Pollution Indicators as a Tool to Eestimate the Groundwater Aaffection Level in Mining Areas

Teresa Bros [a)], Jorge Loredo [b)]

[a)] *IGME. Oviedo Territorial Office. Spain. Email: mt.bros@igme.es*
[b)] *Department of Exploration and Mining. University of Oviedo. E.T.S. Mining Engineers. Independencia, 13. 33004 Oviedo. Spain. Email: jloredo@uniovi.es*

Abstract
Mining activities are usually considered as potential sources of pollutants for water bodies, then it is necessary the search of key parameters, which can give precise information about the level of pollution generated by the mining activities. These parameters constitute the mining pollution indicators, which turn into tools more and more useful to avoid the environmental impact produced in mining areas. The definition of indicators is basic to the application of Decision Support Systems; they support and improve the process to take decisions in order to solve pollution problems. In this paper four groups of pollution indicators which can be useful to solve pollution problems in water bodies derived from mining activities are presented.

Key words: Pollution indicators, mining areas, Decision Support Systems**.**

Introduction
The water framework directive was created to answer to the need to unify the actions as regards of water management in the European Union, and to establish homogenous environmental objectives for all the member states. The last objective of the WFD is to reach the good status of water bodies, through the protection and improvement of the hydric environment constituted by water and dependent aquatic systems, contributing to a sustainable use of water. The WFD establish a communitary performance framework in the field of water politics, requiring the identification, assessment and cost-efficiency analysis of the necessary measures to achieve the good ecological state of waters.

It is well known that the status of water resources is a predominant factor in order to support a sustainable development and in this measure, the anthropogenic action influences in a significant way, and the natural water quality can be considerable disturbed with the development of the mining activities if preventive or corrective actions are not take into account. The pollution generation associated to the extractive activities in a mining area makes necessary the search of appropriate indicators which can put in evidence the pollution degree. This task can result complicate in mining areas due to the absence of homogeneity of the ore deposits characteristics.

In order to carry out a good environmental management of water resources, appropriate information systems allowing to know better the water state and the evolution of the impacts generated in the hydric system and the potential pollution sources in the different parts of the mining area are necessary. This requires the existence of monitoring networks to control the main parameters, as well as geographic information systems and monitoring standardized indicators.

A single management of each mining area is the most suitable technique in order to deepen into the problems associated to mining activity carried out in the area and in consequence to implement an effective politic against pollution.

The decision support systems (DSS) are informatics tools more and more used for a sustainable environmental management. They are about systems that interrelate models made for a mining area with data bases, generating a fun of possible solutions. Main purpose of these systems is to help and to facilitate the decision making process relative to very complex problems where multiple factors are involved.

In a decision making process it is necessary to dispose of very different information, including technical, environmental economical, institutional and cultural considerations. In order to define a model, it is basic to take into account a great variety of data (geological, hydrogeological, mineralogical, physico-chemical, biological, environmental, socioeconomic, etc.). The selected data must exactly represent the situation of the zone under study. In order to define a model, is basic to count on a great variety of data (geological, hydrological, mineralogical, physico-chemical, biological,

environmental, socio-economic, etc.). The selected data must represent exactly the zone under study. All this group of data defines the named *"Pollution indicators"*.

Pollution indicators

The indicators to be defined are measurements or statistical data referred to the water quality change that are related to a specific problem. They must provide information and describe the state of the phenomenon object of study, but with a meaning going further over that the directly associated to an individual parameter (OECD, 1993). The objective of the indicators for a decision making process is to elaborate tools allowing to supervise, communicate and make accessible the scientific and technical information for different user groups (SCOPE, 1995; Winograd, 1995 a, b).

The pollution indicators are an important element to define the degree of environmental impact associated to a mine site, in that it reflect in a quantitative form, the situation of the most relevant aspects. The use of indicators of general scope is not always the most appropriate, since these indicators can be not enough representatives of the characteristics of the zone under study. Neither the use of an excessive number of indicators is very feasible, since they can generate confusion and make more difficult the decision making process. Then, the selection of global pollution indicators for a mine site is a hard and difficult task, due to the great variety of factors and variables taking part in the pollutants generation and furthermore they are usually changing on the time.

In table 1 is included a proposal for a set of pollution indicators responding to the whole of factors inviting to the use in that it involves a bigger control of the affection generated on waters in the mine site area from an environmental point of view. They have been selected to characterize and provide all relevant environmental information for the zone under study. For these purposes they have been associated in four groups describing the main environmental problems associated to mine operations. In some of the groups a series of subindicators have been also defined in order to obtain more detailed knowledge of the problem.

Table 1

Global indicator	Pollution indicator	Subindicators
Water quality	Pollution incidents rate happened in the mine.	
	Quality of mine effluents, surface waters and groundwater.	Content in nitrates, chlorides, sulphates. Content in metals: As, CN, Cu, Fe, Mn, Pb, Zn, Hg, (mg/l).
	Chemical characteristics of tailing ponds.	Content in nitrates, chlorides, sulphates and dissolved oxygen (mg/l).
		pH, Conductivity (µS/cm) and Temperature (ºC) of mine effluents.
		Oil contents.
		DTS and STS
		Content in metals: As, CN, Cu, Fe, Mn, Pb, Zn, Hg, (mg/l).
Water quantity	Volume of mine effluents (m^3/day).	
	Gauging data in rivers and streams of the area.	
	Flow and level variations in natural water surgences.	
	Over exploitation of surface waters and/or groundwater.	
	Spillage to surface waters.	

	Yearly precipitation rate.	
	Piezometric level fluctuations due to pumping or pumping cessation.	
Biodiversity	Presence of protected areas or ecological important areas in proximity. Living species number in water courses. Probability of occurrence of droughts and floods. Species resistance facing to pollution situations.	
Soil types	Presence of pollutants.	Hydrocarbon content
	Heavy metals in sediments.	As, CN, Cu, Fe, Mn, Pb, Zn, Hg, (mg/l),
	Mineralogy of spoil heaps.	Pyrite, galena, sfalerite, arsenopyrite,carbonates,…

The first group (water quality) includes indicators that try to define the chemical characteristics of water forming part of the system, so much of the effluents flowing through the mine as groundwater and surface water flowing on the area, that they are in hydric connexion with the system that has been modified by the mining activities. These indicators show direct information about the main pollution problems in this area.
The second group (water quantity) includes parameters related to flow variations in natural surgences and piezometric level variations. It is also considered in this group the volume of water from possible pollutant sources in the mine.
The third group of indicators (biodiversity) allows knowing the ecological quality of water from the hydric systems in the area (rivers, streams, wetlands, etc.) through the monitoring of the different living species in the water. They offer indirect information about the damage in waters.
Finally, the four groups of indicators (soil types) inform about the presence and the nature of certain substances presents in soils that by different processes such as lixiviation and infiltration can reach the water bodies causing pollutant affections. Furthermore, the knowledge of the mineral species present in the exploited ore deposit can predict in advance the characteristics of water.
Once defined the indicators to be used by the Decision Support System, the next phase is the indicators weighting that allows estimating the relative importance that an indicator has in the case under study.
In the case of mining pollutants the weighting is basically made based on the quantity of pollutant present by litre (mg/l) and/or by Kg of analysed sample. The assignation of a value for each indicator is an operation that must be made by the work team, because although is a subjective valuation the margin of error decreases significatively when the valuation is made by people that know the problem associated to the area under study. A multidisciplinar team is the most effective because the valuation will be made with a more wide perspective. These values are supplied to the Decision Support System, and after analysing all the information provided, they show the results and the different alternatives as solution. In all cases it is necessary to have in mind that the reliability of the result (*output*) will always be connected to the quality of the data (*input*) and to the viability of the models.
Next phase will be the selection of the most suitable alternative. In spite of the Decision Support Systems (DSS) provide different alternatives to solve the problem to the user, it is inevitable that once the system begins to be functional, it will be carry out a proof process to verify that is suitable for the real scenario. Is in this part of the process when the calibration and a re weighting of the indicators can be necessary to reach results that really represent the situation of the mine site.

Conclusions

The definition of pollution indicators for their application in decision support systems in mine water management allows to make an analysis and monitoring of the environmental state for the area affected by a mining operation, whereas the processes included in the mining operations and the potential impacts on the environment. The decision support systems are tools more and more used to diagnose and to solve pollution problems in a mine site. It is very important to remark that the effectiveness of the tool is based on the accuracy of the environmental conditions of the site, represented by the pollution indicators.

References

OECD (1993) OECD Core Set of Indicators for Environmental Performance Reviews. A Synthesis Report by the Group on the State of the Environment, OECD, Paris, 35pp.

SCOPE (1995) Sustainable Development of the Scientific Community on Problems of the Environment. International Workshop on Indicators of Sustainable Development for Decision-Making, 9-11 January, Ghent, Belgium.

Winograd, M (1995a) Environmental Indicators for Latin America and the Caribbean: Tools for Sustainability, En: T. Trzyna (Ed.) A sustainable World: Defining and Measuring Sustainable Development, pp.198-215 The World Conservation Union (IUCN), International Center for the Environment and Public Policy, Sacramento, CA.

Winograd, M (1995b) Conceptual Framework to Develop and use Environmental and Sustainability Indicators for Policy/Making in Latin America and the Caribbean, Position Paper Proyecto CIAT/UNEP, CIAT, Cali, Colombia, 50 pp.