

The Environmental Mineralogy

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Abstract—Global warming and other environmental troubles facing society today, mineral science has any role to play in solving these problems. Traditionally, the major application of minerals and mineral science has been in the understanding of how rocks form (petro genesis) and behave.

Environmental mineralogy is by no means new, but it is certainly seeing an impressive rise in scope and activity. Monographs review the immense literature and diverse applications of environmental mineralogy. Recently, the *Mineralogist* published special “green” issues that focus on environmental mineralogy. The important role of minerals in many interesting environmental problems makes today a very exciting time for mineralogy. Environmental mineralogical topics as the effects of minerals on human health, minerals that form in surficial acidic environments, and microbe–mineral interactions.

Mineral resources are an important source of wealth for a nation but before they are harnessed, they have to pass through the stages of exploration, mining and processing. Different types of environmental damage and hazards inevitably accompany the three stages of mineral development. The negative effect on the environment of the activities involved in harnessing the minerals. An attempt will also be made to examine the possible precautions and remedies that can be applied in order to mitigate the effect of adverse environmental impact of mining activities.

On the other hand, the environmental damage caused by small-scale quarrying of laetrite, clay, gravel and stone in numerous parts of the country by private entrepreneurs is less but more difficult to control. A special mention must be made of the environmental degradation caused by the illegal mining of gemstone. Because of the uncontrolled manner the illegal miners operate, a lot of damage is done to the environment by haphazard pitting and trenching of the ground in many areas.

Keywords: *environmental damage, life cycle, mineralogy, minerals, mineral Economics, mining.*

I. INTRODUCTION

Mineralogy is the study of chemistry, crystal structure, and physical (including optical) properties of minerals. Specific studies within mineralogy include the processes of mineral origin and formation, classification of minerals, their geographical distribution, as well as their utilization.

History of mineralogy early writing on mineralogy, especially on gemstones, comes from ancient Babylonia, the ancient Greco- Roman world, ancient and medieval China, and Sanskrit texts from ancient India and the ancient Islamic

World. Systematic scientific studies of minerals and rocks developed in post- Renaissance Europe. The modern study of mineralogy was founded on the principles of crystallography and microscopic study of rock sections with the invention of the microscope in the 17th century (Needham, 1986)

Mineralogy was heavily concerned with taxonomy of the rock forming minerals; to this end, the International Mineralogical Association is an organization whose members represent mineralogists in individual countries. Its activities include managing the naming of minerals (via the Commission of New Minerals and Mineral Names), location of known minerals, etc. As of 2004 there are over 4,000 species of mineral recognized by the IMA. Of these, perhaps 150 can be called "common," another 50 are "occasional," and the rest are "rare" to "extremely rare."

II. TYPES OF MINERALOGY

Mineralogy is an interdisciplinary science, as is geology, in which the principles of physics and chemistry are applied to Earth materials. There are numerous other applications of minerals outside the realm of petrology or even geology, and the importance of minerals extends into many areas of scientific and technological pursuit including materials science, environmental science, medicine, biology, and engineering (Ramsdell, Lewis, 1963).

A. Physical mineralogy

Physical mineralogy is the specific focus on physical attributes of minerals. Description of physical attributes is the simplest way to identify, classify, and categorize minerals, and they include:

- crystal structure
- crystal habit
- twinning
- cleavage
- luster
- color
- streak
- hardness
- specific gravity

B. Chemical mineralogy

Chemical mineralogy focuses on the chemical composition of minerals in order to identify, classify, and

categorize them, as well as a means to find beneficial uses from them. There are a few minerals which are classified as whole elements, including sulfur, copper, silver, and gold, yet the vast majority of minerals are chemical compounds, some more complex than others. In terms of major chemical divisions of minerals, most are placed within the isomorphism groups, which are based on analogous chemical position and similar crystal forms.

III. ENVIRONMENTAL MINERALOGY

International Mineralogical Association (IMA) Working Group on Environmental Mineralogy and Geochemistry definition: Environmental mineralogy [and geochemistry] is an interdisciplinary field dealing with systems at, or near, the surface of the Earth where the geo sphere comes into contact with the hydrosphere, atmosphere and biosphere. This is the 'environment' on which plants and animals (including humans) depend for survival and which can be disrupted by human activity, particularly that associated with exploitation and utilization of Earth's resources.

Environmental mineralogy is obviously a very diverse sub discipline of mineralogy, and a comprehensive review of its many aspects is far beyond the scope of these column two applications of environmental mineralogy (Rakovan, 2008):

- (1) Remediation of heavy-metal contaminates that are currently in the environment.
- (2) The design of solid forms of radioactive waste for stable disposal.

One significant class of environmental pollutants is heavy metals such as Pb, As, Cd, Cr, and Hg, which are toxic, even at low concentrations, and may act as carcinogens. These may be naturally present, but human activity has greatly increased the flux of biologically available forms of heavy metals in the environment.

If the metals are present in a form that cannot get into plants and animals or is nonreactive (i.e., cannot be metabolized), they are not bio available and pose a much lower health risk. This leads to one possible strategy for contaminant remediation. Instead of removing the metals from the environment, the idea is to change their speciation to a stable, non bio available form, such as being incorporated into the crystal structure of a mineral with low solubility (Bostick et al. 2000).

Mineralogists and other scientists (Wajima et al. 2007) are investigating the potential of converting paper sludge into usable minerals such as zeolots.

Minerals as indicators of specific environment conditions (chemical and physical). The environment parameters that can be inferred from the presence of a specific mineral are: (Irwin, 1997).

- pH
- Radix conditions
- Presence of specific anions
- Drainage with landscape position and
- Temperature & climb sequences
- Transported versus in situ regolith

Minerals can be used as indicators of specific environmental parameters on a variety of scales ranging from the micro (thin section) to macro (hand specimen) to profile (vertical differences) to landscape (hydrology, topography) to even continental scale.

pH – Acid or Alkaline with dominant anion

The pH is the master variable and pH of surface and ground waters (shallow and deep) have a direct effect on the precipitation and stability or persistence of secondary minerals in the regolith.

Redox Conditions

Specific minerals in the regolith are indicators of radix state of the environment under which they formed. They form and persist in a restricted Eh pH range of oxidation potential. Pyrite (black) and mono sulphides ("black ooze") are indicators of reducing environments, where sulphur reducing bacteria catalyze oxidation of organic matter and link it to reduction of Fe³⁺.

Drainage or water activity

The rate of flow of groundwater vertically and laterally (landscape) through a profile, sediments or sedimentary rock can affect the nature of the minerals that form, and the presence of resulting minerals can be used as indicators of the rate of flow of water or in thermodynamic terms the water activity.

Landscape or Catenaries' Position

Regolith minerals can be used as indicators of past landscape position, but interpretation is a combination of drainage and pale landscape evolution or substrate type. The iron oxides, especially hematite and goethite, having their genetic pathways controlled significantly by Water activity or saturation, provide the best indicators of drainage linked to centenary position.

Temperature & Climate

Generally, there are few reliable mineral indicators of current and past temperatures. The main indicators are the iron oxides and hydroxides. Magnetite, commonly found in globules (nodules, mottles) within soil and on the surface as ferruginous lag, is a likely indicator of forest-fires. Iron oxides (goethite, hematite) present in soil matrix and in globules when heated to temperatures above 3000C in the presence of organic matter (top soil organics), transform to magnetite. Therefore, the presence of magnetite is used as an indicator of forest fires.

Transported vs. in situ regolith

Regolith is broadly classified into that produced as a result of weathering of the basement rocks in situ) and that produced due to the transportation processes, which is essence is surficial sediments.

IV. TYPES OF ENVIRONMENTAL DAMAGE

"Environment" as used in this paper has three components, namely, the sum total of external conditions in which organisms exist; the organisms themselves including the floral and faunal community; and the physical surroundings such as landforms. All these three aspects,

which include various entities such as air, water, land, vegetation, animals including human, landscape and geomorphologic features, historical heritage etc. are adversely affected one way or the other during the course of mineral development (Aigbedion, 2007).

Air, land and water pollution

Varying degrees of pollution of air, water and land occur in the course of mineral development depending on the stage and scale of activities attained. While only minor pollution occurs during mineral exploration, more intense air and water pollution emanates from the exploitation stages, particularly if carried out on a large scale. In the oil-producing areas of the country oil spillage of differing intensity resulting from burst pipelines, tanks, tankers, drilling operations, etc. is a common phenomenon.

Damage of vegetation

Vegetation in form of natural forest or crop plantation is usually the first casualty to suffer total or partial destruction or degradation during the exploration and exploitation of minerals in a locality. The vegetation damage is more extensive at the time of mine development and mining operations and is more expensive when crop plantation is affected.

Ecological disturbance

Another adverse effect of mineral extraction and processing activities, which may not be immediately felt, is the disturbance of the ecosystem with possible adverse consequences on the floral and faunal community in general. Oil spillage produces a devastating ecological disturbance in the oil-producing states as well as in areas where leakage occur due to natural breakage of oil pipe line or illegal bunkering. The plants, animals, soils and water are affected.

Degradation of natural landscape

A common negative effect of mining minerals from the earth's surface is the destruction of its natural landscape, creating open space in the ground and generating heaps of rock wastes that cannot be easily disposed off. These phenomena are amply demonstrated in several parts of Nigeria, where commercial mining or quarrying had occurred in the past or is currently taking place.

In the Younger Granite Province, especially the Jos Plateau, tin and columbite mining has resulted in the destruction in places of the scenic landscape which is replaced by unsightly large irregular holes and heaps of debris produced by the opencast method of mining (Brooks, 1974).

Geological hazards

Mining operations normally upset the equilibrium in the geological environment, which may trigger off certain geological hazards such as landslide, subsidence, flooding, erosion and tremors together with their secondary effects.

Minor earth tremors are generated due to blasting of rocks in various quarries. Villages and settlements in the neighborhood of the quarries have experience unpleasant earth movements when the rocks are blasted (Ajakaiye, 1985).

V. MINE DEVELOPMENT: EXPLORATION, PLANNING, APPROVAL AND CONSTRUCTION

Mine development consists of a sequence of activities:

- Prospecting and exploration work to locate and delineate the ore resource.
- Economic, environmental and technical feasibility assessment of the ore body.
- Planning and design of the mine layout, site infrastructure and the mining sequence;
- Obtaining relevant government permits and approvals.
- Construction and commissioning of the operation.

Most environmental impacts during this stage of the mining life cycle are typically associated with planning, exploration and construction.

Planning

Effective planning, commencing at this stage and continuing throughout the life of the mine, has a great influence on minimizing the impact of the operation. Planning is important to avoid or reduce adverse environmental impacts over the life of the mine and after closure. Planning is most effective when the entire life of mine is compassed. Defining the final objectives of mine closure from the outset allows an optimum balance between operational, rehabilitation and closure goals to be selected, thus minimizing the cost of these activities.

Exploration

Exploration activities have some environmental impacts. These are largely related to land disturbances from the clearing of vegetation, construction of camps, access roads, drilling sites and sumps for drilling fluids and fines. Effective planning of the exploration activities reduces potential impacts by using existing infrastructure where possible, taking appropriate care during the construction of access tracks and containing any drilling fluids and fines in sumps.

Construction

Construction activities have significant potential to have adverse environmental impacts. During this phase, often a large transient workforce is employed, workforce numbers tend to peak and material and equipment movements tend to be large. Impacts are typically related to land disturbance caused by earthworks, air emissions from dust, noise from equipment and construction activities and heavy volumes of traffic on access roads. In many cases, specialized third party companies and consultants conduct mine construction activities.

Underground operations control exhaust particulates by installing particulate filters on the exhausts of mobile equipment. Retrofitting equipment with new, more efficient and leaner engines also reduces exhaust particulate and gas emissions, as well as contributing to reduced fuel consumption and maintenance costs.

Other potential impacts

A variety of other impacts may occur because of extraction activities, including noise and vibration due to blasting and the operation of equipment.

In some places, unsightly landscapes have been improved by maintaining buffer zones, planting greenbelts or the constructing barrier fences. Prompt rehabilitation of disturbed areas that are most visible can reduce the visual impact and improve relations with the local community.

VI. SOCIO-ENVIRONMENT PROBLEMS

Some socio-environmental problems are sometimes created as a result of certain peculiarity of the mineral industry. Since minerals are exhaustible and irremovable commodities, the life of a mine and, consequently, the mining activities in a place have a limited time. The stoppage of mining activities imposed by depletion of the available reserves often leads to migration of people from the mining areas to other places. This may result in the formation of “ghost towns”, which are abandoned towns and previous bubbling mining communities.

- **Radiation hazards:** Exposure to natural radiations emitted by some radioactive minerals is a major source of health hazards. The radiation intensity increases when the minerals are concentrated.
- **Precautions and remedies for environment damage:** In order to minimize the ill effects of mineral mining and processing, certain precautionary measures must be taken by both the government and the mining and processing companies.

Since some damage to the environment is inevitable in the course of mineral exploitation, usually, the only option left is to apply some remedy to the damage. The remedy or compensation should depend on the type, extent and magnitude of damage, which can be permanent or redeemable in which case the damage effect fades away as the causative factor is withdraw. The environmental impact of mining and processing activities can extend for many kilometers from the operation site.

VII. ENVIRONMENTAL MANAGEMENT

Environmental management is an activity that is ongoing throughout the entire mining life cycle, from initial exploration to the final closure of the operation and handing over of the site. It encompasses and influences all the different activities of the mining life cycle and is most effective when integrated with the day-today management and planning of the operation. Environmental management consists of systems, procedures, practices and technologies that vary depending on the specific characteristics of the surroundings ecosystem, the legal framework and the mining methods and beneficiation processes employed.

As appreciation of the complexity of environmental considerations has grown, a variety of management tools have been developed to assist company's better control the

effects of their operations and provide a higher level of environment protection. These tools include: environmental management systems (EMS); environmental impact assessment (EIA); environmental technology assessment (EnTA); environmental auditing; life cycle assessment (LCA); cleaner production and environmental reporting (United Nations Environment).

A. Environmental Management Systems

The ISO 14000 Environmental Management system and the European Union Eco-management and Audit Scheme (EMAS) standards provide widely recognized frameworks and guidelines that companies can use to develop their own environmental management systems. These are third-party certified, providing a means by which the company can demonstrate its commitment to improved environmental performance. Many phosphate rock and potash mining companies are looking at the ISO 14000 standards to guide the development of systems that are specific to their needs. Recognition of the growing importance of environmental management systems is evident in a number of countries including many developing countries, where producers understand the competitive advantage of meeting the increasing demands of consumer markets such as the European Union and Japan. As community awareness has grown, demands on industry have increased accordingly. In many countries, both industry and governments are becoming more accountable for the decisions and actions they take. This is partly because of the increased availability of information concerning their actions and more stakeholder involvement in the decision-making process.

In future, community concerns may shift away from a focus on environmental damage at the mine site to the need to balance competing demands for limited natural resources such as fresh water and agricultural land. The mining industry, as a consumer of natural resources, will not be isolated from these pressures. Foresight and the adoption of adequate and effective solutions to arising issues will assist the industry's response.

Governments are responding to community pressure through new legislation. The European Union's Integrated Product policy is one such response. Policy implementation will lead to increasing producer responsibility for their products. It will also increase the use of market instruments to internalize the external environmental costs of products over their entire life cycle. This responsibility will concern not only companies' own activities but also those of their suppliers, transporters and service providers. Mining firms with good reputations to keep and healthy financial resources are more likely (although not certain) to engage in socially responsible mining. Such firms are typically international or they are domestic firms with ties to reputable international firms. In the short run, socially responsible mining costs more and requires considerable financial resources but this is the sine qua non of long-term viability.

There remains a need to create positive demonstration effects to promote sustainable mining through tangible examples of successful, modestly sized operations that practice responsible mining. Rushing to expand the mining sector may increase the likelihood of further accidents that are almost certain to undermine the sector's growth potential. A strategy of mining expansion focused more on the quality than the quantity of mining operations will pay higher dividends over the medium to long term.

The costs of environmental irresponsibility and bad social practices on the part of one mining company are borne by all companies in the region, and peer pressure should reduce the likelihood of major accidents and improve the credibility of the industry. Therefore, the private sector in developing countries should seek to institute mechanisms for collective self-evaluation and self policing with regard to member companies' environmental performance and contributions to community development.

And lastly, for the foreseeable future, there will be a need to provide increased support for the enforcement of all mining laws and provisions by the appropriate government agencies and local communities. It should be recognized that effective enforcement and manageable levels of investment are related. When enforcement is weak, prudence requires that the vetting of prospective investors be more stringent. However, strong enforcement allows greater latitude in opening the mining sector to investors.

VIII. CONCLUSION

Any environmental problem, there is need to assess or measure the magnitude of the problem. This can be done by direct measurements such as calculating the value of economic trees removed and changes in farm produce due to pollution; land, road and property reparation cost; water treatment cost; and the costs of treating diseases directly traceable to the environmental damage. However, direct measurements of environmental damage are not always possible because the damage may be intangible, subtle or even slow to appear. Under such a situation the cost of providing an alternative environment or renewable resources elsewhere, if possible, can be considered.

A major issue concerning the remedy or compensation for environmental damage resulting from mining and processing activities is that those who bear the costs of the environmental damage are the people who live in the environment and not the producing companies. The problem requires the intervention of government through appropriate legislation that can compel the mining/processing companies to internalize the reparation or replacement costs, which are so far borne by the people who live in the environment. Safe disposal of unavoidable waste in stable and aesthetically acceptable structure must be enforced through legislation. Thus, withdrawing the area from mining would have economic impacts on the local communities and

may have social and economic effects that are regional or national.

Extraction and processing of mineral resources is the backbone of the national economy in many developed and developing countries of the world. However, the great danger posed by mineral exploitation such as abandoned sites, biodiversity damage, use of hazardous use of chemicals with potential health risk to mine workers and neighborhood communities deserved urgent attention. Emphasis should shift from waste disposal to waste minimization through sorting; recycling of reagents and water. Safe disposal of unavoidable waste in stable and aesthetically acceptable structure must be enforced through legislation.

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