GIS-APPLICATION FOR ENVIRONMENTAL MANAGEMENT IN MINING AREAS ON THE EXAMPLE OF THE QUANG NINH PROVINCE, VIETNAM

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ABSTRACT

Environmental contamination due to mining in Vietnam increasingly draws attention from decision makers and local residents. Ecological awareness within the mining companies also increases as they realize the need for environmental measures and sustainable development strategies. Many efforts are made to combat environmental pollution. During this process it got more and more clear that decision makers in the mining companies face a serious lack of information. Geographical Information Systems (GIS) are a possible solution as they provide not only tools for storage and management of data but also tools for evaluation and visualization.

The Research Association Mining and Environment in Vietnam (RAME) funded by the German Federal Ministry of Education and Research (BMBF) aims at contributing to close the information gap by developing methods of collecting, managing and reporting environmental information. The developed methods are tested in one of the Quang Ninh coal mining areas. Aggregation of data and their visualization in a map based environmental report allows decision makers to assess the priority of measures and their impacts. In this way, environmental protection investments can be based on actual data and science-based predictions of impacts.

1. INTRODUCTION

Vietnam's coal mining activities are concentrated in the North-east of Vietnam in Quang Ninh Province where coal mining has a long history dating back to the French colonial time. Nowadays coal is mined by several open pit and underground mines of different sizes. The mining sector of Vietnam is dominated by state owned companies. Most companies are subsidiary enterprises of Vietnam National Coal and Mineral Industries Group (VINACOMIN). Coal mining has a considerably large impact on the environment. The mining activities lead to water pollution, air pollution, problems with dump stability, noise emission and vibrations.

The example described in this paper focuses on water issues. The hydrological situation in the project example area is characterized by distinct rainy and dry seasons leading to a highly variable runoff. The drainage system is strongly influenced by mining leading to changing catchment areas. The water pollution is caused by drainage water from open pits and underground mines, seepage water from active and closed waste rock dumps, runoff from coal processing sites, sanitary waste waters from other facilities like workers' bathrooms and kitchens. The most relevant water hazards are high concentrations of Iron, Manganese and fine coal particles, low pH values and partly also increased concentrations of heavy metals.

The RAME research project addresses the important challenge of enhancing environmental management and pollution mitigation in Vietnam's coal mining sector. The project collaborates closely with VINACOMIN. Table 1 shows the project structure with all research fields and institutions involved.

Table 1. Structure of the RAME project.

Environmental Management System, Capacity Building and Project Coordination Bochum University, Environmental Engineering and Ecology VINACOMIN, Environmental Department				
Stabilization and Recultivation of Dumps	**Mine Water Treatment**	**Dust Mitigation and Monitoring**	**Plant Based Technologies**	**Landuse Planning after Mining***
- Aachen University, Mining Engineering - Brenk Systemplanung GmbH - VITE[1] - Nui Beo Coal Company	- LMBV International - Eta engineering - Groundwater Research Institute - VITE[1] - Vang Danh Coal Company	- Aachen University, Mining Engineering - Brenk Systemplanung GmbH - CBM[2] - VITE[1] - Nui Beo Coal Company	- Helmholtz Centre for Environmental Research - BioPlanta GmbH - VITE[1] - Nui Beo Coal Company	- Bochum University, Environmental Engineering and Ecology - DHI-Wasy GmbH - VINACOMIN, Environmental Department - VITE[1]

*planned
[1]VINACOMIN Informatics, Technology, Environment Joint Stock Company
[2]Consulting, Business and Management GmbH

Environmental management in the mining sector in Vietnam is still a new task. Although the mining activities are distributed to many separate companies, the environmental measures should follow a holistic approach for the whole area. In order to do this in a first step the environmental data need to be collected from companies, departments and institutions and combined into one information system that could provide good data to decision makers. Based on these data, measures can be planned, taking into account not only the local view for one single mine but also other neighboring mines and environmental damages outside the mine border. Environmental planning then also could include long-term targets and strategies. Together with an enhancement of the knowledge of the environmental staff the environmental budget could be used more effectively.

As mentioned before there is a high demand for a reliable and easy to apply overall Environmental Management System (EMS) based on the available data. The decision makers need regular environmental reports with a defined structure and aggregated information in order to fulfill their management tasks.

The main objective of the proposed EMS is to enhance an environmental management in order to reach fast and cost effective improvements of the environmental situation in the mining areas. The system should increase the management efficiency of the Environmental Department. It should provide the information for environmental reports used for decision makers in the management level but also for reporting to other institutions outside VINACOMIN.

2. GIS-BASED METHODOLOGY OF ENVIRONMENTAL MANAGEMENT

2.1 Plan-Do-Check-Act-Cycle

The proposed environmental management system is based on the quality management approach called PDCA principle. PDCA stands for PLAN-DO-CHECK-ACT (Deming, 1986) that describes an iterative circle to improve a process or situation. The frame of the management cycle is given by the environmental policy that is setup by the company. The goal of the PDCA-cycle is to meet the goals of the environmental policy.

The PDCA-cycle suggested consists of four steps (see Figure 1).

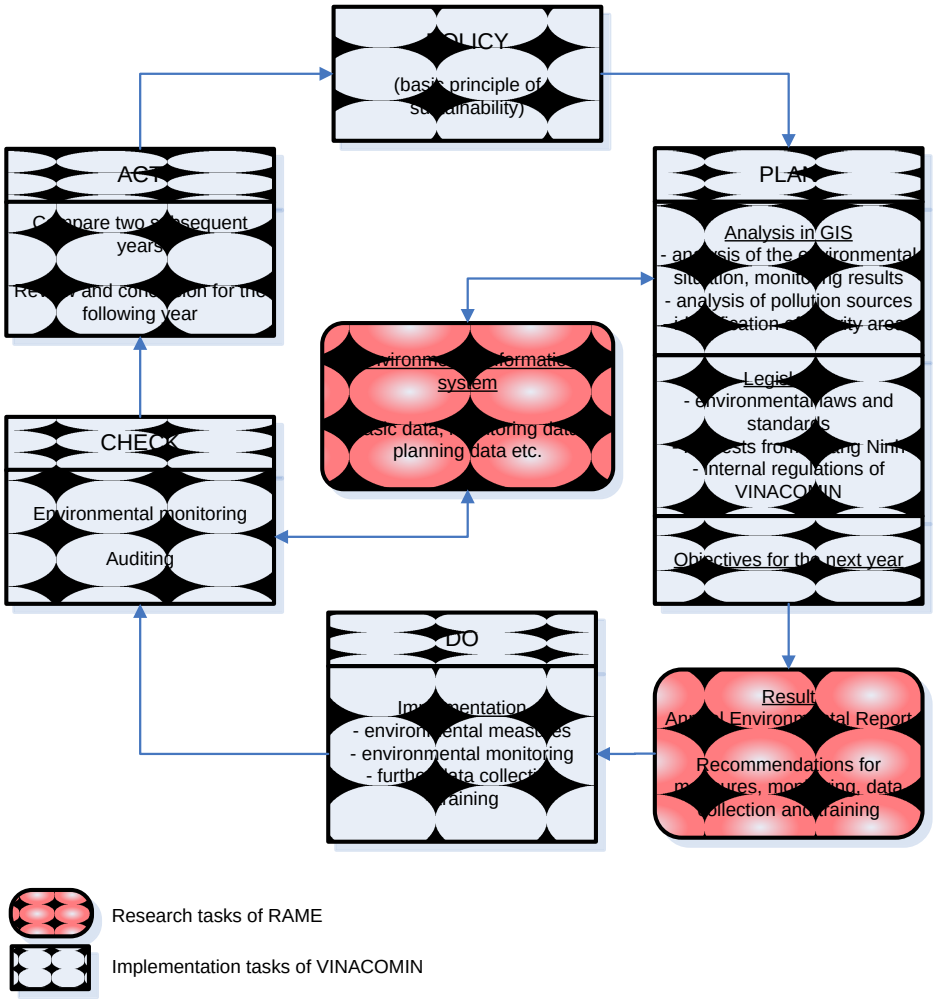

Figure 1. Environmental management system after principles of W. E. Deming, adapted.

The step PLAN establishes the objectives and processes necessary to deliver results in accordance with the expected output. For the EMS it includes an analysis of the environmental situation in GIS based on the monitoring results. Together with an analysis of the pollution sources priority areas and locations are identified. Important inputs for this planning step are also the legislative conditions as environmental laws and standards, special requests by the provincial government and internal regulations of the company. Finally, based on the environmental policy the objectives for the next period, usually one year, have to be defined. The output of the planning step is an annual environmental report giving recommendations

for environmental measures, for improvements of the monitoring system, for further data collection and also for training of environmental staff.

The step DO stands for the implementation of the new processes. For the EMS environmental measures have to be implemented, the monitoring system has to be improved if necessary. Furthermore, the data still missing have to be collected and the environmental staff has to be trained according to the recommendations of the environmental report.

The step CHECK measures the new processes and compares the results against the expected results to ascertain any differences. For the EMS the step is represented by the regular environmental monitoring where the status of the environment in the areas affected by mine activities is recorded and compared with the corresponding environmental standards.

The step ACT analyzes the differences to determine their cause and to determine where to apply changes that will include improvement. For the EMS the impacts of the conducted measures are analyzed and compared for two subsequent years, the current year and the year before. Were the measures successful they can be applied further and in other locations. Otherwise, the measures have to be adapted. The output of this step is a necessary input for the planning step where the cycle starts again. In some cases the review also finds that the environmental policy has to be adapted.

2.2 GIS-based Environmental Report

The annual environmental report was chosen as the environmental management tool to inform decision makers and to enable them to find good investment decisions. The report is divided into the following fields of activity: water; waste rock dumps and waste; air, dust and gases; noise and vibration; landuse; and energy consumption.

The report is based on an ARCGIS 9.3 geodatabase that provides all relevant information such as environmental data, monitoring data, environmental standard values etc. From the geodatabase maps are generated which represent the main element of the report, as each step in the line of argument is visualized by a map. The following paragraphs describe the methodology exemplarily for the field of activity “water”.

Step (1): Basic data like topography, road system, river network, administrative borders but also basic data on the location of mine activities are shown in base maps. They allow the user to orientate on the map. Base maps were created from available topographic data, CAD drawings of mine facilities and satellite pictures. The following base maps have been prepared: topography, administrative borders on district and commune level, licensed mining borders with mine facilities.

Step (2): In case of water issues all processes depend on the water flow direction, so catchment areas are chosen to be the management units. In order to define them, a digital elevation model based on contour lines and additional elevation data was created. Then the natural catchments were calculated using hydrological tools in GIS. As in the project area open pit mining takes place, some artificial catchments are created which have no natural discharge point. The collected water is pumped into neighboring rivers and catchments. This information has to be included in the map and upgraded regularly as the shape of the open pits is changing depending on the coal extraction progress.

Step (3): The environmental situation is described. The map visualizes the environmental quality for the field of activity water, by evaluating available monitoring data, but also other available information on the status of waterbodies. For water currently, the focus is set on surface water bodies as on groundwater and coastal water only very few data are available.

Step (4): The pollution sources for water are analyzed for each catchment and described in a map. Already known and potential sources are visualized. It has to be decided whether they are point, line or areal sources. In case no exact information is available this information has to be estimated from the kind of activity in this location. Pollution sources related to water are mine waters running from underground mines and open pit mines, surface runoff and seepage water running from waste rock dumps, surface runoff from coal transport roads, coal storage areas, coal processing areas, potential runoffs or leaks from fuel stations, truck workshops and storage areas of hazardous substances. This information has to be collected and analyzed in order to identify pollution sources. For mine waters usually monitoring data from the mining companies are available. Other information can be retrieved from a process analysis, landuse data or the corresponding managing departments at the mine. The sources are visualized including information on the type of pollution and the potential or known pollution load.

Step (5): The environmental status of each catchment is assessed and classified according to their environmental quality. Currently, three classes "low quality", “medium quality” and “high quality” are defined. By taking into account all available information on the water quality in a catchment, one of the three classes is assigned to each catchment (see Figure 2).

Step (6): The pollution sources are assessed and classified according to their need for treatment. Depending on the pollution load, the legal requirements, environmental fees etc. the sources are assigned to the different pollutant load classes. Currently, three classes “low pollution load”, “medium pollution load” and “high pollution load” are defined. The pollution sources are assessed and classified depending on the pollution load and its risk potential for the environment, e.g. high pollution loads and sources containing very hazardous substances are considered as “high pollution load” (see Figure 2).

Step (7): The maps from steps (5) and (6) are combined and analyzed using GIS in order to create a map of recommended measures. E. g. high pollution load sources in a catchment with low environmental quality will receive the highest priority for environmental measures (see Figure 2). Other combinations of pollution load and catchment environmental quality will receive high, medium etc. priority. The type of measures depends on the pollution sources. For mine water streams a suitable type of waste water treatment is recommended

Step (8): The implementing company or department responsible for the implementation of environmental measures is determined. Therefore, for each pollution source the responsible mining company has to be identified in GIS.

Step (9): In additional maps further recommendations are visualized, for instance an improved monitoring network or areas where the system still has not enough or not good enough information for decision support.

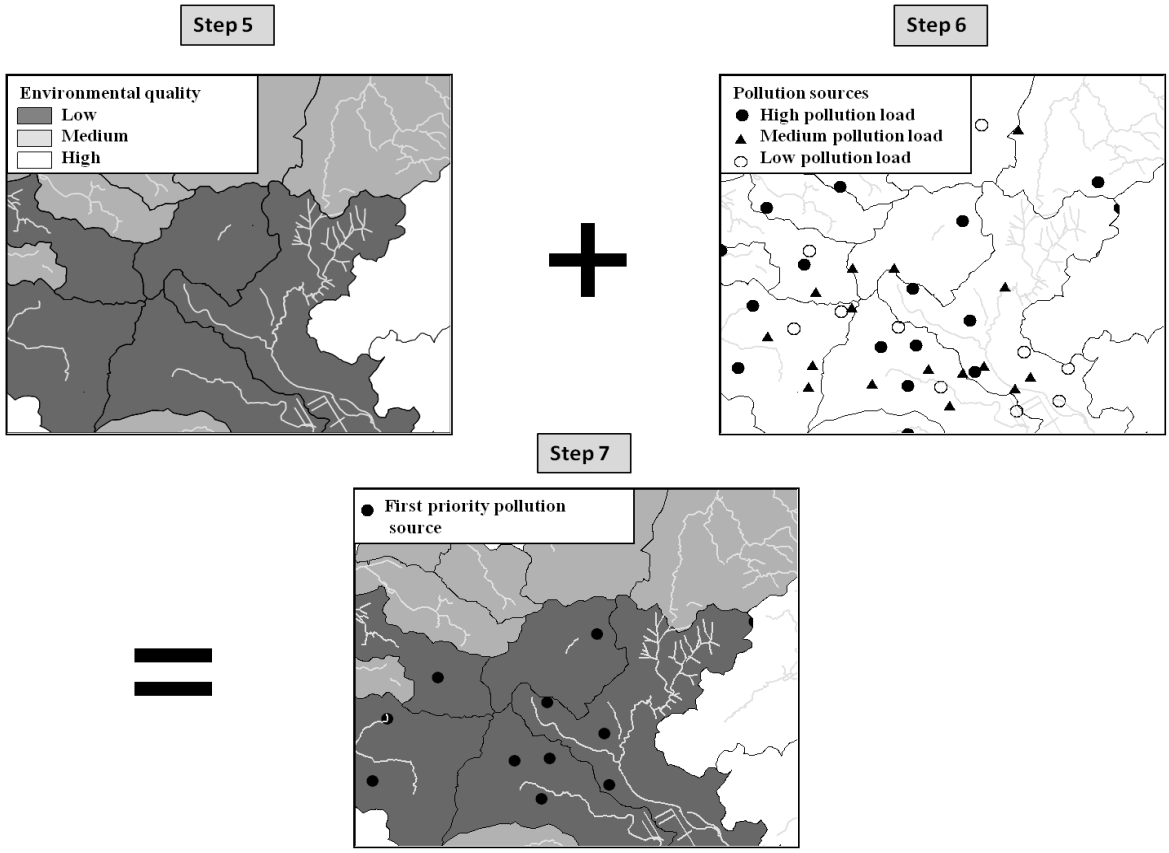

Figure 2. Prioritizing process for water pollution sources.

3. CONCLUSION AND OUTLOOK

The GIS based Environmental Management System that has been developed, allows aggregation of spatial and non spatial data in a plain way. Catchments with low environmental quality and high pollutant load sources can be defined easily. The aggregation of data from different sources and of different quality allows decision makers to get quick and reliable information. The method provides well informed recommendations for priority environmental measures and advanced environmental monitoring. After implementation the recommended measures for pollution and risk mitigation can be evaluated and their impacts easily assessed and visualized in maps. Together with the annual environmental reporting system the environmental management for a mining area is considerably improved.

The proposed methodology has a great potential to contribute to improving the environmental situation in the mining sector. Especially in all those countries that face the challenge of making decisions in the field of environmental protection with limited data sources and limited financial sources.

4. REFERENCES

Deming, W. E., 1986. *Out of the Crisis*. MIT Center for Advanced Engineering Study. ISBN 0-911379-01-0.