Environmental Impacts of Mining Operations A Case Study: Monitoring the Impacts at Abu Tartour Phosphate Mine, Egypt

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Abstract- **Mining operations describe either mines or any of various work functions that are performed in mines, from exploration to waste disposal. The long-term environmental impacts of uncontrolled mining and quarrying operations are disruption of the hydrological cycle, loss of biological diversity, acceleration off deforestation and desertification in fertile areas and poor sustainable development for the future. This paper represents a comprehensive digest of the up-to-date literature on the impact of such operations, with focusing on the environmental impacts of one of the economical ores in the Middle East, Phosphate. The major environmental impacts of mining and quarrying operations to air, water, land and other resources are discussed and suggestions have been introduced to prevent their negative geo-environmental effects. Moreover, the paper presents a case study of the environmental impacts of the Abu Tartour phosphate mine, Western Desert, Egypt, where the mining area has been screened environmentally and the main issues are reported. Technical actions (methods) that may be taken to study and monitor these issues using Geographic Information System (GIS) and remote sensing are demonstrated through the case study. The environmental challenges faced by mining activities should not be underestimated. All the major mineral-consuming areas face problems of one sort or another. Pioneering computer software, designed to identify more sustainable integrated approaches to waste management, has been recently developed. We are invited to take part in the newly and progressively developed new world.**

Keywordst *- Abu Tartour; Environmental Impact ; GIS; Phosphate; Mining*

I. INTRODUCTION

With its huge outcomes from different stages, mining activities are known with their direct and indirect impacts to the environment, not only cause air pollution, water contamination, noise, socio-economic impacts but also have geo-environmental impacts to the soil, land and geological features that might be affected.

Minerals, with agriculture and forestry products, are the primary sources of a nation's wealth. Unlike the other two, mineral resources can easily escape detection and, when they are detected, the feasibility of mining and utilization is determined by a complex interaction of many geological, technological, economic, social and strategic factors [1].

Environmental regulations have become a decisive factor for many minerals industry operations as a result of environmental laws, and restrictive permitting requirements for new projects make mine development an increasingly difficult proposition [2]. However, the mining industry can anticipate that increased environmental regulation is likely to be found in those developing countries that are more intimately locked into the global economy. On the other hand, environmental legislation does not automatically translate into environmental enforcement [3].

Major environmental issues facing mine operators are effluent control and soil reclamation and remediation. The environmental issues arising from mining operations show that mining modifies the existing environment and the distribution of mineral resources. Mineral processing and the resulting tailings, waste rock, chemical reagents, slag, etc. produce numerous wastes and products that can cause contamination to the air and water. The effects of these alterations on the stability of regional and global ecosystems are enormous.

Impacts of mining on the environment have been studied and reported in several cases, Dudka (1997) studied the impacts of some metal mining such as Cu, Pb and Zn on environmental quality [4]. Bell *et. al*, (2001) studied the impact of acid drainage of coal mine. [5]. Similar studies but on the impacts of gold mines on the environment are reported on Anwer (2008) [6].

This paper addresses also the environmental issues that arise during the phosphate extraction at Abu Tartour phosphate mine, Western Desert, Egypt. Although the mine lies in the heart of the desert, the mining operations for ore extraction either from the underground mine, or from the surface operations, do have several environmental impacts that affect the human being, agriculture, and natural resources (groundwater), involving noise, and air pollution.

Other environmental issues at the same area include the movement of sand dunes with its impact on ore transportation.

II. GEO-ENVIRONMENTAL IMPACTS

The main geo-environmental impacts of mining can be summarized as follows (See Table 1):

Mining (both surface and underground) breaks and crushes rock, creating new pathways for oxygen, air and microbes to react with the rock. Thus, both underground workings and open pit walls may generate acid rock drainage (ARD), which can contaminate ground and surface water for decades or even hundreds of years after mine closure. This occurs where "significant" amounts of sulphide minerals are present in the ores and waste rock, and causes a lowering of water pH to about 1.0 to 4.0, which

then mobilizes many other chemical constituents, such as toxic metals and non-metals alone.

Waste rocks are normally disposed of in piles on the surface of the ground at the edges of pits, or outside workings. Many contaminants can be leached out of these waste piles, contaminating surface water and groundwater.

III. New Techniques for Mining Environmental Mapping

New technologies such as remote sensing and geographic information systems have been applied for the preparation of environmental impact assessment for different mining areas. Satellite remote sensing has been extensively used to monitor effects of surface mining [7], [8], [9]. The use of these techniques is based on fact that there are differences in reflection between surface materials at different electromagnetic (EM) wavelengths. It is therefore, possible to classify surface cover types and map their distribution. Due to the sensor's wide field of view, satellite data can prove extremely cost-effective overlarge areas.

A. The Role of Geographic Information Systems (GIS)

For environmental mapping related to mining aspects, GIS could be applied for the following investigations:

1. The application of GIS to environmental impact assessment in the mineral industry.

2. Integration GIS and remote sensing for environmental management at the mining areas.

3. Using GIS techniques to provide a sensitivity environmental map showing the areas of highest and lowest environmental impacts.

TABLE 1: MAJOR ENVIRONMENTAL IMPACT OF MINING (SIMPLIFIED AFTER RAMANI, 2001).

					Pre-mining Development	Surface Mining	Underground Mining	Non-Entry Mining	Process Waste	Post-Mining	Abandoned Land
Air Quality	Noise		Blasting/explosives		•	•					
			Equipment		•	•		•	•		
	Air Blast					•	•				
	Emission		Equipment			•		•			•
			Fires			•	•		•	•	•
			Waste			•	•		•	•	•
Water	Surface Water	Quality	Solids	Dissolve		•	•	•	•	•	•
				Suspend	•	•	•	•	•	•	•
			pH			•	•	•	•	•	•
		Quantity	Toxic elements			•	•	•	•	•	•
			Operationally Related	Consume		•	•		•		
				Suspend	•	•	•	•	•	•	•
	Ground water	Quality	Solids	Dissolve		•	•	•	•	•	•
				Suspend				•			
			pH			•	•	•	•	•	•
		Quantity	Toxic elements			•	•	•	•	•	•
Land	Land Use and Productivity		Surface Stability	Subsidence			•	•		•	•
				Slope Stability	•	•			•	•	•
			Supportive capacity	Habitat	•	•	•	•	•	•	•
				Agriculture	•	•	•	•	•	•	•
			Landform		•	•	•	•	•	•	•
Social Culture	Historical (Archeological)				•	•	•				
	Infrastructure				•	•	•			•	
	Public Safety					•	•	•	•	•	•

TABLE 2: DUST CONCENTRATION AND METEOROLOGICAL CONDITIONS FOR THE MINING OPERATIONS IN ABU TARTOUR (AFTER MOHAMED, 1991).

Operation	Site	Distance In, m	Dust conc. in mg/m^3	Meteorological conditions		
				Temp. ºC		Air velocity, m/sec
				dry	wet	
Drilling	**RG1**	5.0	25	30	25	0.00
		15	10	27	21	0.25
		25	5.33	26	20.5	0.00
		35	1.90	25	20	0.00
	RG2	5	30	33	28	0.00
		15	16.67	28	22.5	0.00
		25	8.33	27	22	0.00
		35	3.33	26	21	0.00
	RG3	5	33.33	40	29	0.00
		15	20	39	28.5	0.00
		25	13.33	38.5	27	0.00
		35	6.67	40	29	0.00
Blasting	**RG2**	0.5	53.33	27	22	0.00
		22	46.67	27	22	0.00
		23.5	40	27	22	0.00
		25	33.33	27	22	0.00
		26.5	26.67	27	22	0.00
		28	20	27	22	0.00
		29.5	13.33	27	2	0.00
Loading	**RG1**	5	23.33	28	18	0.00
		15	11.11	27	19	0.25
		25	5	27	19	0.00
		35	1.67	25	18	0.00
	RG2	5	26.67	33	23	0.00
		15	10.00	30	23	0.00
		25	5.56	28	22	0.00
		35	2	27	21	0.00
	RG3	5	30	41	31	0.00
		15	17.78	39.0	30.5	0.00
		25	8.89	38	30	0.00
		35	3.33	40	28	0.00

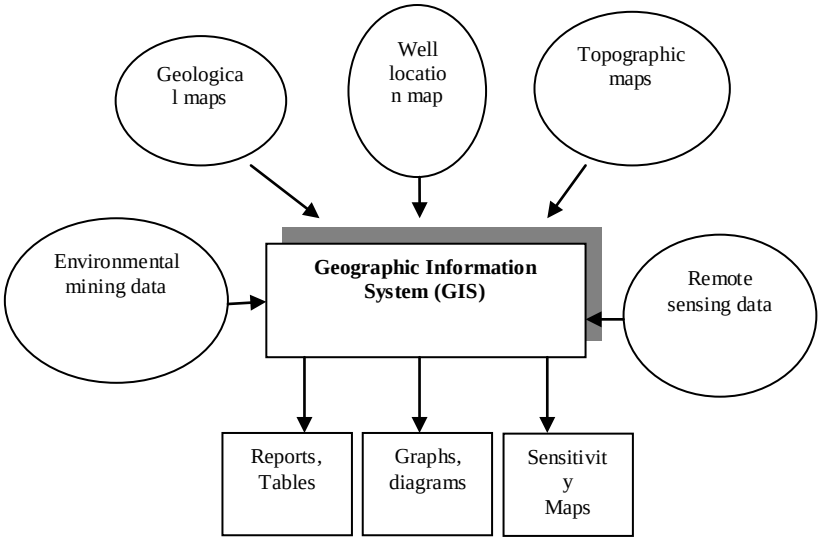

Fig. 2: Input and output data into the GIS for environmental impact assessment at Abu Tartour area

B. Computer Aids

For the constantly changing environment, it is important to be able to monitor the effects of development and land-use as well as document natural changes. By digitally combining satellite data from different years or seasons, the location and extent of changes (e.g. the movement of sand dunes or difference of land usage) can be mapped. The computer allows changes to be determined rapidly over large regions, and information to be updated frequently using new imagery. It is noteworthy to mention that the same exercise undertaken by conventional techniques might take years of groundwork and be out of data even before completion.

C. Mining Environmental Maps

It is usually a perquisite, either from the government or public purposes to produce maps showing current land cover and its changes every two or five years. If the final product is to be at scales between 1:2500 and 1:10000, this task can readily be undertaken using remote sensing. Image processing techniques can be used to obtain quantitative measures of the proximity of environmentally significant land-cover classes to propose mine-sites or transport route. This allows a choice of the best sites for mine dumps or access roads, based on the maximum possible distance between new developments and areas of environmental importance.

D. Monitoring and Map Updating

While surface mining operations are in progress there is often a need for both relevant planning authorities and mine operation to monitor activities within sites. General surveys of sites are often undertaken using aerial photographs; which may be used to provide updated land-cover maps and derivative change maps, are relatively low cost.

E. Restoration Quality Assessment

Once mining is complete, there is commonly a requirement to restore the land surface to its pre-mining use. Remote sensing can play an important and cost effective role in assessing the quality restored land, as well as in comparing the size and shapes of fields in restored and un-mined areas.

IV. Abu Tartour Phosphate Mine: A Case Study

Abu Tartour phosphate deposit is one of the largest phosphate mining areas (1000 million tons, 200 million tons as proved) in the Middle East. The mining area is located in the Western Desert of Egypt, about 60 km from El Kharga City, and 10 km from the main road between El Kharga and Dakhla Oases (Figure 1). The aim of demonstrating this study is to identify the environmental and health impact arises at all stages of the phosphate cycle: extraction, storage, and transportation of the ore at Abu Tartour mining area in its present situation.

A. Environmental Impacts:

Environmental Impacts of the phosphate ore occurring during loading, unloading and several subsequent mining operations can be classified as follows:

1) Surface Mine

- Dust created during operations causing respiratory problems,
- Blast effects,
- Noise and vibration effects from machinery,
- Creation of large hole in the ground, and
- Waste materials leading to the pollution of groundwater.

2) Underground Mine

- Waste rocks excavated during tunneling
- Subsidence (surface stability due to change in underground excavations),
- Machine dangers, and water consumption.

3) Ore Restoration

- Transportation of the phosphate is carried out by the following utilities:
- Conveyors, from extraction site to loading points,
- Trucks (lorry), from loading point to Assiut factory (300km), and
- Railway, from Abu Tartour to Safaga port at Red Sea for export.

The above forms of transportation exhibit common environmental hazards such as,

- Dust effect during operations,
- Trucks and rail transport cause damage to buildings in the town,
- Road damage, between Abu Tartour and Assiut by haulage trucks is
- a major environmental impact,
- Loss of ore during loading and unloading processes in the form of dust,
- Affecting human health,
- Air pollution from engines powering transportation facilities, and
- Noise as a result of engines, horn, and wheel-rail intersections.

Fig. 1: Location map of Abu Tartour area, Egypt

4) Other Issues

Dust concentration and meteorological conditions in Abu Tartour mine were studied by Mohamed (1991) [10]. The results showed clearly that the dustiness of the atmosphere during drilling, and loading operations is the same. The dust concentration during miming operations is in the range of 5.5 to 33.33 mg/m3, which are above the acceptable levels (1-76 to 5 mg/m3).(See Table 2).

Ore transportation is facing a major problem due to the movement of sand dunes over the main road and the railway. The rate of advance and direction of movement are beyond the scope of this paper; however it is believed that remote sensing would contribute in the study of this phenomenon.

V. Method and Analysis

An approach for environmental impact assessment that integrates remote sensing data and environmental information into a geographic information system (GIS) is suggested and presented in Figure 2.

Among all the environmental impacts associated with the extraction of phosphate ore of Abu Tartour, the most important factors that could be identified by using remote sensing and GIS techniques are subsidence and ore transportation.

A. Subsidence

Remote sensing data has been used to detect and delineate areas of subsidence as a result of surface and underground mining. Volk et al. (1990) have used Landsat-TM data to determine environmental effects of subsidence in the Ruhr region of Germany [11].

At Abu Tartour mine, one of the main problems obstructing the development and extraction of the ore is the supporting system due to frequent subsidence. The rate of advance and the limits of this subsidence are still causing severe problems; the mine has suffered from a great collapse in 1987. It is suggested that satellite remote sensing data are used for the detection of the rate of subsidence in Abu Tartour area.

B. Ore Transportation

Satellite remote sensing can be used to study the movement of sand dunes around railway and the roads. A scene or more of suitable remote sensing data is required for several years to study the rate and direction of advance of the sand dunes. Having succeeded to define such technique a further work is needed to minimize the effect of the dunes.

C. Input Data

- Satellite imagery (1980-2010) Landsat TM and Spot Pan,
- Digital elevation models,
- Iso-grade maps (P2O5) distribution,
- Geological maps,
- Wind direction map in different seasons,
- Water wells distributions and characteristics,
- Transportation scheme (trucks, trains, others),
- Storage areas,
- Layout of the mining area,
- Artificial lake,
- Mining plant,
- Administration area,
- Green areas, Residential city, and
- Others.

D. Attributes

- X, Y coordinates (using GPS),
- Noise level at different zones,
- Water quality parameters and others.

E. Output Data

- Sensitivity maps for the environmental zones,
- The best storage place for the waste materials,
- Static water level,
- Future expansion of the residential city,
- Determining the areas of the most environmental impacts,
- Socio-economic studies of the project,
- Updating maps, and
- Statistical analysis
- Determining the areas of the most environmental impacts,
- Future studies for the expansion of the mining works,

For environmental mapping related to mining aspects, GIS could be applied for the following investigations:

a) Integrate GIS and remote sensing for environmental management at the mining areas

b) Use GIS techniques to provide a sensitivity environmental map showing the areas of highest and lowest environmental impacts

F. Comments

Selection of either surface or underground mining method is no longer based on mining, geological and economic considerations only, but environmental impacts should be considered. The working methods and restoration should be controlled to a much higher degree so that mines and quarries cause less environmental hazards. Reclamation of the land-use after the mining compilation is a must. Mining safety regulations (M.S.R.) should be changed for more safety and environmental considerations.

It is recommended that the authorities start to protect the residential area from dust and other hazards by constructing green fans around the mine area. At the same time groundwater wells need continuous monitoring for more safety and better control of contaminants. It is highly recommended to establish a GIS system in Abu Tartour project to assist in monitoring the overall progress and support the decision making.

VI. Conclusions

Mining activities are becoming highly international. They face fashionable environmental challenges that are difficult to counter by merely adopting new, environmentally friendly practices. Mining authorities must recognize that a haphazard approach to tailings deposition and storage may result in problems that can damage public health as well as lead to a market collapse.

The most efficient approach to long-term tailings safety includes development of a tailings management plan, identifying the major environmental issues and any associated risks and then implementing the necessary engineering practice plan.

The environmental impacts of mining operations express the need to develop an environmental monitoring system using GIS, remote sensing and computer aids. The study of Abu Tartour mine area recommends the design and implementation of a suitable technique for rapid low-cost production of sensitivity maps by integrated Geographic Information System with digital image processing system. Such a technique will have potential uses in environmental investigations. Creating Geographic Information System will facilitate the management of the environmental impacts in the area and to evaluate environmental trends over the past 30 years.

The environmental challenges faced by mining activities should not be underestimated. All the major mineral-consuming areas face problems of one sort or another. Pioneering computer software, designed to identify more sustainable integrated approaches to waste management, has been recently developed. We are invited to take part in the newly and progressively developed new world.

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