seven thousand five hundred cedis). The involvement of the private sector in solid waste management will complement the effort of the Assembly. Concerning liquid waste disposal, majority of the people (about 60%) depend on public toilet facility while the remaining (40%) have access to private places of convenience. Inadequate public toilets especially in the rural areas compel some of the people to dispose of human excreta in the bush.

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Lack of maintenance on existing public toilets creates unpleasant environment. Indiscriminate defecation into drains results in offensive odour. The unwillingness of the people to pay public toilet fees calls for public education to sensitise community members. This would forestall the outbreak of epidemic like cholera. Public Private Partnership (PPP) is being encouraged to bring into focus reliable liquid waste disposal equipment like Cesspit Emptiers. A good number of people use septic tank, while others use pit latrine. Urban communities in the district especially Obuasi are being encouraged by the Assembly to build domestic toilets. Existing public toilets in Obuasi and its environs are being rehabilitated and privatised with two (2) from their waste Management Department. Owing to poor management of the existing public toilets there is the need to encourage private participation in the liquid waste management on Build Operate and Transfer (BOT) service agreement.

3.9. ENVIRONMENTAL SITUATION

3.9.1 Conditions of the Natural Environment

Natural resources that can be identified in the district include rivers, rocks, forests, sand, clay and gold. Human activities have had some impact on the natural environment in the district. These can be identified in the areas of agriculture, logging, mining and sand winning. The vegetation cover of many hill tops in Obuasi have been destroyed by toxic arsenic trioxide in emissions from the ore treatment plant of Ashanti Goldfields Company, whilst the surface of many others have been laid bare through surface mining. In addition, extensive slime dams have been built from sludge from the ore treatment plants at various sites on the land surface in the immediate environs of Obuasi Township. These are limited to areas closest to and in Obuasi.

There are environmental inadequacies in all environmental categories such as water supply, sanitation facilities, sullage disposal, storm water drainage, solid waste disposal, house-tenure and crowding, and indoor air pollution from inefficient fuel and the mining operations. In addition, there are other environmental problems associated with mining such as ambient air pollution arising from the high level of particulate matter including silica, noise pollution because of blasts and vibrating leading to cracks on buildings in and around the company.

Consequently, the disease profile of the district shows a high preponderance of environment-related diseases such as malaria, diarrhoea diseases, upper respiratory tract infection and intestinal

worms among others. Peculiar miners' diseases include silicosis and pulmonary tuberculosis. This occurs because health safety standards for miners have been low in the past and this has also resulted in fatal accidents.

These environmental problems and the related health outcomes threaten the sustainable urban management of the company to support economic growth. Since mining requires land as a basic input of production, the direct impact of mining operations in the district is very significant. These relate to environmental degradation, socio-economic disruption, and the impact of urban consumption of biofuel and land use conflicts.

Apart from air pollution and the effects of blasts, surface and ground water sources are either chemically polluted or are silted. There are a number of sources of surface and groundwater pollution that result from the operations of the AGC and other gold mining companies in the district. These include

i. Chemical pollution
ii. Increased sediment load resulting in siltation;
iii. Changes in hydrological characteristics of streams

These problems are more acute with strip mining activities of the most of the small-scale mining firms in the district. The main source of pollution for the company is largely with chemical pollution of groundwater. With regards to chemical pollution, the main concern is usually with potential cyanide contamination of surface and groundwater resources by the gold mining companies and the pollution arising from the use of mercury by the small scale (both legal and 'galamsey') gold mining operations. The use of explosives by these companies and also by the AGC, especially when it occurs close to water bodies could be another source of chemical contamination.

The concession areas of the company within the district have been largely downgraded and impoverished with regard to plant and animal life because of the mining activities. One can imagine that this current phase of gold extraction will only lead to a virtual extinction of some endangered species because of widespread production of loud noise during the mining operations.

Land degradation, vegetation degradation and loss of wildlife appears to be on the increase in the district because most the company and other small mining firms engage in surface/strip mining rather than underground mining.

3.10. ASHANTI GOLDFIELDS COMPANY LIMITED

3.10.1 A CORPORATE PROFILE

The Ashanti Goldfields Company Limited (AGC) is an African –based international gold mining and exploration group with six producing mines in four African countries: Ghana, Guinea, Tanzania and Zimbabwe. The mines in which the Group has interests have over 27 million ounces of proved and probable gold reserves and Ashanti has exploration projects in eight (8) African countries. The company is listed on four international stock exchanges.

3.10.1.1 Ashanti's Mission and Vision

To be a premier precious metal mining company in Africa.

3.10.1.2 Objectives

- Consolidate its position as a premier African gold producer.
- Diversify into other precious metals.
- Maintain or improve operational and financial track record.
- Maintain the best mining practices and the highest safety standards
- Enhance shareholder value for the long term
- Be a good corporate citizen

3.10.1.3 Strategy

The company's strategy seeks to

- Increase ore reserves
- Maintain cash generation through strong operational performance
- Maintain appropriate levels of protection and commitment levels in its hedge book
- Secure operational and financial gains by continually improving systems and resources.
- Achieve a complete and an integrated four or five star rating across the Group

3.10.2 ASHANTI EXPLORATION IN AFRICA

The Company's exploration strategy to date has been to focus on gold projects only in Africa. The Company has projects in the major gold belts of West, Southern and East Africa.

When deciding whether to pursue an exploration project, the Company assesses its geological potential, political stability of the country in which a potential project is located, its regulatory and fiscal regime, security of title to property and economic conditions, as well as the project area's access to infrastructure such as roads and power.

The management of the company believes that the African continent offers a wide range of exploration and development opportunities, and that the Company is particularly well positioned to take advantage of such opportunities because of its operational base in the region and its position as an African gold mining company.

3.10.3 ASHANTI IN THE NINETIES

The 1985 programme of expansion and modernization was to continue into the nineties. In the 1990, new mining equipment was purchased for mining surface oxides at Sansu and a new heap leap plant was commissioned. During March 1991 a new oxide treatment plant came online. With the help of International Finance Corporation loans, production soared to record levels in 1992, but it had already become clear that if increased levels were to be sustained still further investment would be needed. For this reason, the Ashanti Mines Expansion Programme (AMEP) was initiated, again financed by the International Finance Corporation (IFC), with an annual target of 1.0 moz. (One million ounces) by 1995. The main thrust of the programme was to enable Ashanti to exploit the large, lower grade underground resources, which has been identified as the ones most likely to be profitable in the long term.

3.10.4 AN INTERNATIONAL COMPANY

In 1994, the Ghana government, the majority shareholder, announced plans to sell 20-25 percent of its interest in AGC in share floatation, and the company was listed on the London and Ghana stock exchanges. It was the largest floatation ever organized by any gold mining company – the coordinating and advisory team alone numbered over 200 people. Each of the company's 10,000 employees received five free shares.

In 1996 AGC was listed on the New York stock exchange to raise new capital, it was the first African company to appear on Wall Street.

3.10.5 A GOLDEN FUTURE

The mine at Obuasi has been in continual production for over 100 years, and the ore body continues to be highly prospective, with proven and probable reserves estimated to be at more than 20 million ounces. The AGC's plans and investments have the aim of maintaining group production at around one million ounces per year, and Mr. Sam Jonah, the company's new Managing Director, the first Ghanaian Chief Executive appointed in 1986, is confident that he will meet this target.

Ashanti operates one of the largest and richest gold mines in the world. At its present production rate it will remain one of the top ten gold producers for a long time to come.
But the AGC now has new horizons: no longer a gold producer with a single mine in Ghana, it has operating, exploration and development projects on many of the most promising gold mineralisation belts of sub- Saharan Africa. The future certainly looks golden.

3.10.6 IMPLICATIONS FROM THE CORPORATE PROFILE

It can be inferred from the above corporate profile that although the AGC Limited in Ghana has a lot of visions strategies and objectives, much attention is given to maintaining the best mining practices and safety standards for their workers. The company, as can be seen from its objectives, has much interest in consolidating its position as a premier African gold producer with little regards to residents in its mine areas and environmental safety.

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF DATA

4.1. GENERAL OVERVIEW

In this chapter, data collected from the production and waste management heads, workers of the waste management department and Environmental Protection and Safety departments of the Ashanti Goldfields Company (AGC), Obuasi in Ghana; and data from other environmental agencies are analyzed and evaluated.

To assess the solid waste management possibilities of the company, the following activities are considered:

- Solid waste generation
- Waste management practices of the company in terms of Pollution Prevention and Pollution Damage Prevention exercises.

4.1.1 SOLID WASTE GENERATION AT THE AGC. COMPANY LTD.

Mining wastes include all solids or semi-solid materials that are no longer considered of sufficient value to retain in a given setting, although some of the mine wastes that are generated may be of significant value in another setting.

4.1.1.1 Estimation of solid-waste quantities

The quantity and general composition of the waste material that is generated by the company is of critical importance in the design and operation of solid waste management system of the company. Unfortunately, reliable quantity and composition data were difficult to obtain because most measurements are of the quantities collected or disposed of at treatment and disposal sites.

An indication of how and where wastes are generated in the company is shown in the simplified materials-flow diagram presented in Table 4.1 The study revealed that wastes are generated at the start of the process, beginning with the mining of gold from the ore and rocks. Wastes are generated at every step in the process as gold and other raw materials are converted to other forms for consumption.

The study reveals that about 39 per cent of the mine wastes that are generated are made up of soil overburden, with waste rocks, tailings and topsoil constituting 25%, 17.9% and 7.1% respectively. Table 4.1 shows the nature of solid wastes from mining by the AGC.

Table 4.1. Nature of Mine Solid wastes at the A.G.C.

Type		Percentage of total wastes
Soil overburden		39.3
Waste rocks		25
Tailings		17.9
Top soil		7.1
Spoils		7.1
Others[1]		3.6
Total		100

[1] Others include slags, slurrys, glass, oil and grease containers, etc.
Source: Author's field work (August, 2001).

It is evident from Table 4.1. that the company generates varied forms of waste that need to be managed well. Soil overburden and waste rocks as well as tailings constitute significant components of mine wastes whereas the top soils, spoils, slags, slurry, glass and other containers used in mining also account for about 17.8 percent of the total waste generated.

The study shows that hazardous substances such as cyanide are usually used and applied to treat tailings in greater amounts. However, no information was available on the quantities of cyanide that is used by the company in its waste treatment systems.

As can be seen from Table 4.1, the solid waste from mining and processing activities in the study area include soil overburden, waste rocks (boulders), spoils, mill-tailings and mined out land. Others include the topsoil, subsoil, and containers, which are usually extracted and kept separately for eventual use. In addition, both extracted and non-mineralized rocks with a grade below tailings are also other forms of solid waste from mining operations at the A.G.C Limited, Obuasi. (For details of nature of wastes, see section 2.4).

Basically, gold is the main mineral product that is mined by the company at Obuasi and almost all the forms of waste mentioned above are produced in larger quantities from the mining operations. Apart from the big rocks (boulders) that are usually blasted and brought to the surface, there are other forms of ore, that is, gold bearing that are usually blasted and milled to extract the gold.

The study also show that in each ton of ore only about 7 grams of gold can be extracted and this means that large amounts of tons of ore would have to be produced daily before enough quantities of gold is also extracted. After the gold is extracted, the remaining ore and the ones that do not bear any gold also add up to increase the volume of wastes produced.

In order to assess the relation between the rate, at which wastes are generated and collected, item six of the questionnaire was used to elicit data on waste generation rate by the company. The data on weekly estimates of generation rates of the company are presented in Table 4.2.

Table 4.2. Solid waste Generation Rates of the AGC

Type	Unit of Load per week	Range*	Class mark
Soil overburden[1]	Tons per vehicle load	15.6 – 17.50	16.6[4]
Waste rocks[2]	Tons per vehicle load	14.3 – 16.6	15.4
Tailings	Tons per vehicle load	12.5 – 13.1	12.8
Others[3]	Tons per vehicle load	12.6 – 14.8	13.7

*In 1000 tons

1. **Soil overburden includes topsoil and subsoil**
2. **Waste rocks include boulders, mineralized and non-mineralized rocks**
3. **Others include spoils, slags, containers, etc**
4. **Class mark; eg. 16.6 is a class mark for the range15.6 – 17.50**

Source: Author's fieldwork, (August 2001).

Table 4.2 presents weekly solid waste generation rate of the AGC Limited. It also shows the types of these wastes that are generated and the tons per vehicle loads that were used to estimate the waste quantities. Range on Table 4.2 refers to the difference between the highest and the lowest tons per vehicle load of waste that are generated by the company in a week. Each type of waste has its class interval and the class mark for each class interval is the mid- value of the class. For instance, the class mark for the class interval 15.6 – 17.50 is 16.6, that is, (15.6 +17.50) / 2

According to the Production Manager of the company, waste quantities are estimated based on their volume and multiplied by a swell factor (which is obtained through surveying the waste quantities). The waste load per vehicle is, therefore, a simplified way of estimating the waste quantity that is usually generated.

4.2 MANAGEMENT SYSTEMS

4.2.1 DAY – TO – DAY SOLID WASTES MANAGEMENT

The study reveals that direct activities that are considered and co-ordinated on daily basis include waste generation rates, on-site storage, collection, transfer and transport, processing, and disposal. These activities are associated directly with the management of solid wastes in the company. Indirect activities that are also important part of waste management programme include financing, operations, equipment, personnel, costs and budgeting, contract administration, ordinances and guidelines, etc.

4.2.2 WASTE MANAGEMENT METHODS OF THE COMPANY

This part of the study reveals how the various types solid wastes of the AGC Limited are managed. These management methods are then compared with the world conventions of mine waste management in the checklist provided on Table 2.2 of this study.

4.2.2.1 Mine Tailings

The study reveals that wastes like tailings are disposed in impoundments, which are also close to the mine. The tailings pond is built with mined rocks, tailings formed by excavations in earth and concrete. It is a pond made to contain tailings formed by excavation in the earth, by concrete dams or from the tailings itself, or a suitable material. This is the most common system used for managing tailings and it is on record that tailing impoundments have many advantages, and in recent years, safety factors, environmental problems and aesthetic values have dictated the size, location and design of impoundments. The management of the tailings in the impoundments involves the application of cyanide and other chemicals. The most toxic chemical used in the treatment of auriferous ore **(see Appendix F, page 104)** and tailing management by the Company is cyanide.

When the ore and mine tailings are treated with cyanide, civil and chemical engineers, who are also employees of the AGC, usually build the pond. Because of their special skills in the construction and management of ponds these engineers are normally employed by the company to construct the ponds and the impoundments. The sides of the ponds are built in the form of steps so that the pond could stand a test of time and also to make it effective enough to contain the tailings. This method also reduces the possibility of the cyanide overflowing the pond, thereby, causing pollution. With the application of cyanide, the used water settles and drains above the tailings; it is then collected, treated and reused. If the spent cyanide solution is not neutralized it can cause extensive damage to many living organisms.

Mineral wastes, such as tailings, spoils, glass and soils are generally handled on-site, as for example, when surface mines are reclaimed. The A.G.C has presently completed its surface mining and is now concentrating on underground mining and the recovery of gold from previous and old tailing dumps.

As compared with the checklist in Table 2.2, it can be seen that as far as the management of tailings in impoundments is concerned, to a greater extent, the AGC's management of the mine tailings conforms to the world standards. The problem with the tailing management by the company is that since it usually takes much time for the Company to construct the impoundments, after the wastes are produced, they most of the time spend a lot of time on the ground before they are collected for disposal. According to the world standards, instead of the mining firms storing the wastes in impoundments two weeks after production, they usually spend more than seven weeks on the ground before they are collected, hence this increases the possibility of the waste polluting rivers, streams, groundwater and the environment.

According to the Assistant Plant General Manager of the Pomporra Treatment Plant (PTP), a waste management plant of the AGC, Obuasi, there is a new technology called Carbon-In -Leach (CIL) which is now employed to reclaim and extract gold from the old heaps. This method is considered very economical as compared to the underground and surface mining since only water and air are basically needed to wash the old tailing dump to extract the gold. With the new

technology, about 2.5 grams can be extracted from a ton of tailing waste and the new method permits about 5000 tons of old tailing heaps to be treated daily. Water is basically re-used, directed and collected in a collection system.

It was revealed that the solid wastes involved in the mining operations at the A.G.C Obuasi are so voluminous that they make long distance transportation or sophisticated treatment of the waste uneconomical. The CIL technology, on the other hand, is very economical and it is also an incentive for the company to reclaim old heaps.

The mine tailings are usually used by the company as an underground fill, for road and building construction and in the manufacture of bricks by dreg pressing and in the manufacture of foam building blocks and products. The company mostly uses the tailings together with the rocks and overburden to construct embankments and ponds.

Apart from the company itself, other subsidiary firms such as road and building contractors, as well as individuals and households purchase most of the rocks and tailings for various purposes. Some of such firms that made use of the wastes are Mining and Building Construction (MBC) and Mining and Civil Construction (MCC), which are also separate construction firms at Obuasi. As part of the terms of payment, the company may sometimes convey the waste in it trucks to the firm or individual for additional charges that range between ¢65,000.00 and ¢100,000.00 per load depending on the type of truck.

Owing to the many uses to which most mine wastes are put by the company, the volume of waste that is buried usually reduces by about 1/4 of the total volume, and the rest kept or stored in heaps and dumps and in ponds for longer periods.

The results from the study show that there was no indication that the company had plans to reduce its waste production as the demand and price for gold keep increasing, thus permitting more exploration and mining of gold and hence greater waste generation. In each ton of ore only about 7 grams of gold can be extracted and this means that large amounts of tons of ore would have to be produced daily before enough quantities of gold is also extracted. After the gold is extracted,

the remaining ore and the ones that do not bear any gold also add up to increase the volume of wastes produced.

4.2.2.2 Waste Rocks

The management of waste rocks (boulders and mineralized rocks is a vital part of mine waste management by the Company. The waste rocks are usually treated and kept in heaps for about four or five months before they are collected for disposal.

It came to light that about 90% of the mine rocks are used by the company and other firms for refilling some mine areas, potholes in the streets in Obuasi and other nearby towns also to check erosion. The rocks are also grinded into smaller particles to be used as chippings and terrazzo. In view of this, most mine rocks are usually gathered in heaps for some periods and used when needed. Most of the waste rocks are also used to construct ponds, embankment and dams to contain mill tailings.

As compared with the checklist on Table 2.2, since waste rocks are usually treated and kept in heaps for about five months before disposal the company's management of waste rocks conforms to the world standards.

4.2.2.3 Slags, Spoils, and Slurrys

During the smelting process of an ore to extract gold, metal sulphide and arsenides produced from individual layers can be separated due to differences in their specific gravity. Such layers are called slags. They are also waste materials produced after mixing chemicals with gold that has been heated (liquefied) to remove unwanted substances from it. Spoils are a mixture of earth and stones that are dug out during the mining process.

Slurrys are also a mixture of water and small pieces of solids that are usually produced after the refining process. The chemical composition of these wastes is so toxic that much attention needs to be given to their management. Like the mine tailings, the company disposes the slags, spoils and slurrys in impoundments and therefore, has similar characteristics and effects as far as environmental pollution is concerned.

4.2.2.4. Soil Overburden

Wastes such as spoils and overburden are usually considered as valuable resources, which may be used to build a landscape. The overburden is also normally kept in heaps for some periods. They are usually used by the company to improve access and slopes in pit areas, and used to backfill around steep pit and quarry faces. In addition, they are also used by the company to maintain adequate surface drainage, as a cover material for landfill with refuse, and constructing screening bunds and natural landforms around the surface mine landscapes.

Stabilization at the A.G.C Obuasi invariably begins at the design stage of waste heaps and tailings ponds by reducing the length and angle of slopes and by terracing or staircase grading of inclines to reduce liability to erosion. Physical stabilization method involves covering the surface of waste with materials that prevent or retard erosion by air or water. The company also uses chemical stabilization that involves reacting a substance with mineral wastes or applying a surface layer to form air and water resistant crust which will effectively stop dusts from blowing and inhibit erosion by water.

In addition, most of the particles of the metals and others from smoke, dusts, oil, spray, sulphur salts and fluoride from the mining operations constitute the greater health hazard, even though they account for only 3 percent of all particulate air pollution. Most of the dusts from gold, smock, and dusts from the mining operation, which can be inhaled deeply into the lungs, are of increasing concern.

As compared with the checklist in Table 2.2 it can be seen that part of the overburden, for example topsoil, are usually separated and used for reclamation. Because most of the topsoil and the subsoil are usually kept in heaps for about **five months** instead of **two weeks**, particulate and water pollution from dusts usually occurs, especially during harmatan season.

4.2.2.5 Reclamation

The company's reclamation and revegetation programme has expanded rapidly. Ten different areas of the mine are now being rehabilitated. Twenty five million (25,000,000) seeds have been broadcast and almost two hundred thousand (200,000) grass slips planted. Air emission levels for the year were better than the World Bank's standard. A sewage treatment plant was also

constructed to treat waste and septic effluent from the Obuasi mine and township. At Obuasi, the first phase of sulphide treatment plant neutralization project was successfully completed.
The study also indicates that the company has installed a cyanide neutralization project, and in view of this, cyanide in Obuasi's watercourses is now reduced and in some cases it is non-detectable.

4.2.2.6 Sulphuric And Oxide Plant of the AGC Ltd.

The company has another plant at Sansu, also in the Ashanti Region, which is also very active currently than most of the plants at Obuasi. It is a sulphuric and oxide plant and at this plant site too, almost all the solid wastes are managed and buried at areas close to the mine site. The disposal method is also the same as those in Obuasi, but at Sansu, the heap rocks, and most of the solid wastes are kept at places which are quite close to a stream called Suhyen that serves the Sansu and Suhyenso communities.

4.3 WASTE COLLECTION SYSTEMS IN THE COMPANY

Information on collection of wastes of the company, one of the most costly functional elements is presented in two parts, dealing with

- the types of collection systems; and
- the efficiency of the collection system.

4.3.1 Types of Collection Systems.

The collection system provided by the company to collect wastes from sites is centered on the use of large movable container trucks and stationary compactors. Compactors are of the type that can be used to compress waste materials (for instance, soil and tailings) directly into large containers. Based on their mode of operation, the collection system of the company is classified into two categories: hauled-containers systems and stationary container system.

4.3.1.1 Haul Container System

In this system, the containers used for storage of wastes are hauled to the processing, or disposal site; emptied and returned to either their original location or some other location. There are two types: Tilt frame containers and large truck-tractor containers. The collectors, usually two to a

truck, are responsible for driving the vehicle, loading full containers and unloading empty containers, and emptying the content of the container at the disposal site.

The tilt-frame container trucks are ideally suitable for the collection of all types wastes from locations where the generation rate warrants the use of larger containers. These are more often used than the truck-tractor containers. The applications of truck-tractor containers is similar to that of tilt-frame container system but the truck-tractors are better for the collection of demolition (example, large waste rocks) at construction sites.

4.3.1.2 The Stationary-Container Systems

These are the collection systems in the company in which the containers used for the storage of wastes, (for example, mine tailings) remain at the point of waste generation, except when moved for collection. Labour requirements for essentially loaded stationary container systems are essentially the same as for hauled stationary container system.

4.3.2 Efficiency of Waste Collection System.

It was revealed from the study that containers size and utilization are not as critical in stationary system using self-loading collection vehicles equipped with a compaction mechanism as they are in hauled – container system. Trips to the disposal sites, or processing stations are made after contents of a number of containers have been collected and compacted and the collection vehicle is full. Because a variety of container sizes and types are available in the company, the stationary containers are usually used by the company for the collection of all types of wastes.

Information from the manager of the waste management department shows that because of increasing costs, including the cost of labour, workers' compensation, and fuel and equipment costs, there is a remarkable movement in the waste collection system toward the use of large truck containers that can be emptied mechanically using a vehicle equipped with an articulated pick-up mechanism. Because mechanical collection systems are adopted by the company, the individual containers on the trucks are mostly standardized to be compatible with the wastes generated.

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Item 29 of the questionnaire was used to obtain information about the time that wastes generated spend on the ground on site before they are collected and the rate of collection. Table 4.4 details out the results.

Table 4.3. Waste collection periods and amounts collected in a month.

Waste type	Time of collection After generation	Monthly range of collection by all vehicles (1000 tons per vehicle load)	Typical Class Midpoint
Soil overburden	Between 3 – 6 months	4.500 – 5.6	5.05
Waste rocks	Between 3 – 6 months	3.6 – 4.1	3.85
Mine Tailings	Between 3 – 7weeks	5.7 – 8.8	7.25
Others	Between 1 – 3 weeks	2.8 – 4.8	3.8

Source: Author's field work, (August 2001).

Table 4.4 shows that almost all the forms of wastes generated by the company spend much time before they are collected. As compared to the world standards in terms of the times the wastes need to be collected and managed. For instance, by world standards, tailings, soil overburden and others (which includes spoils, slags and slurrys) are supposed to be collected and managed within **two weeks**, and waste rocks **four weeks** after production, and not the six months, or the six weeks that we have on the table. It could therefore, be seen that the company's waste management system does not conform to world standards as these periods differ considerably considering the data on Table 4.4.

In addition, since the topsoil and sub-soil are usually used for reclamation and other projects, and once the mining activities are continuous and on going the soils are usually allowed to stand a test of time before they are collected for various purposes.

Furthermore, it was revealed that the vehicles that are used by the company for collection are also used to transport the wastes to treatment and disposal sites. Even though, most of the wastes are disposed at places closed to their production sites, others like tailings are usually transported over long distances to impoundment sites where the wastes are treated and stored in impoundments.

Although, data about the number of times and cost of collection and disposal were not available at the time of the study, observations at the study area showed that the rate of collection was very slow as compared to the rate of waste generation. Problems such as costs, number of container trucks, and large waste volume act as constraints as far as the frequency of waste collection, crew size and distance to disposal sites are concerned.

4.4. DISPOSAL

On the issue of disposal, most of the solid wastes from the AGC, Obuasi are usually dumped close to the mine and wastes like overburden and waste rock can occupy vast areas, often of equal size to tailings impoundments. The wastes are usually dumped on the land and the heaps can reach a height of about 36 feet. Moreover, most of the mine solid wastes still end up being disposed of on or in the earth. Table 4.5. shows the proportion of wastes that end on land at the A.G.C. Obuasi, Ghana.

Table 4.4. Proportion of Wastes that end up at Various Units

Waste	Share of total waste disposed (per cent)
Land disposal[1]	77
Recovery of metals through reclamation	11
Dispatch to other units[2]	8
Distillation for recovery of metals	2
Discharge to Sewers, rivers, streams, etc.	2

[1]Includes surface impoundments, waste dumps, underground fills, mine rock and tailings usage for various purposes.
[2]Includes wastes sent out in trucks to households and other firms for use in various purposes.
Source: Author's Field Work (August, 2001)

It is evident from Table 4.5. that a greater proportion of the solid wastes from the mining activities by the company of about 79 percent end up in the land.
In addition, Table 4.5 also suggests that only about 21 percent of the total waste produced are used for various purposes, such as for use by households as landfills to check erosion, rewashed

to recover metals by the company, or purchased by other firms to be used as raw materials in the production of blocks, quarry stones, road construction, and so on.

It should also be noted that these methods of managing wastes by the A.G.C have not changed over the past few years, and this also suggests that much of the mine wastes are disposed in the land for many years. According to the Assistant Plant General Manager of the Pomporra Treatment Plant, a waste management plant of the AGC, several technologies, however, are under consideration as alternatives to land disposal. One way of categorizing these technologies is whether they destroy, immobilize, or separate the wastes.

The disposal of mine wastes by the company is seen as important in impoundments, land filling and backfilling excavations and reclamation. This suggests that most of the residues from mine wastes end up in the land, as Table 4.5 suggests. These wastes are disposed at great cost to society and the environment. This is due to the fact that, with the 77 per cent of wastes buried in land and 2 per cent in rivers and streams, heap leakage and acid and alkaline contamination which are very probable also increase the rate of pollution of rivers, streams, land, the air, and groundwater bodies.

4.4.1 Waste treatment

On waste treatment, out of the various forms of wastes generated by the company, only waste rocks and tailings are usually treated to extract gold that has been stacked in some of the wastes. Because most rocks and tailings are usually used for the construction of tailings dam and embankments, they usually spend considerable period of time on the ground before they are collected **(see Table 4.4, page 57).** The tailings are treated and stored in impoundments while the rocks and other forms of soil are kept in dumps for about 3 to 5 months before they are collected. Sulphric cyanide is usually sprayed on such wastes in the heaps as way of treating the wastes.

4.4.2 Recycling and Reuse

The recycling of oil, grease and other chemicals containers used during mining have a major impact on the quantity of wastes that must be disposed of. From the various wastes generated by

the AGC, there are a number of uses to which many of them are put. Table 4.6 shows the quantities of solid wastes produced and the amounts that are put to various uses.

Table 4.5. Reuse of mine wastes at the AGC, Obuasi.

Waste category (1)	Gross discards* (in 100,000) (2)	Wastes put to various uses Quantity * (3)	Per cent (4) = (2) x 100 / (3)
Waste rock (boulders)	44.1	6.8	15.4
Waste rocks	13.7	0.4	2.9
Tailings	12.7	0.6	4.7
Soil overburden	85.4	8.0	9.3
Top soil	11.3	0.5	4.4
Spoils	22.8	0.0	0.0
Others	2.8	0.1	3.6
Total	192.8	16.4	40.3

*** Hundred thousand tons per year (estimated)**

Source: Author's, fieldwork. (August 2001).

Table 4.6 shows that only 1,640,000 tons of solid waste from mining representing 40.3 per cent, out of the total gross discard waste of about 19,280,000 tons are put to various uses by the company, households and other firms such as in the manufacture of bricks, embankments, ponds, and for use in the construction of buildings and roads (see Section 4.3). The remaining waste goes into the environment. With the exception of spoils, slags, glasses and containers, it is clear from the Table 4.6 that many of the wastes from mining have some important uses as discussed already, although these use are not frequently made.

4.4.3 Implications of the case study.

It can be inferred from the above case study that the AGC Limited produces mine solid wastes that are similar to other gold mining countries in the world. In terms of their management, however, there are varied characteristics. Returning to Table 2.4 in chapter two and, this time

adding the waste management procedures of the AGC Limited, we can derive Table 4.6 as shown below.

It can be seen from Table 4.6 that of the eight acceptable methods of waste management systems practised by other countries, the AGC practices only three of them. The remaining five were not handled on the basis of world standards.

Therefore, Table 4.6 reveals that even though some of the AGC's solid waste management methods conform to world's standards, there is more room for improvement. Whereas in other gold mining countries the state, local authorities and the mining companies themselves are actively involved in the management of wastes from their mining operations, in Ghana (or at the AGC), the solid waste management is done by the mining company itself. In addition, whereas in other countries mining firms contract other waste management companies to manage their wastes, in Ghana the mining company does this by itself.

TABLE 4.6 WASTE MANAGEMENT SYSTEM OF AGC AND SOME SELECTED COUNTRIES

WASTE	Acceptable Method of Management	USA	BRITAIN	DENMARK	KRYGYSTAN	SOUTH AFRICA	GHANA (AGC)
1. Waste rocks (boulders)	A*	N.A	A*	N.A	A*	A*	A*
2. Waste Rocks	A*	A*	A*	A*	A*	A*	A*
3. Tailings	B*	B*	B*	B*	B*	B*	B
4. Soil overburden	C*	C*	C*	C*	C*	C*	C
5. Topsoil	C*	C*	C*	C*	C*	C*	C
6. Spoils	B*	B*	B*	B*	N.A	N.A	B
7. Containers	D*	D*	D*	D*	D*	D*	D*
8. OTHERS[a]	B*	B*	B*	B*	N.A	B*	B

[a]OTHERS—includes Slags and Slurry

*Indicates an acceptable method of waste management (by world standards).
Indicates Unacceptable method of waste management.

N.A = Not Available

Source: Adapted from Quarrie, Joyce (1994) Earth Summit (1992) " *The UN Conference on Environment and Development*" Held in Rio de Janeiro, Brazil. London: Regency Press.

Among other reasons, most of the wastes spend much time on the ground before they are collected and disposed. Hence, there are usually delays as far as waste management is concerned and these delays permit some of the wastes to flow and contaminate rivers, soils, streams, and groundwater. This may have a profound impact on the communities living on and around the concession areas.

Taking into consideration the aforementioned waste management practices of the AGC limited which was obtained through extensive observation and interviews of some of the workers of the company, a summary of the company's waste management practices are compared to the checklist of the world conventions summarized on Table 2.2 in chapter two of this study. Table 4.7 details these relationships.

TABLE 4.7 A CHECKLIST FOR AGC MANAGEMET OF MINE WASTE (BASED ON WORLD CONVENTIONS)

ACTIVITY	CONVENIONS REQUIREMENT	AGC MANAGEMENT PRACTICES CHECKED		
		Complete Adherence	Partial Adherence	No Adherence
EXCAVATION	1. Using appropriate equipment to minimize size of excavations.	----	✓	----
	2. Construct drill pads	----	✓	----
	3. Well positioning of drill holes and excavations to avoid environmental disaster	----	----	✓
	4. Recycling of drilling fluids	✓	-----	----
	5. Allow uncontaminated water to settle before discharge to natural drainage	----	✓	-----
	6. Store oil based fluids in steel or appropriate plastic tanks	✓	-----	-----

CONSTRUCTION & DEWATERING	7. Bury materials in chemically unreactive rocks to prevent surface and groundwater contamination	-----	----	✓
ABANDONMENT	8. Inspect all excavations during operations and backfill or seal them	-----	✓	----
	9. Rehabilitate the site to a condition consistent with pre–existing character of the area	----	✓	----
	10. Bury/remove all refuse from exploration sites	----	-----	✓
	11. Exploration sites rehabilitation be completed within three months of abandonment	----	✓	----
TAILINGS DISPOSAL	12. Tailings be stored in impoundments two weeks after production	✓	----	----
	13. Capacity of impoundment should be sufficient to contain tailings volume	✓	----	----
	14. Be deposited by sub aerial deposition to maximize consolidation and decay of degradable contaminants	----	----	✓
	15. Impoundment be located down stream to the processing plant so that run-off and spillage will report to the impoundment	-----	✓	----
	16. No discharges to natural drainage other than emergency passageway	----	----	✓
	17. Routinely monitor phreatic water levels as specified in the EIA or EAP	----	✓	----
WASTE ROCKS	18. Should be disposed four weeks after operation	-----	✓	-----
	19. Manage any chemically reactive	-----	----	✓

	waste rocks to minimize leaching and acid generation			
WASTE DUMPS AND OVERBURDEN	20. Be progressively reclaimed two weeks after production	----	✓	----
	21. Topsoil and subsoil be separated and kept in an environmentally friendly manner	✓	----	----
	22. May be used for eventual restoration/reclamation	✓	----	----
CONTAINER DISPOSAL	23. Be stored and maintain precautions to minimize risk of spillage and groundwater quality	----	✓	----
	24. Only reuse containers when no environmental hazard would occur	✓	----	----
DISCHARGES TO WATER	25. Undertake regular in-stream monitoring to ensure water quality	✓	----	----
	26. Report the quality and quantity of any unavoidable discharge to natural drainage in the EIA or EAP	----	✓	----
	27. Treat contaminated water to a standard to be agreed between the EPC and the company	✓	----	----
RACLAMATION	28. Reclaim scarred land within three to four weeks after production	----	✓	----
TOTAL		**9**	**13**	**6**
		28	**28**	**28**

Source: Author's field work (August, 2001)

Table 4.7 shows the waste management practices of AGC Limited summarized under the headings: Complete Adherence, Partial Adherence, and No Adherence. The waste management requirements by World Standards under each activity is listed and checked with that of the AGC to determine whether there is compliance or not. **Complete adherence** refers to where the company's waste management practices conform to world standards. For instance, with the recycling of drilling fluids the study showed that the company recycles all of its drilling fluids immediately they are produced, hence this is a situation of complete adherence.

On the other hand **partial adherence** refers to compliance but unsatisfactory management practice. For example, in the case of using appropriate equipment to minimize the size of excavations, it came to light that although the company uses the appropriate equipment, they are below standards and few and hence are unable to meet the demands of the mining operations. This situation, therefore, denotes partial adherence. **No adherence** means there is no application of UN standards in managing wastes. This is seen in the case of the management of burying waste materials, minimization of leaching and acid generation, and to maximize consolidation and decay of degradable contaminants, among others.

The world conventions on waste management are used as checklist against the AGC's waste management practices. It is a very large document, which cannot be produced in this research work. However, for the purpose of comparison to Ghana's mining and environmental guidelines, some parts of it that concerns the management of mine solid waste are extracted and produced in this research work. Marks are not awarded for each activity but with interviews and extensive observation at the study area, the symbol (✓) is applied to indicate whether there is compliance or not.

4.4.3.1 Excavation and tailings management

For example, Table 4.7 reveals that under excavation, out of the **six activities** to be done to ensure proper and efficient waste management practices, only **two** of the world standards are fully adhered to by the AGC, with partial and no adherence receiving **three** and **one** point respectively. This suggests that wastes such as oil fluids have the opportunity to contaminate streams, rivers and groundwater bodies.

With regards to tailings disposal, the company completely adheres to **two** of the **six** rules with partial and no adherence recording two points each. This implies that there is the possibility of spillage and discharges of water to natural drainage system. In addition, activities such as monitoring phreatic water levels in line with the EIA or EAP standards are notably minimal.

4.4.3.2 Construction, Dewatering and Abandonment.

With construction, dewatering and abandonment, the company completely adheres to only **one** method out of the five rules of acceptable management, and partial and no adherence recorded **three** methods and **two** methods respectively. This means that the AGC does not bury unreactive rocks to prevent surface and groundwater contamination. In addition, it also means that exploration sites are not rehabilitated within the three months of abandonment and also not all wastes are removed from exploration sites.

4.4.3.3 Waste rock, Waste Dump and Overburden

Out of the two management activities governing waste rocks, none is fully complied with and one each is recorded under partial and no adherence. Waste dumps and soil overburden require three management related activities and complete adherence to world standards recorded two points whilst one point is recorded under partial adherence. This implies that the company's management of waste dumps and overburden is above average.

4.4.3.4 Container Disposal

In terms of container disposal, discharges to water, and reclamation, the study reveals that the AGC fully conforms to three of the six management activities. Partial adherence also recorded three points. This also implies that the company is doing well in terms of the management of containers and monitoring of discharges of water to other streams and rivers. Reclamation of scarred land is also done but at a slower pace. Hence there is the possibility of water contamination resulting from run offs from waste dumps and overburden.

With regards to compliance to world standards or not the study further reveals that the AGC knows of the existence of the world conventions for to be the most effective and efficient means of managing mining waste. However, the company adopts Ghana's mining laws, which do not

conform to the world standards of managing mining waste. The mining laws of Ghana do not specify time frame that wastes need to be collected and disposed of. In many instances too, Ghana's mining laws fall short to those of world standards. Moreover, laxity and lack of effective enforcement usually lead to non-compliance of Ghana mining rules and regulations. Among other reasons, these are the reasons why the AGC does not adhere to the world standards for managing mining wastes.

On the issue of monitoring, information from the company shows that the company has full time environmental officers, who supervise environmental monitoring and compliance. In spite of this, however, there is more room for improvement as far as compliance to world standards is concerned.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1. GENERAL OVERVIEW

This chapter summarizes the findings of the study and attempts to suggest steps to be taken to solve the problems identified. As could be detected soon, some of the steps recommended to tackle a specific problem might contribute in no small way to the solution of other problems. The steps, therefore, overlap. In trying to solve the problems too, alternative strategies could be adopted either in isolation or in combination.

5.2. SUMMARY OF FINDINGS

Attempts were made in chapter two to review some of the policies of international as well as Ghana's environmental policies and guidelines as regards to the disposal of solid mining wastes. Chapter four also highlighted the solid waste disposal and management methods of the A.G.C Limited, Obuasi, Ghana The A.G.C. Limited at Obuasi has three main solid waste disposal and management departments, two in Obuasi and one at Sansu, about three kilometers from Obuasi.

It came to light from the study that the main problems associated with mining operations include land devastation, soil and land degradation, and water and air quality changes. The use of cyanide as the main chemical for processing eventually leads to the pollution of rivers and water bodies. Underground mining has, on its part, given rise to problems with water quality change and potential for subsidence, especially if underground mine water is pumped to the surface.

Effort is made in the study to obtain international waste management standard as benchmark against which AGC's management techniques are assessed. Ghana's guidelines are also compared with the international standard guidelines on waste management. The idea behind is that if Ghana falls short of international guidelines, then one cannot blame AGC for failing to meet international standards.

It was realized from the study that the AGC adopts and uses Ghana's mining regulations and guidelines, which do not conform to the world standards of managing mining waste. The mining laws of Ghana do not specify time frame that wastes need to be collected and disposed of. In many instances too, Ghana's mining laws fall short to those of world standards. Moreover, laxity and lack of effective enforcement usually lead to non-compliance of Ghana mining rules and regulations. Among other reasons, these are the reasons why the AGC does not adhere to the world standards for managing mining wastes.

From Table 4.7 in the previous chapter, it can be seen that the total points obtained from the company for complete adherence on efficient waste management by world standards is 9 points out of 28 points; with 13 and 6 for partial and no adherence respectively. Hence, with a score of 9 out of 28 it is important to note that in terms of complete compliance to UN standards on mining waste management, the AGC needs to do more to achieve the remaining 19 points. This will go a long way to safeguard the health of the mineworkers, residents in the community, and the environment in general.

Tables 4.6 and 4.7 show that considering world standards wastes such as tailings, soil overburden, topsoil, spoils, slags and slurry are not effectively managed by the AGC. Only waste rocks and containers are properly managed by the company. Wastes such as soil overburden and topsoil are not considered as toxic or hazardous by the company but the problem with their management is that their continuous stay on the ground for long periods usually dirties and contaminates rivers and streams. In addition to this, they cause a lot of air pollution during dry season. Others like tailings, spoils, slurrys and slags are so toxic and hazardous that their improper management can have an adverse impact on the environment and human health.

Over the years, governments' policy on mining in Ghana has been characterized by a lack of effective link between the mining sector and other sectors. Hence, it has become increasingly clear that many mining firms in Ghana produce unknown quantities of wastes and mishandle these wastes.

Even though pragmatic measures are taken by the company to ensure environmental safety, there is the need for additional efforts to ensure more effective and efficient solid waste management systems. A careful study of the company's profile suggests that much priority was not given to waste management (**compare to section 3.10**). As was noted in chapter four, there is a minimum level of application and compliance to world conventions regarding to proper and efficient management of mine wastes. It was also indicated in chapter four that the chemical composition of solid mine wastes is so toxic that, even before they are buried, the environment and surface water bodies are already polluted, and hence much attention and resources must be devoted to their proper management.

Most of the mine wastes are not often disposed soon after they are mined, as the UN conventions require. This is true of soil overburden, spoils, topsoil, tailings, slags and slurrys. They are usually kept in heaps and dumps for quite long periods before they are collected for disposal or reclamation. Therefore, world conventions in terms of the periods for which wastes need to be collected and managed are not complied with. Hence any activity of wind, air or rain facilitates pollution of the atmosphere and water bodies.

Impoundments are constructed near the mine sites, the tailings and mine rocks that are usually used in the pond construction add to pollution since the construction, which is usually done by the company itself, usually takes long periods to complete. Hence the delay in disposing the wastes. Reclamation of waste dumps is usually done at a slower rate and therefore, topsoil and subsoil, rocks, muddy water and other forms of wastes spend much time before they are disposed of.
It was also noted from the study that most of the solid wastes from mining activities, as indicated already, contain chemicals like cyanide, zinc, lead, ore and other forms of oil. Zinc, for instance, is usually associated with lead in mine wastes and is a common cause of phytotoxicity and mortality in plants by its interference with iron metabolism (**compare to Appendix E, page 101**).

It is pertinent to note that the health and safety standard to which factory and mine workers in Ghana are exposed are many and therefore, require urgent attention. For example, the Mines Department has indicated numerous health hazards facing miners and the people living around the

mine areas to include nystagmus, ankylostomiasis (miners anaemia) and silicosis (**see Appendix F, page 104**) to mention but a few. These pose considerable hazards to human health. The problem is even more serious because the quantities and types of chemicals that are released into the atmosphere and water bodies by the company are fully not known.

Although a number of laws, rules and regulations regarding mining activities have been enacted, which include the PNDCL 153 of 1986, Minerals Ordinance 1936 and the Minerals Act 1962, the Mines Regulation Act 1976, among others, little is done in terms of the enforcement of such rules and regulations concerning the management of mine wastes and its resultant contamination of rivers, streams, lakes the environment and human health.

The waste disposal and management site of the company's sulphuric and oxide plant at Sansu, have been sited in areas that are close to rivers and streams without regard for the environmental effects of such industries on the residents in the area. Many effluents, oils, acids, cyanide and arsenic are emitted untreated into waters, soil and the atmosphere. Little is being done to check and treat the waste at the source level of waste generation. As compared to the AGC's plant at Obuasi, it can be seen that pollution level and damage level management of wastes are promoted by the company instead of effectively managing the waste at the source level.

In general, there appears to be an appreciable concern for pollution in rivers and water bodies arising from mining activities in the Obuasi and its environs, but it appears that there is no serious concern for air and land pollution in the mines and it is important that provision be made also to prevent atmospheric pollution.

5.3. RECOMMENDATIONS

This part of the chapter is designed to put forward certain proposals or recommendations which will help to streamline an effective management of solid wastes from mining activities in Ghana by examining the relevant problems and flaws outlined above.

At the moment there is no clear policy or legislation on the siting of mining industries in Ghana. Although the EPA and Department of Town and Country Planning, at least in the urban areas,

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have plans and regulations for land use, there is no effective co-ordination between these agencies and the other relevant departments, which approve the establishment of mining industries in the country.

The mining firms are most of the time, sited at places where the minerals are known to exist, regardless of other environmental implications. A case in point is the siting of AGC's production plant at Sansu, which is sited at a place near a river and other sources of streams.

It is, therefore, my recommendation that there is the need for effective co-ordination and involvement between the Government, EPC, Ministry of Science and Technology, Ghana Investment Promotion Center, Ghana Chamber of Mines and all relevant departments and organizations in order to create industrial sites conducive enough to minimize, if not alleviate environmental problems.

Furthermore, it was realized from the study that most of the solid wastes from the mining operations of the company are stored and managed in impoundments, heaps, tailings dam waste dumps and mine pits. It appears that the AGC's management methods are in line with international standards as most of these waste management systems are widely accepted as means of storing mine solid wastes. It was, however, realized from the study that a greater percentage of the UN conventions on mine waste management (about one- third of it) is not being complied or adhered to by the AGC Limited. It is therefore, my recommendation that the Government, the EPA, and all agencies concerned with environmental safety sit up, enforce, and ensure that the company complies with the world conventions as it is required of it to do.

In addition, since Ghana's Mining regulations do not specify time frame at which wastes are supposed to be collected and disposed, it is hereby suggested that Ghana's Environmental and Mining Regulations need to be reviewed to include time dimensions.

Again, it was also realized from the study that dust control measures at most of the mine sites are ineffective, especially during harmatan season. There exist water pollution problems at all the three disposal sites of the company, and therefore, the workers and other residents in and around the mining areas lack sufficient quality water, especially during dry season.

The general recommendations arising from these observations are that the AGC and for that matter all mining companies should strive to continually improve their waste disposal and management systems in controlling the wastes. A careful siting and design of overburden, tailings and waste rocks dump are essential to minimize the possibility of water pollution; and very toxic materials can be buried under less harmful wastes and construction of gently sloping dump and dam walls assists with later revegetation.

Due to poor planning, sometimes the company misplaces the topsoil during the mining operation and had to borrow topsoil from somewhere to be used as refilling, thereby, making it difficult to reuse the land. In view of this, it is suggested that provision should be made for separate storage of topsoil, subsoil and "non-mineralized" overburden in an uncontaminated area of the site.

In addition to this, mechanism must be put in place to dispose and safely store the wastes immediately they are produced (in compliance to world standards) so that they do not have enough time to contaminate the environment. Again, the government and all relevant bodies must ensure that the mining companies in the country, and for that matter, AGC should, as a matter of extreme importance, effectively manage their wastes at the source level as it is being done in the USA, Great Britain, Denmark, South Africa, and other major mining countries in the world. This will not only minimize and prevent wastes from entering the environment before they are controlled, but also ensure that the AGC and other waste production firms in the country bear greater part of the waste disposal costs in the form of prevention costs and avoidance costs.

In addition, it is my considered view that separate waste management companies should be given the responsibility of constructing the ponds and the tailings dams. They should also be motivated and encouraged in order not to delay the construction to ensure that there is a smooth storing of the wastes soon after they are produced. Management and all others concerned need to ensure that all contractors are made fully aware of their environmental responsibilities towards waste management.

The various components of the mine that are usually monitored include the mine pits, waste dumps, tailing dam, layout of tailings pipeline, stockpiles, processing plants and its environs, ore

spent heaps, solution ponds, sedimentation ponds, site storage and security of chemical, for example, cyanide, fuel and storage and dispensing facilities, maintenance workshops and rehabilitation of disturbed areas. Information available from the company clearly indicated that the company is taking a lot of measures to improve its environmental performance taking into consideration the above observations, but much is required of it in terms of air and water contamination.

In addition to the above, since a greater percentage of the solid waste, especially mined rocks and tailings is usually used up by households, firms, the company itself and the community for various purposes, it is my recommendation that those mined rocks that are known to be toxic be excluded and stored in environmentally friendly manner.

It is also being recommended that the Government, EPC, District Assemblies and other environmental organizations in the country should, as a matter of extreme importance work on mechanism to ensure speedy implementation of policies that should enforce effective monitoring to ensure the mining companies in Ghana comply to international standards. Appropriate incentives such as taxes, charges, subsidies, and marketable rights or permits must be put in place to motivate the mining firms to comply with the world standards. For instance, items like pollution charges, taxes and subsidies should be instituted to motivate and ensure that mining firms reduce their pollution levels and to comply with world standards for managing wastes.

5.3.1 Reclamation Plan

The reclamation of the land surface disturbed by the mining operations is an essential element of mining. It is therefore recommended that detailed reclamation planning of a mining operation should start before the mining begins so that plans for final topography and intended final land use can be followed and methods of removal, and stockpiling of topsoil and overburden, can be carried out more efficiently.

Reclamation of disturbed lands should begin as soon as possible so that pollution is minimized in the initial years of the operation. Although the company is doing well as far as reclamation and

revegetation is concerned, activities like landscaping screen planting, and planting of tailings pond walls should often take place progressively and should be completed before the pond is full. It is also suggested that details of the provision made by the mining company and the prospective ones for the rehabilitation of the disturbed surface areas during operation and after closure as well as the financial provision for reclamation be required as a necessary part of the procedure for licensing mining ventures.

5.3.2 Posting of Reclamation Bonds by Mining Industries

In June 1999, the EPA enacted Environmental Assessment Regulations (LI 1652), which required all mining companies to post reclamation bonds. The object of the bond was to provide financial security which ensures that irrespective of what happens to a mining company in the course of its operations, the reclamation or rehabilitation of its disturbed mine sites would be carried out. Since the enactment of the regulation, the Agency has conducted fieldwork, consultations with stakeholder and desktop research on reclamation plans and bonds.

In November 1999, and in accordance with the Environmental Assessment Regulations 1999 (LI 1652), the Agency requested all mining companies to submit Reclamation plans upon which calculations of the quality of the individual bonds would be based. Subsequently, the Agency commenced protracted negotiations with the individual mining companies in June 2000. As at now, the Abosso Goldfields, is the first and the only mining company in Ghana to successfully post a reclamation bond (Environet, 2001). The posting of a bond as a security for performance of reclamation is increasingly gaining acceptance in many leading mining centres, including South Africa. It is therefore, my recommendation that, as a matter of policy, the practice be introduced in Ghana after carefully working out the details.

It is also suggested that the EPC, the EPA, and other agencies responsible for environmental safety should be given powers to enforce standards and regulations that it sets. Government should, as a matter of extreme importance work on mechanisms to ensure speedy procedures and set up Tribunals to deal with mining companies that offend environmental rules.

It was also observed from the study that there was a low level of implementation of Environmental Action Plans at most of the disposal sites. It is also my recommendation that, in

addition to ensure compliance with environmental laws, the Government, District Assemblies, the company and all other agencies responsible for the environment should be actively involved to see to it that the mining companies in the country improve their environmental performance at the mine sites taking into consideration the above observations.

Another suggestion is the creation of National Environmental Police Unit to handle environmental criminal cases. It is again, my recommendation that the Ghana Police Service, in consultation with the Attorney General Department would see to the immediate establishment of a National Environmental Police Unit in the country to enforce existing laws and regulations pertaining to environmental quality in the country.

In addition to the above recommendations the following provisions are also proposed.

5.3.3 Comprehensive Mining Plan for Ghana

Currently, Ghana does not have a comprehensive mining plan that sets out general details and procedures such as standards, enforcement and monitoring of mining operations in the country. The author views the lack of this plan as a serious gap which the mines commission, supported by Geological Survey, should do well to address. It is therefore recommended that the Mines Commission and Ghana Chamber of Mines increase action on the preparation of a comprehensive mining plan.

5.3.4 The Mines Department

The mines department is the front-line organization to ensure proper control of mining activities in the country. Unfortunately, the increase in the capacity of the department has been outpaced by the growth of the mining sector. The situation makes it difficult for the department to cope with the demands of the industry. The situation, therefore, calls for a vigorous effort to strengthen the department both in terms of staffing and other logistics.

5.3.5 The PNDCL 153

The Minerals and Mining Law of 1986 PNDCL 153 has some general provisions to prevent the environment but they lack elaboration. Some key areas such as air and water pollution, land

reclamation are not provided for. With this law the licensee is required to know in advance the potential consequences of his mining activities. This is why the Environmental Impact Assessment (EIA) is done before commencement of mining operations. It also seems that the principal aim of PNDCL 153 was to attract investors into the mining sector. It has been noted that since its enactment there has not been any subsidiary legislation to elaborate the basic provisions of this law. It is therefore my recommendation that this law be reviewed to include subsidiary legislation to elaborate the basic provisions of this law

5.3.6 Mining Regulations of 1970

In addition to Minerals and Mining law of 1986 (PNDCL 153), Mining Regulations of 1970 have been in force for more than a quarter of a century. These regulations have very few provisions to safeguard the environment. It only seeks to protect the safety of miners but not the people living around the mine areas. Most of the concerns these regulations were intended to address have assumed wider dimensions. The mining industry in Ghana, until 1986, was dominated by underground mines, which have relatively fewer environmental impacts. It is, therefore, my recommendation that the mining regulations be reviewed to address all current concerns in the mining industry.

5.4. CONCLUSION

Section two and Appendix B of this study indicated clearly that the world has a well documented rules and regulations, in addition to Ghana's Mining Guidelines, Ghana's Environment Action Plans, the Mineral and Mining law 1970, and a host of others to guide the operations of mining companies and other industries in the country.

Most unfortunately, many of these regulations are not adhered to by the mining firms due in part, to lack of finance and logistics, lack of qualified personnel and experts, lack of information and research data on mining operations in the country, poor planning, and a weak institutional strengthening and efficient allocation of responsibilities which make environmental agencies unable to effectively enforce environmental laws and prosecute offenders, among others. These problems are severally responsible for the low level of compliance to environmental rules and the

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implementation of Environmental Action Plans, thereby, leaving surface waters, rivers, groundwater, land, soils, plants, vegetables and air qualities at the mercy of these mining companies. At the same time, since investors risk their capital in a bid to maximize profits and minimize costs, and since government also lacks the necessary machines and capital to tap the resources efficiently, the government and other environmental agencies, sometimes tend to be more flexible on these investors on their operations.

Even though the economists may be more concerned about economic growth and human welfare, the quality of life depends on human security, a sound environment to live in, safety, comfort and other factors relating to health, pleasure and happiness. Even though we are faced with the problem of trade offs, our problem should be to developing strategies to control and minimize pollution of all forms. In addition, wise use of existing technology can buy us some time to develop and institute new pollution control technology and new energy sources, to phase in an earthmanship economic and production system, and to achieve pollution stabilization in the years to come if we begin from now.

It is the writer's view that if the above suggestions are adhered to, we can expect a bright future for Ghana's development – a pristine environment and good health for the people of Ghana. The success of the mining industry in managing and controlling their wastes efficiently depends on the concerted efforts of the government, mining companies, and environmental agencies in solving the aforementioned problems.

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APPENDIX A

SOME SCENES OF WASTE GENERATION AND DISPOSAL SITES AT THE AGC, LIMITED, OBUASE

PANEL A

PANEL B

PANEL C

PANEL D

PANEL E

PANEL F

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APPENDIX B

GHANA'S MINING AND ENVIRONMENTAL POLICY GUIDELINES

The Ghana's Mining and Environmental Guidelines was prepared over a three-year period in 1985, during which broad consultations were made between government agencies, mining companies, non-governmental organizations, universities, research institutions an indeed the general public. These guidelines cover exploration, exploitation, commissioning, environmental impact assessments and environmental action plan . These guidelines resulted from a collaborative effort between the mineral commission, the Environmental Protection Council (EPC), and lately the erstwhile Ministry of Environment. The guidelines were to pre-empt permanent environmental damage by mining companies and promote sound environmental stewardship.

Under the Minerals and Mining Law, 1986, the Secretary for Lands and Natural Resources was empowered to make by-legislative instrument-regulations to restrict prospecting near any water body, prevent pollution of water, ensure public safety and the safety and welfare of workers, prevent injury to persons or property by chemicals and set penalties for offence against the regulations. The Ghana and Environmental Guidelines form the basis for Environmental Regulations under the Minerals and Mining Law (PNDL 153), 1986, and they are being updated and made into regulations by the mining sector.

Under the guidelines, new mining companies are expected to conduct full environmental impact Assessment (EIA) where existing mining companies will prepare an Environmental Action Plan. The guidelines are based on the conviction that the most successful and cost-effective environmental controls are those which are integrated into project planning from inception.

Approach

The Guidelines are divided into three parts:

1. General guidelines for exploration, mining, minerals procession and de-commissioning
2. Detailed guidelines for the preparation of an Environmental Impact Assessment for a new mining project
3. Detailed guidelines for the preparation of an Environmental Action Plan for existing mines.

The guidelines address mineral exploration by requiring liaison, controlling access and activities and specifying abandonment procedures. Accordingly, for new mines, emphasis was given in the guideline for the preparation of Environmental Impact Assessment to ensure that modern, pre-emptive environmental controls are built into the design of new mining projects during the planning phase. Environmental Impact Assessment guidelines were intended to be given to the proponents of new mining projects. However, for the established and recently constructed mines, there was no longer an opportunity to minimize environmental impact by design and alternative strategy was proposed, based on self assessment, preparation and implementation of an Environmental Action Plan, Annual Environmental Report and feedback.

GUIDING PRINCIPLES

The guiding principles used in the preparation of these guidelines were as follows:

1. All mining causes environmental impact
2. Environmental impact can be minimized by planning, design and management
3. Balance is required between the minimization of environmental impact and the need for mining to contribute positively to Ghana economic growth and exports. The approach to minimizing environmental impact should be hierarchical, determined by technical feasibility, cost and benefit.

POLICY REQUIREMENTS

For the purpose of the research, the policy guidelines, among others, that relate to the management of wastes (especially solid wastes) would be extracted and highlighted. The following requirements were made:

A. Exploration Liaison

- Exploration will be carried out by a company with a valid prospecting license
- The Company shall obtain from the minerals commission a set of forms entitled Environmental overview, which are required to be filled in and submitted to the minerals commission prior to the commencement of field exploration
- At least seven days prior to the commencement of each phase of work, a company representative shall visit the relevant landowner or landuser representatives and describe and/or determine the expected effects on vegetation, land use, air and water quality and noise levels, the location of any scarred groves, burial grounds or other fetish lands, and the location of any area of environmental sensitivity to local people.

B. Drilling and Excavations

- The company shall position drill holes and excavations to avoid areas of local environment or cultural sensitivity.
- The company shall, minimize the size of any excavations by using appropriate equipment
- The company shall construct drill pads so that the drilling rig and storage area for fuel, hydraulic oil, drilling field etc will drain to a sump.
- The company shall recycle drilling fluid as much as possible and/or use biodegradable fluids.
- The company shall allow uncontaminated water based drilling fluid to settle before discharge to the natural drainage
- The company, shall at all times, store oil based drilling fluids in steel or appropriate plastic tanks. Disposal of oil based drilling fluids will be done only by incineration or other environmentally accepted means.

C. Shaft/Decline Construction and Dewatering

- The company shall not dewater and old shaft unless a prior (earlier) water quality analysis has shown that the shaft water is not contaminated.
- In cases where chemically reactive materials will be brought to the surface, the company shall bury these materials in chemically unreactive rocks or dispose of these materials in appropriate manner so as to prevent contamination of surface and ground waters.

D. Abandonment

- When an exploration site is abandoned, the company shall rehabilitate the site to a condition consistent with the pre-existing character and utility of the area
- The company shall inspect all excavations made during the course of the excavation and backfill and/or seal them.
- The company shall bury or remove all refuse from its exploration areas.
- The exploration site rehabilitation, as described above, should be fully completed within three months of abandonment

E. Waste Rock Disposal

- The company shall, where practicable dispose waste rock by backfilling existing excavations
- For waste rock disposal on the surface, the company shall dispose of any chemically reactive waste rock so that the potential for acid generation and contaminant leaching is minimized and the final surface is suitable for reclamation

- All waste dumps shall be progressively reclaimed where practicable
- Reclamation of spent heaps will commence within twelve months of the date when each heap was diverted to the natural drainage
- For new surface mines, the locations and site selection criteria of any waste dumps, their capacities and the quantities of reactive and unreactive waste rock types in each must be done by alternatives considered.
- When surface disposal of chemically reactive rocks is unavoidable, a conceptual dump design is required to show how the dumps will be constructed so that the potential for acid generation and contaminant leaching will be minimized and how final surface will be made suitable for reclamation.

F. Tailings Disposal

The company shall design and generate the tailings disposal system to achieve the following minimum requirements:

- Permanent storage of tailing solids in an impoundment
- Tailing impoundment structures should be constructed of chemically stable materials in accordance with sound geo-technical, structural and hydraulic engineering design and construction practices to withstand the expected seismic activity in the area.
- The capacity of the impoundment will be sufficient to contain the volume of tailing anticipated over the life of the mine or alternatively, the impoundment will be designed and operated to provide staged increases in capacity.
- Tailing may be deposited by sub aerial deposition to maximize consolidation and decay of degradable contaminants, and minimize seepage
- Where applicable, the tailing impoundment will be located down stream to the processing plant so that run off and any spillages will report to the impoundment. Other upslope drainage shall be diverted around the impoundment.
- An emergency (alternative) passageway or arrangement will be provided to pass the run off from an extreme rainfall event and prevent overtopping of the embankment. The EIA or EAP will specify the return period of the extreme rainfall event and design criteria for the emergency spilling. In staged construction, the EIA or EAP will specify the spilling configuration to the stage
- Any discharge to the natural drainage other than via the emergency passageway will not be permitted until the requirements of discharges to water are met.
- Phreatic water levels will be routinely monitored as specified in the EIA or EAP. Stabilization by revegetation of the main embankments will commence within 12 months of the completion of construction.

G. Storage Facilities and Container Disposal

- Where hazardous material such as oils, grease, solvents and other chemicals are stored, the company shall segregate potentially reactive materials and instigate and maintain precautions to minimize the risk of spillage, and ground water quality.
- A company shall only reuse containers when no environmental and/or safety hazard would occur from their reuse. All other containers shall be disposed of in a safe and environmentally sound disposal area.

H. Water Management

- The company should, as a matter of importance, identify all water sources
- The company should maximize recycling of water
- Categorize catchments according to the quality of drainage water, such as "clean", "turbid", and "contaminated"

- The company should develop a water management plan to prevent both surface and groundwater pollution, as far as possible, and as agreed between the company and the Environmental Protection Council.

Discharges to Water

- Where discharge of water to the natural drainage is unavoidable, the company shall report the quality and quantity of the discharge in the EIA or EAP.
- Uncontaminated drainage may be discharged untreated
- If the discharge is contaminated, the company shall treat the water to a standard to be agreed between EPC and the company before discharging to receiving waters
- Treatment of contaminated waters requires a designated treatment pond or vessels so that the treated water can be monitored prior to discharge to the natural drainage. The EIA and EAP will specify the treatment, monitoring and the method of the discharge.
- During the discharge, the company shall undertake regular in-stream monitoring to confirm that acceptable water quality is maintained downstream. The EIA or EAP will specify the extent and frequency of monitoring.

J. Reclamation

1. The company shall prepare an initial Reclamation plan as part of the EIA or EAP and execute the plan to achieve the following minimum standards:
2. The reclamation objective for non restorable land will be to chemically and physically stabilize the land an leave it in a safe condition and return it to same land capability as prior to mining
3. The reclamation objective for non restorable land will be to
4. chemically and physically stabilize the land and leave it in a safe
5. condition and encourage vegetation
6. The Reclamation plan shall encompass all land on the concession to be disturbed by the company and any of its tributors
7. The reclamation plan shall
    - Identify land which is restorable (such as the tops of waste dumps and land used for stockpiles) and land which is non restorable (such as deep open pits and the steep outer faces of waste dumps)
    - Identify the quantities of reclamation media to meet the required quantities
    - Identify the sources of reclamation media to meet the required quantities
    - Identify applicable reclamation techniques
    - Develop a planned approach to progressive reclamation as an integral part of the mine plan
    - Commence reclamation as soon as possible after the commencement of operations
    - Where applicable, undertake reclamation trials to refine techniques

8. A final (formalize) reclamation plan shall be developed within the first two years of operation and submitted so the EPC, Mines Department and the Minerals Commission.

In the case of a mine located in a forest/wildlife reserve a copy of the reclamation plan shall be submitted to the Forestry Commission

9. A final reclamation plan shall be developed within the last five years of mining operations planned ceasure
10. The company shall honuor all commitments made in the reclamation plan except where written permission is given by the EPC in the light of new evidence
11. Government reserves the right to request companies to post reclamation bonds.

K. Monitoring

The company shall monitor its operations to

- Confirm the validity of impact predictions (where applicable)
- Demonstrate compliance with regulations
- Identify any unforeseen effects
- Determine whether remedial action is required

REQUIREMENTS FOR ENVIRONMENTAL ACTION PLAN (EAP)

- All existing mining operations shall submit an EAP every 2 years. The plan will cover 5 years and shall comprise two year EAP and a 3-year rolling plan for the subsequent years
- A company shall honour all commitments made in the EAP except where written-permission has been given for modification by the EPC in the light of new field evidence
- New mining companies shall submit EAP as part of the EIA.
- EAPs shall be submitted to EPC for approval and copy each sent to the minerals Commission and the Mines Department

REQUIREMENTS FOR ANNUAL REPORTING

- Companies shall submit on annual environmental report at the end of each calendar year to the Environmental Protection Council, Minerals Commission and the Mines Department. The contents of each report will be agreed between these institutions and the company.
- Companies shall submit copies of environmental audit report(s) undertaken by the Minerals Commission, EPC and Mines Department. Such reports will be kept confidential and shall not be in the public domain.

GHANA ENVIRONMENTAL ACTION PLAN

In March 1988, the Government of Ghana initiated a major effort to put environmental issue on the priority agenda. The exercise culminated in the preparation of a strategy to address the key issues relating to the protection of the environment and better management of renewable resources. The objectives of what became known as the National Environmental Action Plan (NEAP) was to define a set of policy action, related investments, and institutional strengthening activities to make Ghana's development strategy more environmentally sustainable

(EPC, 1994). A National Environmental Policy was, therefore, adopted to provide the broad framework for the implementation of the Action Plan. The policy aimed at ensuring a sound management of resources and the environment, and to avoid any exploitation of these resources in a manner that might cause irreparable damage to the environment. Specifically, the policy provided for

- Maintenance of ecosystems and ecological processes essential for the functioning of the biosphere
- Sound management of natural resources and their habitats.
- Guidance for healthy environmental practices in the national development effort.
- Integration of environmental considerations in sectoral, structural and socio-economic planning at all levels.
- Common approach to regional and global environmental issues.

According to the plan, appropriate incentives and sanctions were put in place and pursued to ensure compliance with the provisions of the policy. In addition, it was envisaged that the fundamental aims of the policy will be pursued and achieved through harmonization and enforcement of relevant laws and treaties on the environment, and through the implementation of the NEAP.

A. POLICY ACTIONS

The EAP provides a coherent framework for interventions deemed necessary to safeguarding the environment.

Government undertakes the following policy actions, among others, that are deemed essential: land management, forestry and wildlife, water management, marine and coastal ecosystems, Human Settlements and pollution control. Under pollution control, the following policy actions were undertaken:

- Adopt policy framework for the extraction of water for the different uses, integrated planning for river basins, and the control of waste discharge into water bodies
- Prepare and adopt regulations for environmental control of mining operations
- Prepare and adopt regulations for environmental control of industrial operations;
- Adopt proposed legislation to control the import and use of pesticides and other hazardous chemicals
- Adopt revised factories, offices and shops Act of small scale industries
- Adopt water system for greater energy efficiency in industry.

B. POLICY INSTRUMENTS

For the successful implementation of National Environmental Policy (NEP), the following provisions were put in place to develop appropriate instruments geared towards

- Improving the scientific base of environmental policy, among other things, through appropriate research programmes.
- The assessment of the potential impact of certain public and private projects on the environmental dimension in national policies
- Establishment and implementation of appropriate standard of guidelines so as to ensure an acceptable level of public health and environmental protection to improve access to information on the environment.
- Harmonization of appropriate legal instruments,
- Improved access to information on the environment.

Legislation are also enacted to prescribe the necessary environmental quality standards and guidelines for mining and manufacturing industries. To this an EIA would be required for all new investments that would be deemed to affect the quality of the environment.

In addition, penalties and incentives will be instituted to encourage the adoption of environmentally sound production technologies to discourage pollution.

C. INSTITUTIONAL STRENGTHENING

To enhance the effectiveness of the EPC - as the custodian of the natural environment, the coordinator of all activities relating to the environment, and the lead agency for the implementation of the Action Plan- Government will review the statues of the council, including its placement within the administrative machinery of the country. The EPC will be entrusted with the responsibilities for setting environmental quality standard as well as for ensuring the enforcement of these standards.

In addition, other agencies to be involved in the implementation of the EAP will be strengthened to ensure the efficient performance of their assigned roles

As can be seen from the above, the government of Ghana has put in place a very good machinery, agencies and structures to check permanent environmental damage caused by mining companies in Ghana. It is, therefore, believed that if the above polices an environmental regulations are properly enforced, monitored and adhered to by all concerned, a sound environmental stewardship can perhaps be promoted.

APPENDIX C

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

DEPARTMENT OF ECONOMICS AND INDUSTRIAL MANAGEMENT

INTRODUCTION

The questionnaire below is to help a student from the Kwame Nkrumah University of Science and Technology, Kumasi, to elicit information on solid waste disposal and management procedures of your company. He is working on the topic "Solid Waste Disposal and Management in the Mining industry in Ghana. A Case Study of Ashanti Goldfields Company (AG.C)" Limited.

It would be very much appreciated if you could provide answers to all the questions by ticking and providing your own answers in spaces provided.

The study is purely an academic exercise and every information, including your personal views will be taken in absolute confidence. Your assistance is, therefore, needed to make the study a success.

Thank you.

QUESTIONNAIRE FOR THE PRODUCTION MANAGERS

A. Personal Data of Respondent

1. Gender: Male [ ] Female [ ]
2. Age .....
3. Marital Status: Married [ ] Single [ ]
   Widowed [ ] Separated [ ]
   Divorced [ ] Deserted [ ]

4. Level of Education: None [ ] Primary [ ]
   Secondary/ Commercial [ ]
   M.A. / MSC Ph. D [ ]
   Others (professional, Vocational, etc) [ ]
5. How long have you worked with the company? (Please specify)
   .....

B. Solid Waste Generation Questions

6. What type (s) of product (s) does your company produces? (Please Specify) .....
7. Does your company's products have any wastes after production
   Yes [ ] No [ ]
8. If yes, what type (s) of waste does your company discard? (Please Specify) .....
   .....
9. What are the raw materials used by your company?, if there is any? (Please specify) .....
   .....

10. Can the Solid Wastes from your company's main products (if any) be used for the manufacture of other products?
    Yes [ ] No[ ]
11. If yes, please explain .....
    .....
12. How does your company gets rid of the waste materials produced
    a. by conveying them with the company's waste disposal vehicles [ ]
    b. by paying other companies to evacuate them. [ ]
    c. Other means (Please specify) .....
    .....
    .....

Solid Waste Disposal

13. Does the government levy any tax on your company for the controlling or/and checking wastes: Yes [ ] No [ ]
14. If yes, what type of tax is it? (Please explain) .....
    .....
15. How much does it cost your company to clear the waste generated per month? .....
16. Does your company has problem clearing its wastes?
    Yes [ ] No[ ]
17. If yes, please state the problems clearly
    .....
    .....
    .....
    .....
18. Does your company uses part of its solid wastes?
    Yes [ ] No[ ]
19. If yes, explain some of the uses .....
    .....
20. Does your company has any plans to use more of its solid wastes in some way?
    Yes [ ] No[ ]
21. In what form shall this take? (Please explain clearly)
    .....
    .....
22. Does your company has any plan to reduce gold extraction and hence reduce waste production? Yes [ ] No[ ]
23. Please give suggestions to other mining companies and / or the government which will ensure a successful clearing of mining and other industrial solid wastes.
    .....
    .....
    .....

LIBRARY
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SCIENCE AND TECHNOLOGY
KUMASI-GHANA

QUESTIONNAIRE TO ORGANIZATION OF WASTE MANAGEMENT RESPONSIBILITIES (E.G. E.P.A. SAFETY DEPARTMENT

A. Personal Data of Respondent

1. Gender: Male [ ] Female[ ]
2. Age .....
3. Marital Status: Married [ ] Single [ ]
   Widowed [ ] Separated [ ]
   Divorced [ ] Deserted [ ]
4. Level of Education: None [ ] Primary[ ]
   Secondary/ Commercial [ ]
   M.A. / MSC [ ] Ph. D [ ]
   Others (professional, Vocational, etc
5. How long have you worked with the agency? (Please specify)
   .....
6. Which organization provides the enforcement of national environmental policy?
   .....
   .....
7. Which organization develops the national solid waste management policy? .....
   .....
8. Who is responsible to enforce national solid waste management policies and environmental impact assessments?
   .....
9. Identify and where possible, provide copies of national laws ordinances or Acts concerning the disposal of industrial solid wastes including mining activities in Ghana .....
   .....
10. Provide copies of and regulations in force concerning the implementation and enforcement of environmental laws mentioned in questions (3) and (4) .....
    .....
11. Do you have local bye-laws or equivalent concerning question number (9)?
    Yes [ ] No [ ]
12. Are there existing laws regulating the manufacture, importation, use, and distribution of hazardous waste? Yes [ ] No[ ]
13. Which organization manages the
    - transfer and haulage of mining waste? .....
    - disposal of mining refuse in your area? .....
14. Describe how policies relating to waste disposal, public health and health education are implemented. .....
    .....
    .....

15. Who has the power to impose and enforce penalties, if any exist, concerning public health and environmental degradation?
    .....
    .....
16. Can the EPA or EPC sue or prosecute the offenders relating environmental issues Yes[ ] No[ ]
17. Who monitors the air and water quality? .....
    .....
18. Has the EPA the necessary equipment and the expertise to monitor water and air quality? Yes[ ] No[ ]
19. How often does your agency carry out this exercise?
    .....
20. Who bears the cost of monitoring and enforcement of solid waste management policy ? .....
    .....
21. Do you have laws governing the siting and location of mining firms in the country? Yes[ ] No[ ]

QUESTIONNAIRE FOR WASTE MANAGEMENT STAFF

A. Personal Data of Respondent

1. Gender: Male [ ] Female [ ]
2. Age .....
3. Marital Status: Married [ ] Single [ ]
   Widowed [ ] Separated [ ]
   Divorced [ ] Deserted [ ]

4. Level of Education: None [ ] [ ] Primary[ ]
   Secondary/ Commercial [ ]
   M.A. / MSC [ ] Ph. D [ ]
   Others (professional, Vocational, etc [ ]
5. How long have you worked with the company? (Please specify)
   .....

Waste Generation, Collection and Disposal

6. Do you have information on waste generation rates for
   a. Individual mining waste? Yes [ ] No[ ]
   b. Combined mining waste? Yes[ ] No[ ]
7. If yes, how was this information developed?
   a. Through surveying
   b. Through measurement of waste collected [ ]
   c. Through sampling [ ]
   d. Other means (please specify explain) [ ]
   .....
   .....

8. If your answer to question (6) is yes, provide information of waste generation rates for all or any of items (a) and (b) in question number (6)

.....

.....

9. If only combined or individual mining waste generation rate has been estimated or provided, please indicate which categories of wastes are included.....

.....

10. Please describe your basic refuse or waste collection system with each of the producing unit (department)

.....

.....

.....

WASTE MANAGEMENT EQUIPMENT AND MANTENANCE

11. What are some of the problems you encounter regarding productivity of the various types of equipment?

- Access to the source [ ]
- Delays in traffic [ ]
- Long travel time off the collection route [ ]
- Breaking downs while on route [ ]
- Slow loading and unloading systems [ ]

(Please, check where applicable and specify others)

.....

.....

.....

12. What are some of the problems and issues you perceive regarding the productivity of workers?

- Working conditions [ ]
- Time spent on loading waste [ ]
- Laziness [ ]
- Procedures are slow [ ]
- Lack of supervision [ ]
- Loss of time in traveling to disposal sites [ ]
- (Please, check where applicable and specify others)

13. What type of equipment do you use for collecting and loading solid waste? (Please specify) .....

.....

.....

14. Are there any incentives (e.g. bonuses, early release from work, recognition awards, etc) for workers to provide more effective or productive collection efforts? Yes [ ] No [ ]

15. Is there any training or are there any tests that are regularly scheduled to enable and encourage upward mobility of workers, as far as solid waste collection is concern?

Yes [ ] No [ ]

16. If yes, please specify and explain some of such facilities

.....

.....

.....

17. If your answer to question number (15) is No, do you have plans ahead to encourage and train the waste workers? Yes [ ] No [ ]

18. Considering the problems with waste collection stated in question (11) and (12), what are the serious and the most pressing problems you encounter as far as waste collection and disposal in concerned? (Please specify)

.....

.....

Disposable Systems

19. What type of disposable system do you have? .....

.....

20. If your disposal systems include land sites, please provide the following

- Size of the disposal area .....
- Its location from the producing sites .....
- How long has this site been used? .....
- Surface area available .....
- Topographical character .....
- Presence of surface water .....
- Soil type .....
- Surrounding land use .....
- Initial land value .....
- Condition of access road .....
- Length of access road from producing sites .....
- Equipment available at the site .....
- Method of land filling e.g. open dumping, sanitary landfill, etc.

.....

- Hours of daily operation .....
- Cost of daily operation .....
- Depth of groundwater .....
- Estimated cost of solid waste disposal .....

21. Do you think that resource recovery is technical or economically feasible in your department? Yes[ ] No[ ]
22. If yes, do you recycle some of the wastes for the mining operations? Yes[ ] No[ ]
23. If no, why not?.....

.....

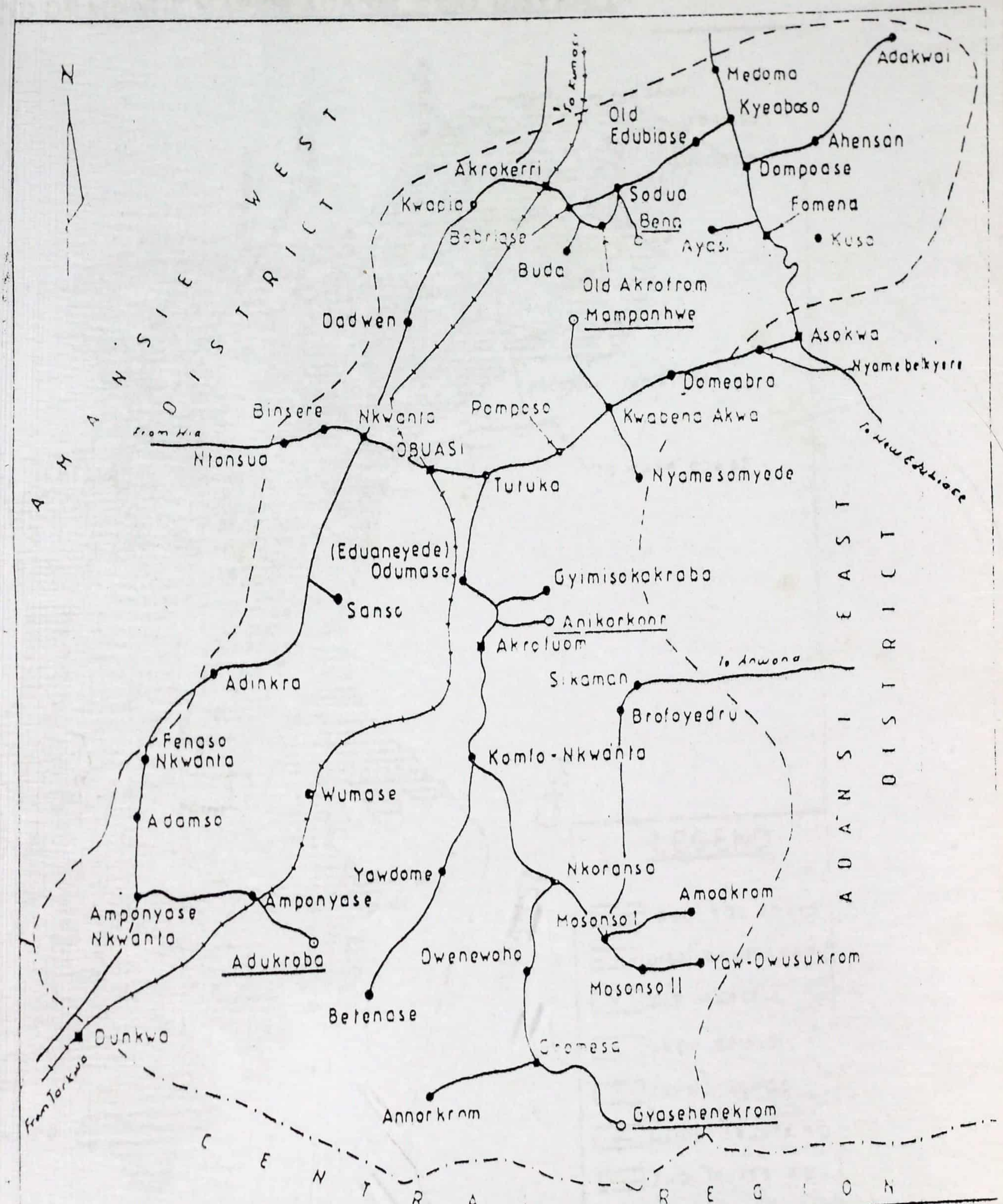
24. How is waste collected from its producing units and at the disposal sites? .....

.....

25. Do you think that the present disposal system used by your company effective as far as environmental and health issues are concerned?
    Yes[ ] No[ ]
26. If your answer is No, what alternative disposable system would you consider appropriate? .....
    .....
    .....
27. How are provisions established by your company for the
    i. Maintenance of waste disposal vehicles?
    .....
    .....
    .....
    .....
    ii. Allocation of waste disposal equipment for various departments?
    .....
    .....
    .....
28. Do you prepare an Environmental Impact Assessment reports?
    Yes[ ] No[ ]
29. Which of the following methods do you adopt to manage the solid waste from your company?
    Sanitary Landfills [ ]
    Impoundments [ ]
    Incineration [ ]
    Open dumps [ ]
    Reclamation [ ]
    Other (please specify) .....
30. If your company adopts reclamation policy, how often do you adopt it? .....
    .....
31. Do you experience any problem with any of the above methods used as far as environmental issues are concerned? Yes [ ] No [ ]
32. If yes, state briefly the problem (s) .....
    .....
33. Do you monitor your waste management system? Yes [ ] No [ ]
34. How often do you do that? (Please specify) .....
    .....
35. Do you report to the Minerals Commission, your waste management activities? Yes[ ] No[ ]
36. How often do you report? .....
    .....

APPENDIX 61

LOCATION MAP OF ADANSI WEST DISTRICT



LEGEND

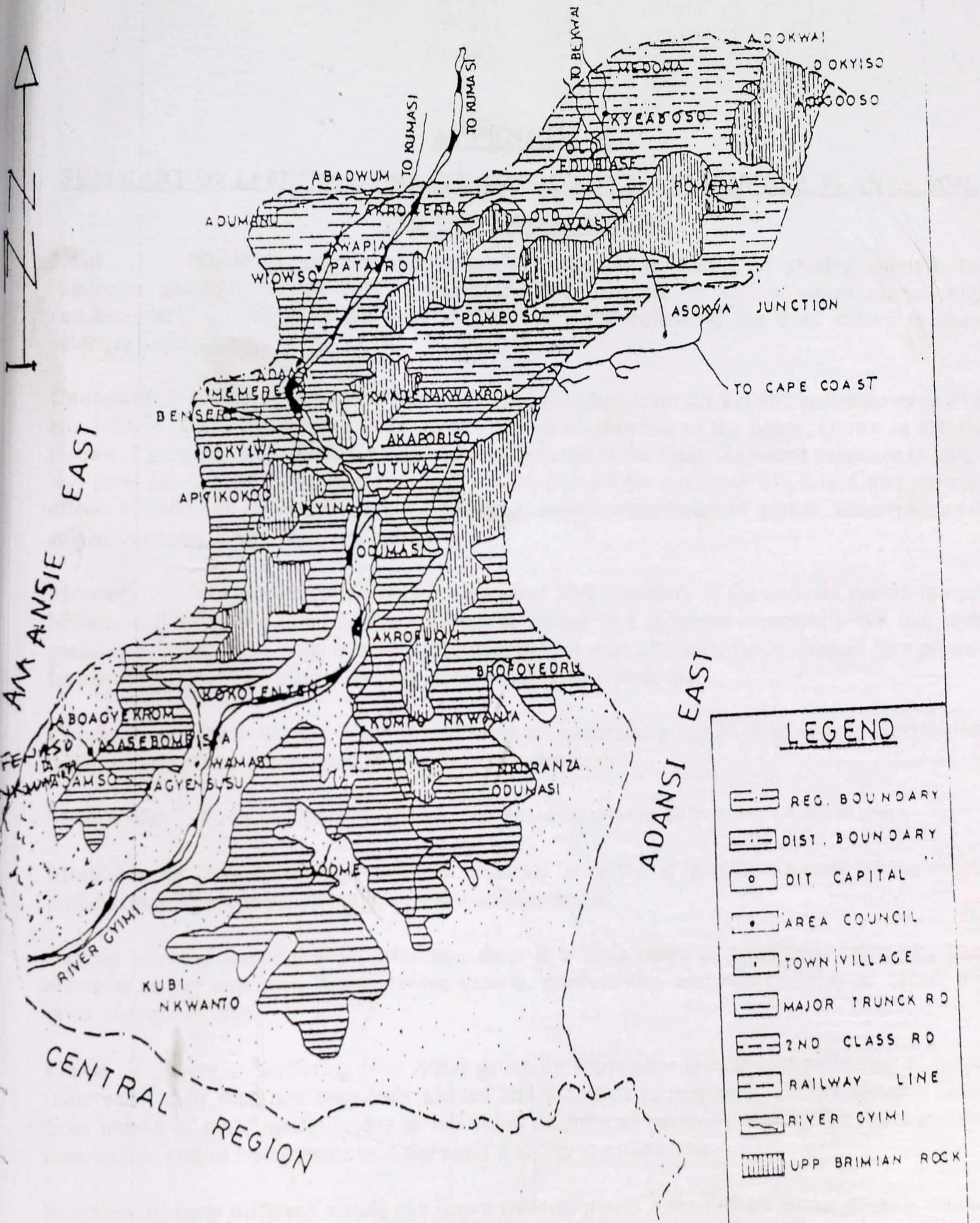
- Regional Boundary
- District Boundary
- Road
- Railway Line
- ■ Major Town
- o Project Community
- • Other Community

LOCATION MAP OF
ADANSI WEST DISTRICT
(Ashanti Region)

Scale 1 500,000

APPENDIX D2

RELIEF AND DRAINAGE MAP OF ADANSI WEST DISTRICT



APPENDIX E

SUMMARY OF EFFECTS OF HEAVY METALS ON MAN, ANIMALS, PLANTS, SOIL AND THE ENVIRONMENT

Lead Toxic to animals and man. Can result in poisoning of grazing animals, but ruminants generally excrete 99% of lead ingested from grass. In lead poisoned animals high concentrations are found in the liver and kidney. Lead poisoning has been shown to cause selective brain damage.

Cadmium Toxic to animals and man. Readily absorbed from the gut and accumulates in liver and kidneys. Cadmium has been shown to cause decalcification of the bones, known as atai-itai disease. Cadmium is absorbed by man and concentrated in the body. Repeated exposure to only a few parts per million in the diet can lead to bone decay after a number of years. Other reported effects of cadmium on man include hypertension, anemia, retardation of growth, abnormalities of spleen, pancreas, heart, liver and kidney.

Mercury Toxic to man. Mercury is associated with disorders of the nervous system in man. Minamata disease was identified as mercury poisoning in a Japanese community that had eaten shellfish and fish from a bay contaminated with methyl mercury compounds released by a plastics factory. Other reported effects on man include loss of hair, teeth etc.

Copper Toxic to man is unlikely. Sheep are particularly sensitive to copper intoxication. Some accumulation occurs, particularly in animal livers.

Manganese Toxic to animals and man. Can cause spontaneous location tetany in cows.

Molybdenum Toxicity to man unlikely. Toxicity is likely in grazing animals where excess molybdenum, low copper and high sulphate-sulphur occur.

Various scientist consider it probable that there is a wide range of conditions caused by trace elements as yet unproven that influence growth, productivity, and susceptibility to cancer and other diseases in man.

Plants Plants suffering from metal generally show poor growth and yellowing of leaves (chlorosi$); their roots are frequently stunted and the plant consequently suffers drought. Death from uptake of toxic metals is due to inhibition of enzyme reactions, damage to cell walls and membranes, and/or interference with the plant's ability to utilize iron.

Excesses of many different metals can prove toxic to plants even though some, namely copper, manganese and zinc, are required in low concentrations for normal growth. The metals below are the commonest associated with industrial activities. Although plant toxicity levels are affected by many factors, guidance levels are given below to act as guides.

Aluminum In uncontaminated but acidic soils, aluminum and manganese are regarded as major causes of plant toxicity. Aluminum is generally abundant in both soils and mine wastes, and becomes toxic in low and high pH soils, plant species vary greatly in their tolerance to aluminum, some accumulating it to a level of 37% in ash samples.

Antimony Antimony is moderately toxic to various species of plants, but is generally only present in soils in low concentrations with few of its salts soluble.

Arsenic Valency is important in relation to the toxicity of arsenic. Arsenic trioxide and sodium arsenic are considered poisonous whereas the free element is not. There is a slight barrier to absorption into plant roots and also to translocation into shoots, and in addition plant growth is generally restricted before arsenic is present in amounts dangerous to livestock (Gillham, 1980).

Damage to vegetation is improbable in normal soils, with total arsenic value of 1 – 40 *u*g/g, but above 2 *u*g/g of soluble arsenic has caused toxicity in alfafa and barley. In Zimbabwe mine dumps up to 2000*u*g/g arsenic have been successfully vegetated but above this concentration, tolerant plant populations are necessary.

Cadmium Cadmium is not considered to be a normal constituent of soils, it occurs at less than 1 *u*g/g (dry weight) in grass/clover swards. It occurs in sulphide deposits especially those containing zinc, lead or copper, and is generally found only in low concentrations in mine wastes. However, it is moderately toxic in that about 3 *u*g/g in plant tissue causes reduce growth in a range of species. Grasses in regions of mining activity have been reported containing up to 10 *u*g/g dry weight.

Chromium Chromium is moderately toxic to plants. Generally less than 0.2 ug/g is found in grasses growing in uncontaminated soils and toxicity symptom develop in some species grown in sand culture, with an addition of only 5 ug/g soluble hexavalent chromium (chromates and dichromates).
In nature chromium generally occurs as chromite (trivalent) which is highly insoluble and not readily available to plants.

Cobalt Toxicity varies greatly with plant species. Sudan grass containing 19-32 ug/g (dry weight) shows toxicity symptoms, whereas leaves of ash trees have been reported containing as much as 10,000 ug/g without apparent toxicity.

Copper Most plants contain higher tissue concentrations of copper than are found in their growth medium. Natural soils occasionally contain toxic levels of copper. Toxicity symptoms generally begin to appear at pH 5 or below, with total copper in excess of 150 *u*g/g. Most plants die in the presence of 0.1% (1000 *u*/g) total copper in the substrate. High concentrations affect plants by interfering with iron metabolism and results in chlorosis.

Lead Lead, zinc and other heavy metals frequently occur together; it is therefore difficult to ascribe symptoms and levels of toxicity. Most of the lead in soil is sparingly plants in normal soils.

Absorption by roots can lead to high concentrations of lead in plant tissues without visible evidence of toxicity or reduction in growth rate, although there is some evidence that a barrier to absorption exists in the roots and also to translocation into shoots.

Manganese Large amounts of manganese are found in normal soils, but this only becomes soluble and cause toxicity in acidic soils where the pH is below 5.0. The exchangeable manganese content of naturally acidic soils from 1.2 638 *ug*/g. In general plants with the more then 400 ug/g (dry weight) of manganese in tissues show toxicity symptoms.

Nickel Nickel is toxic to most plants when water soluble concentrations in soil exceeds a few *ug*/g. Nickel is present in normal soils at up to 100 *ug*/g.

Zinc Zinc is usually associated with lead in mine wastes and is a common cause of phytotoxicity and mortality in plants by its interference with iron metabolism. Generally, total soil concentrations in order of 1% Zinc are limiting to normal plant populations.

It is noteworthy, that it is still not possible to quote definite toxicity concentrations of individual metals because of the many factors involved. This is because there are usually several metals involved and the interactions between them may multiply the potential problem (synergistic effects). For example, combinations of metals in solution such as nickel and zinc, copper and zinc, and copper and cadmium are more toxic than their individual toxicities would suggest. Alternatively, the presence of phosphates or calcium can reduce the toxicity of lead, zinc and copper (antagonistic effects).

APPENDIX F

GLOSSARY

Auriferous A substance eg. ore that contains gold, especially gold bearing mineral.

Reagent- A substance which acts on another in a chemical reaction.

Flotation reagents Any of several reagents used in the froth flotation process.

Filtration reagents A reagents used to remove suspended and/ or colloidal material from a liquid by passing the suspension through a relatively fine porous medium eg. a canvas or other fabric diaphragm.

Flocculant To cause particles to aggregate in large particles. To thicken a clay suspension by addition of synthetic polymer. The addition of a suitable electrolyte to a clay suspension to cause the clay particles to agglomerate and settle.

Coagulant A soluble substance, such as lime which when added to a suspension of very fine solid particles in water, causes these particles to adhere in clusters that will settle easily. It is also used to assist in reclaiming water used in flotation.

Refining reagent Reagents used to free from impurities, to free from dross or alloy, to purify as metals, to cleanse.

Grinding Aid An additive to the change in a tall mill or rod mill to accelerate the grinding process. Grinding aids find particular use in the grinding of Portland cement clinker but in the UK their use is precluded by t5he4 conditions laid down in the British standard.

Smelting The chemical reduction of a metal from its ore by a process usually involving fusion, so that earthy or other impurities separate as lighter as and more fusible slags and can readily be removed from the reduced metal.

Ankylostomiasis (miners' anaemia) The form of rheumatoid arthritis affecting the spine. It usually occurs predominantly in young males and produces pain and stiffness as a result of inflammation of the sacroilac, intervertebral and costovertebral joints.

Carcinogenic Chemicals or constituents that have the ability to produce tumors during the life –time exposure of laboratory animals. They are usually associated with cancer in man.

Mutagenic These chemicals or constituents that usually interact with DNA causing changes in its structure. It usually results in the loss, addition or replacement of bases, altering their sequence in the DNA and affecting the fidelity of the genetic message.

Phytotoxicity The development of skin disease as a result of too much exposure to heat or sunlight. Many workers receive occupational sun exposure and suffer long term adverse

effects. The same problem occurs in plants resulting in the yellowing of the leaves and stunted growth.

Biodegradable Substance that is able to decay naturally and harmlessly. Compare with non-biodegradable.

Complex ore An ore containing two or more metals eg. Lead-zinc ore. Many complex ores are difficult and costly to treat eg gold ore with arsenic or antimony minerals, or ore composed almost entirely of several sulfide minerals.

Complex A unit that consist of a mixture of rocks of two or more genetic classes, ie igneous, sedimentary, or metamorphic with or without highly complicated structure.

Metabolism A term proposed by Barth (1962) for the redistribution of granitizing materials within sediments by metabolisation, transfer and reprecipitation, as opposed to metasomatism involving addition of new materials.

Chlorosis The yellowing of the leaves of plants, sometimes caused by a deficiency of iron necessary in the formation of chlorophyll.

Precipitation The process of separating mineral constituents from solution eg by evaporation or by cooling of magma (to form igneous rock)

Silicosis Pneumoconiosis(a sickness) due to the inhalation of dusts of stone, sand, or flint containing silicon dioxide, with formation generalized modular fibrotic changes in both lungs (Dorland 27th. Ed)

Nystagmus Involuntary movements of the eye that are divided into two types; jerk and pendular. Jerk nystagmus has a slow phase in one direction followed by a corrective fast phase in the opposite direction and it is usually caused by central or peripheral vestibular dysfunctioning. Pendular nystagmus features oscillations that are of equal velocity in both directions and this condition is often associated with visual loss early in life.(Adams et al, Principles of Neurology, 6th. Ed pp. 272).

Organic compound. A compound containing carbon with very few exceptions.

Compound Two or more elements combined by chemical bonds.

Concentration The ratio between the amount of solute and the amount of solvent or solution in which the solute is dissolved.

Acid A substance which produces hydrogen ions in water solution.

Distillation A process of evaporating a liquid and condensing its vapour.

Energy A property of a matter which may be converted to work under the proper circumstances.

Entropy A degree of disorder in a system.

Evaporation A process by which a molecule leaves the surface of a liquid or solid and enters the gaseous state.

Fluid A material which flows (liquid or gas).

Metal An element which tends to lose elements in chemical reactions.