ENVIRONMENTAL RECLAMATION AND POST-MINING LAND USE PLANNING

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The RAME research project started its first activities in Vietnam at the end of 2005. The aim of the BMBF (German Federal Ministry of Education and Research) funded research and development project is to develop methods to reduce the environmental impacts due to hardcoal mining in Quang Ninh province / Vietnam by selected technical measures and enhancement of the environmental management. Based on a preliminary survey, dump stabilization and recultivation, mine water treatment, dust mitigation and post-mining landuse were identified as main research fields and are the subjects of subprojects. This publication highlights the RAME research on post-mining land use planning which is a completely new subject for the Vietnamese mining industry.

1. The RAME joint research project

In 2005, the Research Association Mining and Environment (RAME) and the Vietnam National Coal – Mineral Industries Group (VINACOMIN) agreed on a collaboration in order to develop environmental concepts and measures for Quang Ninh hardcoal mining areas. RAME is coordinated by the Institute of EE+E Environmental Engineering+Ecology, Ruhr-University of Bochum (Prof. Dr. Harro Stolpe, Dr. Katrin Brömme) and is funded by BMBF (German Federal Ministry of Education and Research).

2. Subprojects of RAME joint research project

The subjects of the joint research project RAME are related to main environmental problems of hard coal mining in the Quang Ninh Province, Vietnam [1]. The RAME research project consists of 6 subprojects (fig. 1).

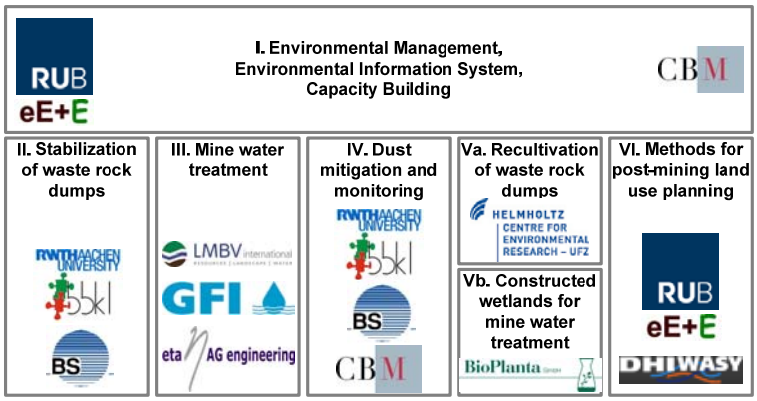

Figure 1 *The RAME project structure*

2.1 Subproject I: Environmental management, environmental information system, capacity development

Decisions on environmental measures require knowledge about emission sources, transmission paths, immission areas etc. Furthermore, knowledge about environmental technologies, hazards, legislation, the available budget and the costs of measures is required. In order to manage all these information, an environmental information system and environmental reports were developed. The environmental reports are instruments for environmental management. They contain information about the status of the environment and recommendations for monitoring and remediation measures.

The subproject (project start 2007) is carried out by the Institute of Environmental Technology and Ecology at Ruhr-University of Bochum and CBM GmbH, Aachen (capacity development).

2.2 Subproject II: Stabilization of waste rock dumps

The project site for dump stabilization (project start 2008) is a typical dump; it is filled with heterogeneous waste rock materials using the sidehill fill dumping method. Thereby, a segregation of waste rock particles occurs where fine particles stay at the upper part and coarse materials move towards the foot of the dump. Further stability risks are caused by mechanically labile material layers inside the dump and subsidence processes due to uncompressed materials. The task of the subproject is to investigate the dump in order to quantify the stability and to develop solutions to reduce the risks of landslides.

The research of the subproject has two main components. One is the investigation of the dump stability by monitoring of dump movements, other signs for failures, seepage water flows and geomechanical investigations by drillings and trial pits. This component also investigates the risk of acid mine drainage from the dump. The second component is a large scale test of a different dumping method in layers including compression by trucks under controlled conditions in order to develop technical guidelines for the dumping process in the future [2][3][4].

The subproject is carried out by the Institute of Mining Engineering I, RWTH Aachen University and the company Brenk Systemplanung, Aachen.

2.3 Subproject III: Mine water treatment

Within the framework of subproject III, a mine water treatment plant for an underground anthracite mine in Northern Vietnam was developed. Limiting factors for the development of a suitable treatment process have been the rather limited financial resources, the limited size of the construction area, the tropical and humid conditions in Northern Vietnam and the prerequisite of the Vietnamese partners to run the plant with a low amount of additional chemical substances besides lime.

Because of the high volume fluxes and the very limited space, only active treatment was an option. While Fe and coal particles can be removed by classic oxidative mine water treatment (neutralisation by lime, oxidation, flocculation, sedimentation), Mn removal is more demanding. Thus, most effort was spent on developing a suitable Mn removal. Based on preliminary tests, sorption to parallelly precipitating iron hydroxides and catalytic oxidative Mn removal was chosen as Mn removal method [5][6][7].

The implementation planning was finished with great support of the Vietnamese partners in 2010. It was then supplied to the Vietnamese partners, who realized the construction. The plant successfully started its operation in August 2012.

The subproject is carried out by the companies LMBV-International, eta engineering AG and GFI Dresden.

2.4 Subproject IV: Dust Mitigation and Monitoring

The project site for the dust mitigation subproject (project start 2009) includes open pit mines, large waste rock dumps, coal and waste rock transport routes, coal screening areas and a coal processing plant as well as a coal harbour. Furthermore, the area is located very close to residential areas of Ha Long City which are especially sensitive to dust emissions. The task for the subproject is to perform an extended dust monitoring in the area following the production chains of the coal. As a result, the most relevant dust sources were identified. Subsequently, dust mitigation measures were developed and tested for these dust sources.

The subproject is carried out by the Institute of Mining Engineering I at RWTH Aachen University and the companies Brenk Systemplanung and CBM GmbH, both in Aachen.

2.5 Subproject Va,b: Plant based methods (Recultivation, Constructed Wetlands)

One task of this subproject (project start 2008) was to develop and test long-term stable and sustainable concepts for a recultivation of the dump site. The subsequent step includes recultivation measures aiming to assist nature by utilizing natural succession. Locally adapted plant species occuring already in the original natural vegetation are grown in distinct islands serving as colonization initials. The chosen methodology aimed at developing a fully functioning, self-sustaining system that involves besides plants also natural processes of soil development and nutrient cycling.

In order to develop the method in detail, the subproject designed recultivation experiments. The experiments compare tree species and grass species as well as different ways of soil improvement. Furthermore, the recultivation results are compared with already established plantations using traditional recultivation trees [8][9].

The second task of this subproject is mine water treatment by constructed wetlands for an area where the acid water in a lake strongly affects the agricultural production downstream. Beside other mine influenced waters, seepage water drains a waste rock dump into the lake. The subproject has the task to test whether this kind of water can be treated successfully in a constructed wetland.

The constructed wetland was designed as a passive biological treatment facility with two treatment steps in two basins one after another. The first basin contains a limestone drainage passage covered by mixed manure. The second basin contains a planted gravel filterbed. The pilot scale constructed wetland has a designed capacity of 4.4 m^3/h [10] and is in operation since 2011.

The subproject is carried out by the Helmholtz Centre for Environmental Research – UFZ in Leipzig and the company BioPlanta GmbH in Leipzig.

2.6 Subproject VI: Methods for Post-Mining Land Use Planning

The project on post-mining landuse planning is presented in more detail in the following chapters of this publication.

3. Framework conditions for post-mining land use planning

The subproject on environmental reclamation and post-mining land use planning (project start 2011) has the task to develop an approach for planning of post-mining land use under consideration of the surrounding land uses and land use requirements.

The chosen project area is Hon Gai region where in the near future all large open pit mines are closed and partly shifted to underground mines. The large open pit mines in this region are Nui Beo, Ha Tu and No. 917 mines. At least in Nui Beo mining is continued in the

underground. Here the works for preparing underground mining have begun already.

The open pit mining in this region over a long time has created a special mining landscape with deep open pit holes, high waste rock dumps, a system of haulage roads and other mining facilities in between. Furthermore, other land uses like residential areas are scattered between the mining areas. The water regimes of surface and ground water are adapted to the mining needs. Most of the area has no vegetation cover.

The post-mining land use planning has to take into account all framework conditions due to active and abandoned mining and shall contribute to mitigate land use conflicts between mining / urban areas / conservation / tourism, etc. in this region. A planning and communication concept is developed, which includes already existing and new ideas for post-mining land use.

The subproject is carried out by the Institute of Environmental Technology and Ecology at Ruhr University of Bochum and DHI-WASY, Syke.

4. Solution approach for post-mining land use planning

The project develops rehabilitation and landuse planning concepts on the example of the region Hon Gai where in the near future three open pit mines will be closed down. The planning concepts work on both the regional and the local scale. They consider local economic, social and environmental aspects.

The planning works start on a regional scale by developing a regional masterplan concept. Based on this, local post-mining rehabilitation concepts with technical details are developed. Furthermore, an assessment of mine water impact on marine environment is performed. The final combination of the regional and local concepts leads to an integrated masterplan concept. Fig. 2 shows the described approach schematically.

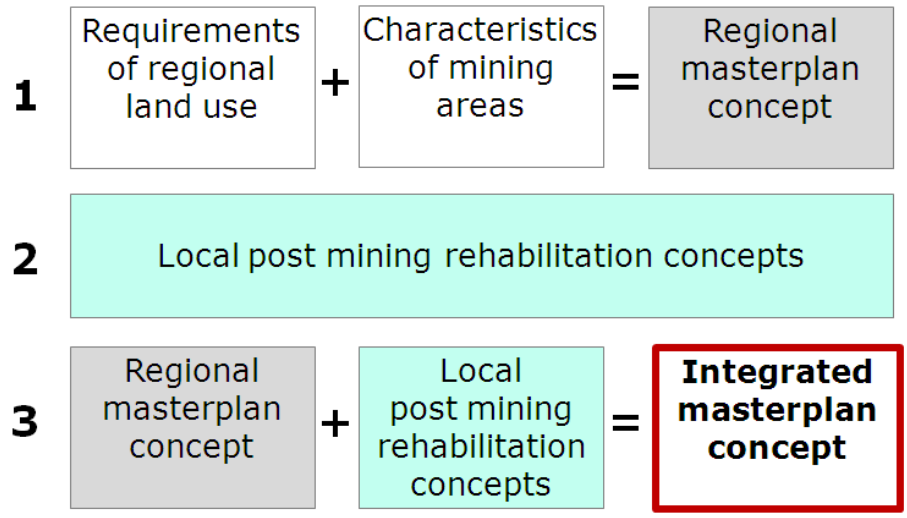

Figure 2 *Methodology of developing the masterplan concept*

4.1 Regional masterplan concept

As a basis for the regional masterplan concept the status of the region at important time steps has to be described and modeled in GIS (ArcGIS 10). Important time steps are:

- current status
- status at open pit mine closure
- planned status with active underground mining

- planned status after recultivation of open pit mines

For the time steps detailed status and planning information on land use and morphology have to be collected and processed into GIS.

In order to be able to decide which post-mining land uses are suitable for certain areas a list of post-mining land uses is developed which includes all necessary requirements to be fulfilled for establishing a certain type of land use. The list of post-mining land uses should be based on standard land uses used for regional planning in Vietnam. Table 1 shows the definition and assigning of requirements for the example of residential land.

Table 1: *Example for requirements of post-mining land use*

Post-mining landuse:	**Residential land**
Requirements: • *Safety factor*: high • *Degree of soil compaction*: high, no ground settlements • *Terrain, slope characteristics*: horizontal or mild slope • *Water drainage status*: effective water drainage • *Soil quality (nutrients, contamination)*: no contamination, eventually suitable for gardening • *Micro-climate*: no wind tunneling, good fresh air ventilation	

In order to describe the former mining areas in detail certain distinguishable categories are defined. Examples are waste rock dump plateau, waste rock dump slope, open pit slope, in-pit dump in former open pit etc. Corresponding with the requirements for post-mining land uses characteristics are defined. Table 2 shows an example.

Table 2: *Example for characteristics of mining areas*

Mining area category:	**In-pit dump in former open pit**
Characteristics: • *Safety factor*: low • *Degree of soil compaction*: low • *Risk for ground settlements*: high • *Terrain, slope angle*: horizontal or mild slope • *Water drainage status*: for rainwater depending on slope, soil for groundwater depending on original levels before mining • *Contamination status*: partly acid soils	

The characteristics of the mining areas strongly influence the reclamation methods, the reclamation costs and the suitable post-mining land uses. The mining area categories are visualized in GIS maps.

In a next step, the mining area categories and the post-mining land uses are compared and combined in order to develop regional masterplan concepts. On the one hand, they are visualized in GIS. On the other hand, they also will be visualized in 3D (Visual Nature Studio 3) for a better communication with all local stakeholders.

A comparison of different concepts with regards to economic aspects will be implemented in order to select planning concepts which will be developed further. For selected planning concepts then planning on a more detailed technical level is continued.

4.2 Local post-mining rehabilitation concepts

The local post-mining rehabilitation concepts investigate from the technical point of view how to transfer the land from mining area with certain characteristics to the selected post-mining land use. One possible example is: which technical measures have to be undertaken in order to re-use a former open pit mine refilled with waste rock dump as an industrial zone.

Furthermore, the local concepts investigate the water resources and drainage regime after mining in order to develop recommendations for post-mining water management in these areas. Environmental modeling is used to optimize post-mining land use with regards to environmental impacts on the marine environment.

4.3 Integrated masterplan concept

In a final step the results from the regional and local planning concepts are combined into an integrated masterplan concept. The concept consists of reports, GIS maps and 3D visualizations. In case of implementation of the masterplan concept all further planning and design works in the course of the rehabilitation then have to be based on it.

5. Conclusion

In the course of the RAME project, a solid mutual trust was built between German researchers, engineers, planners and developers and Vietnamese decision makers, engineers and planners. It lead to successfully implemented projects with benefits for both sides. Especially the permanent on-site presence of the RAME coordination proves to be very helpful. For a successful project progress, it is important to integrate the Vietnamese side in all planning steps and decision processes. For the recently started subproject on post-mining land use planning this is most important as such a planning process always is a process of try and error as well as active discussion with all involved stakeholders. Post-mining land use planning is a very new subject for the Vietnamese mining industry. The corresponding RAME subproject develops approaches and methods based on extensive experiences in German mining areas but adapted and suitable for the local circumstances.

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TÓM TẮT

Phục Hồi Môi Trường và Qui Hoạch Sử Dụng Đất Sau Khai Thác Mỏ

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Dự án nghiên cứu của RAME (Hiệp hội Nghiên cứu khai thác mỏ và Môi trường) đã bắt đầu các hoạt động đầu tiên của mình tại Việt Nam từ cuối năm 2005. Mục tiêu của dự án nghiên cứu và phát triển này được BMBF (Bộ Giáo dục và Nghiên cứu Liên bang) tài trợ là nhằm phát triển các biện pháp giảm thiểu các tác động đến môi trường do hoạt động khai thác than tại Quảng Ninh – Việt Nam bằng các giải pháp ky thuật được chọn lựa và nâng cao năng lực quản lý môi trường. Dựa trên cơ sở khảo sát ban đầu, phạm vi nghiên cứu đã được xác định bao gồm: ổn định và phủ xanh bãi thải, xử lý nước thải mỏ, giảm thiểu bụi và sử dụng đất sau khai thác mỏ và các nội dung nghiên cứu này là chủ đề của các dự án thành

phần. Bài viết này trình bày nghiên cứu của RAME về quy hoạch sử dụng đất sau khai thác là một vấn đề mới hoàn toàn đối với ngành công nghiệp khai thác mỏ ở Việt Nam.

Người biên tập: ***Nguyễn Chí Nghĩa***