5th International Symposium

MINING AND ENVIRONMENTAL PROTECTION

10 - 13 June 2015., Vrdnik, Serbia

MINING AND ENVIRONMENTAL PROTECTION

PROCEEDINGS

Vrdnik

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5th International Symposium **MINING AND ENVIRONMENTAL PROTECTION**

Editor: prof. dr Ivica Ristovic, Faculty of Mining and Geology, Belgrade

Publisher: Faculty of Mining and Geology, Belgrade

For publisher: Prof. dr Ivan Obradovic, Dean

Technical desing: SaTCIP, Vrnjacka Banja

Printed by: SaTCIP, Vrnjacka Banja

Copies: 150

ISBN 978-86-7352-287-6

The publication of this Proceedings approved by the Council of Faculty of Mining and Geology, University of Belgrade

All Papers in Proceedings are reviewed

This Proceedings was published with the financial assistance of the Ministry of Education, Science and Technological Development of Republic of Serbia

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5th International Symposium
MINING AND ENVIRONMENTAL PROTECTION
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GUIDELINES FOR PREPARATION OF MINE WASTE MANAGEMENT PLAN

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Abstract: *Mining operations and processing plant generate vast amount of waste (extractive) which falls under the scope of the Mining Waste Directive (MWD). The MWD has been implemented in Macedonian legislation through the Law on Mineral Resources. Waste Management Plans WMP are documents that describes the measures that should be implemented at the site to prevent or reduce adverse environmental effects, which may result from the extractive waste disposal or treatment. This paper presents our experiences and guidelines for preparation of management plan for waste generated in extractive industries in line with MWD. Also the paper point some of the most important measures necessary to assure that extractive waste is managed and controlled in a safe and environmentally acceptable manner.*

Keywords: *Mine Waste, Management Plan, Environment, Measures, Control*

1. INTRODUCTION

Waste management is one of the most important steps in achievement of sustainable development goal. The waste should be rationally handled and disposal sites should be carefully selected in order to reduce the environmental and risks to human health [1]. Preventive and protective measures taken should be based on best national and international practice, without prescribing the use of a particular techniques or specific technologies, but rather taking into account the technical characteristics of the mining waste facilities (MWF), their geographical location and local environmental conditions. Directive 2006/21/EC of the European Parliament and the Council of 15 March 2006 on the Mine Waste Management, known as the Mining Waste Directive (MWD) and amending Directive 2004/35/EC was published in the Official Journal of the European Union on 11 April 2006 (L102/15). The overall objectives of those regulations was to prevent or reduce as far as possible any adverse environmental effects as well as any resultant risk to human health from the Mine Waste Management. Requirements of the MWD have been transposed into Macedonian legislation through the Law on Mineral Resources.

2. OBJECTIVES OF THE MINE WASTE MANAGEMENT PLAN

WMP are very complex documents dealing quite diverse aspects of extractive waste management processes and site specific conditions. That way setting the clear objectives of the documents is the first step in creation of successful WMP. Overall objectives of the WMP could be summarized as follows [2]:

1. Prevent or reduce waste production and its harmfulness, in particular, by considering:
   - waste management in the design phase and in the choice of the method used for mineral extraction and treatment;

- the changes that the extractive waste may undergo in relation to an increase in surface area and exposure to conditions above ground;
- placing extractive waste back into the excavation void after extraction of the mineral, as far as is technically and economically feasible and environmentally sound in accordance with existing environmental standards at the Community level and with the requirements of the Directive, where relevant;
- putting topsoil back in place after the closure of the Mining Waste Facility (MWF) or if this is not practically feasible, reusing topsoil elsewhere; and
- usage of less dangerous substances for the treatment of mineral resources.

2. To encourage the recovery of extractive waste by means of recycling, reusing or reclaiming such waste, where this is environmentally sound in accordance with existing environmental standards at Community level and with the requirements of the Directive where relevant.
3. To ensure short and long term safe disposal of the extractive waste, during the design phase, management during the operation and after-closure of a mining waste facility and by choosing a design which:
   - requires minimal and, if possible, ultimately no monitoring, control and management of the closed Mining Waste Facility;
   - prevents or at least minimises any long term negative environmental effects from the Mining Waste Facility to the water, air and soil; and
   - ensures the long-term geotechnical stability of MWF.

3. STRUCTURE OF MINE WASTE MANAGEMENT PLAN

Considering the above objectives, mine waste management plan should contain enough information that specify the obligations of certain mine for dealing with mine waste in line with Mine Waste Directive and Law on Mineral resources, its possibility for implementation and achievement of MWMP objectives. According to the MWD Guidelines the following MWMP structure has been established [3]:

1	**Facility Classification**	Review on the criteria for classification of the Mining Waste Facility
2	**Waste Characterisation**	Background information's
		Description of the waste nature and its intended handling
		Geo-technical waste characteristics
		Geo-chemical waste characteristics
		Monitoring of the drainage systems
3	**Construction and management of Mining Waste Facilities**	Description of the Mining Waste Facility
4	**Risk assessment to the environment and human health**	Stability of Mining Waste Facility
		Surface and ground water pollution
		Air pollution
		Soil pollution
5	**Prevention measures of environmental risks**	Protection measures of water
		Protection measures of air
		Protection measures of soil
		Slope stability and overall strength of MWF constructive elements
		Environmental protection measures in case of emergency
		Administrative measures
6	**Control and monitoring procedures**	Monitoring during the construction and usage of MWF
		Monitoring during remediation phase
		Post closure monitoring
7	**Emergency Plan**	Purpose of the emergency plan
		Scope of the emergency plan
		Objectives of the emergency plan
		Alert in case of an accident on the MWF
		Alert levels and activities on the site location
8	**Proposed plan for closure aftercare and monitoring**	Selection of acceptable methods for closure / remediation
		Remediation Plan for MWF

3.1 Facility Classification

For all mining waste operations including a Mining Waste Facility, all operators must classify their Mining Waste Facility as Category A or provide justification that it is not a Category A facility. This is a particular requirement of the Mining Waste Directive (Article 5.3(a)) and must be included in the Waste Management Plan for the site.

Criteria for determination of Mining Waste Facilities as Category A are listed in Annex III to the Mining Waste Directive 2006/21/EC and include:

- If a failure or incorrect operation, e.g. the collapse of a heap or the bursting of a dam, could give rise to a major accident, on the basis of a risk assessment taking into account factors such as the present or future size, the location and the environmental impact of the waste facility; or
- it contains waste classified as hazardous under Directive 91/689/EEC above a certain threshold; or
- it contains substances or preparations classified as dangerous under Directives 67/548/EEC or 1999/45/EC above a certain threshold.

A Mining Waste Facility shall be classified under Category A in accordance with the first indent of Annex III of Directive 2006/21/EC if the predicted consequences in the short or the long term of a failure due to loss of structural integrity, or due to incorrect operation of a waste facility could lead to:

(a) non-negligible potential for loss of life;
(b) serious danger to human health;
(c) serious danger to the environment.

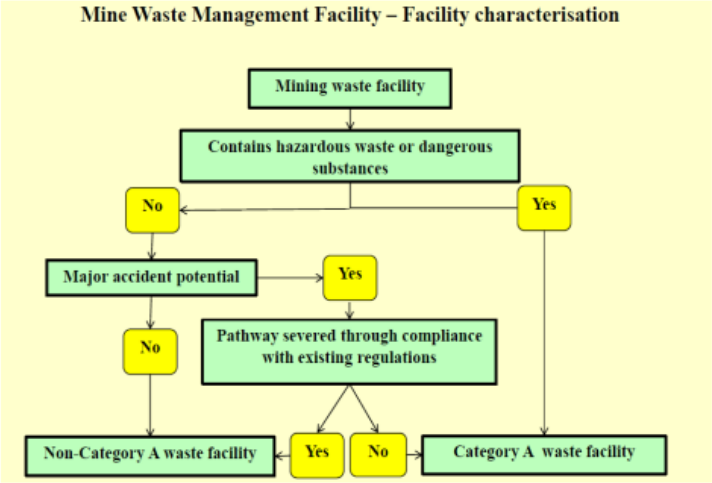

Figure 1 *Scheme for classification of the Mining Waste Facility [3]*

3.2 Waste Characterisation

In order to perform a proper and reliable waste characterisation in accordance with the Commission Decision (2009/360/EC) of 30 April 2009 and to complete the technical requirements for categorization of waste set out in Directive 2006/21/EC of the European Parliament and of the Council on mine waste management it is necessary to take into account the following information [4]:

- geological characteristics of mining site;
- background information of mining site;
- nature of the waste and its intended handling;
- geo-mechanical characteristics of the waste;
- geo-chemical characteristics of the waste.

In order to categorize the waste generated during the exploitation of mineral resources following information's have particular importance:

- The geological characteristics of the mine site and vicinity, including mineral and chemical composition of waste-rock;
- size and geometry of the mining site.

Background information of extraction/excavation site provide an overview and introduction to the basic background condition of mine site and objectives of its usage. Those data include information about:

- Activities in the field of exploration, extraction and processing;
- Description of the extraction method applied;
- Nature of the intended product/s.

Description of the nature of all the wastes occurring in each prospecting, extraction and processing operation, including overburden, waste rock and tailings, by providing information on the following elements:

- origin of the waste in the extraction site and the process generating that waste such as prospecting, extraction, milling, concentration,
- quantity of the waste,
- description of the waste transport system,
- description of the chemical substances to be used during treatment,
- classification of the waste according to Commission decision 2000/532/EC (1), including hazardous properties,
- type of intended MWF, final form of exposure of the waste and method of deposition of the waste into the facility.

To determine geo-mechanical characteristics of the waste, relevant parameters to be considered include: grain size, plasticity, density and water content, degree of compaction, shear strength and angle of friction, permeability and void ratio, compressibility and consolidation.

3.3 Construction and management of Mining Waste Facility

Based on environmental risk assessments suitable choice of a location and definition of measures necessary to prevent pollution of soil, air, groundwater or surface water, is particular important for the design and construction of Mining Waste Facility taking account of protected areas and geological, hydrological, hydrogeological, seismic and geotechnical factors in line with national legislation.

In respect of the construction and management of Mining Waste Facilities following issues must be considered:

- Efficient means for collection of contaminated water (and leachate if produced).
- Measures necessary to reduce erosion caused by water or wind.
- Measures that will be taken to ensure that the Mining Waste Facility will be constructed, managed and maintained in order to ensure physical stability in the short and long term.
- Measures that will be taken to prevent pollution or contamination from the Mining Waste Facility of soil, air, surface water or groundwater in the short and long term.
- Measures that have been adopted to minimise as far as possible damage to the landscape.

- Arrangements for rehabilitation of the land and the closure of the mining waste facility.
- Arrangements for aftercare of the mining waste facility.

Figure 2 shows procedures that covers safety management of tailings facility [5].

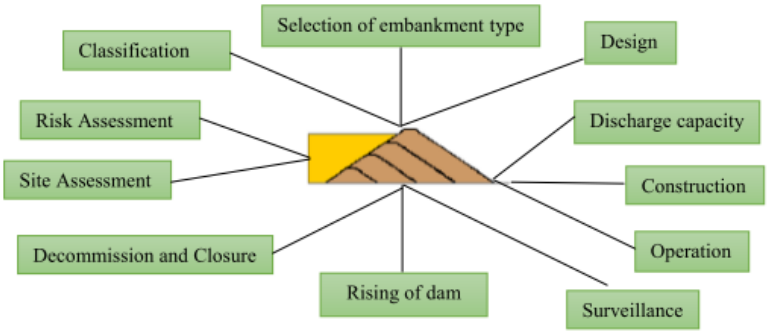

Figure 2 *Procedures of safety management tailings dam* [6]

3.4 Risk assessment to the environment and human health

Environmental risk assessment is realized through systematization and analysis of existing information and support for implementation of the planned activities of the Mining Waste Facility, their environmental impact and compliance with the Law on Mineral Resources. Environmental risk assessment refers to changes that may occur in the waste-rock which on the surface is exposed to weathering and its environmental impact (based on the identification of the source-path transmission-receptors).

Risk assessment is intended to show that the proposed measures will ensure human health and prevent short or long term harms of the environment, as well as safety disposal on mining waste. During environmental risk assessment should be taken into account the stability of MWF in order to draw attention to the fact that these facilities will be stable for a longer period.

Ecological risk assessment identify all potential hazards and pollution associated with the disposal of the waste-rock, risks and impose measures for risk management that are propose to be implement in order to mitigate these risks. The proposed mitigation measures should meet the requirements of mining waste in accordance with the Law on Mineral Resources, including the need to prevent air, water and soil pollution.

Figure 3 shows risk assessment steps [5].

Scope and purpose of risk assessment is to determine and identify all stakeholders in the risk assessment. Risk assessment is a structured methodology aimed at:

- Identifying hazardous substances inventory
- Identifying possible accidents
- Estimating the Frequency of each Event
- Defining causes for each event
- Estimating the frequencies of each scenario
- Assessing the magnitude of the consequences of each scenario

Figure 3 *Risk assessment steps* [6]

Risk assessment provides a basis for development of risk management system. Risk management goals are:

- minimize the likelihood of adverse safety or environmental impacts;
- detect and respond to potential failures;
- establish contingency and emergency preparedness plans to deal with significant events. (The Mining Association of Canada, 1998).

Risk assessment helps to focus on cost effective approaches to improving the performance of MWF.

3.5 Prevention measures of environmental risks

The environment is a complex system whose components are interconnected and dependent on each other, so that changes in one part can cause changes in other ones. Therefore, the issue of environmental protection, can be resolved only with integrated systematic approach.

In order to ensure maximum efficiency of proposed measures and to ensure their successful implementation, their integration into a comprehensive management/control plan (EMP) seems very good idea. Such plans could provide sound base for further implementation of Environmental Management Systems (EMS) according to ISO 14001: 2006.

The Environmental Management Systems will provide complete set of tools that enables on mining top management to respond on current and future problems in the field of environment. Proper implementation of EMS result in many benefits. The plan for the control and management of the environment as part of the EMS focuses on the way how objectives are achieved. Protective environmental measures are classified into several main groups:

- Measures of water protection;
- Measures of air protection;
- Measures of soil protection;
- Measures to ensure stability of the Mining Waste Facility;
- Protective environmental measures in case of an emergency;
- Administrative measures.

3.6 Control and monitoring procedures

Control and monitoring procedures are relevant to mining waste operations and MWF so, within WMP a clear monitoring procedures should be proposed as appropriate.

In order to monitor the environmental quality during the construction and operation of MWF as well as during the closure/remediation and extended period after the closure of MWF (post-monitoring), it is necessary to develop a monitoring plan, taking into account the specifics of the planned activities and local conditions.

The monitoring plans should define monitoring objectives, locations, techniques and frequency of monitoring, including in minimum following data sub-sets:

- initial monitoring - scheduled to begin before the construction and usage of MWF,
- monitoring during usage and remediation - which generally uses the infrastructure developed in initial monitoring, and only when necessary includes other facilities;
- after-closure monitoring - which includes a smaller number of locations/objects and lower monitoring frequency, but for a longer time periods [1].

3.7 Emergency Plan

After all strategies for the risk reduction are adopted during design and construction of the MWF, the Emergency Plan (EP) refers to the residual (remaining) risks management. Emergencies that may arise in the MWF [7] could be summarized as follow:

1. Natural disasters, earthquakes, floods, erosion of surrounding land;
2. Unplanned embankment failure;
3. Over-topping of embankment;
4. Unplanned chemical/process solution release into the environment;
5. Bomb/terrorist threat;
7. Vehicle or Mobile equipment incidents jeopardising integrity of the facility;
8. Fire / Explosion; and
9. Other Emergencies.

The emergency management systems are widely used for disaster management planning. This generally covers the planning and coordination requirements for large-scale events such as earthquakes, floods and large fires, and also includes large emergencies involving hazardous materials. Emergency management involves a cyclical process of four phases [8]:

- **prevention:** regulatory, physical or operational measures to prevent emergencies or mitigate their impact,
- **preparedness**: arrangements to mobilise and deploy all necessary resources and services,
- **response:** actions taken during and immediately after an emergency to minimise the impact,
- **recovery**: arrangements to restore the facility to normal as quickly and efficiently as possible and to assist the community to recover.

Emergency planning plays a key role in this cycle of emergency management, focussing primarily on the phases of preparedness and response. Therefore emergency planning presents a cyclical process as illustrated in **Error! Reference source not found.**4**Error! Reference source not found.**. All of stages are inter-related and plan details should be continually evaluated and revised as appropriate.

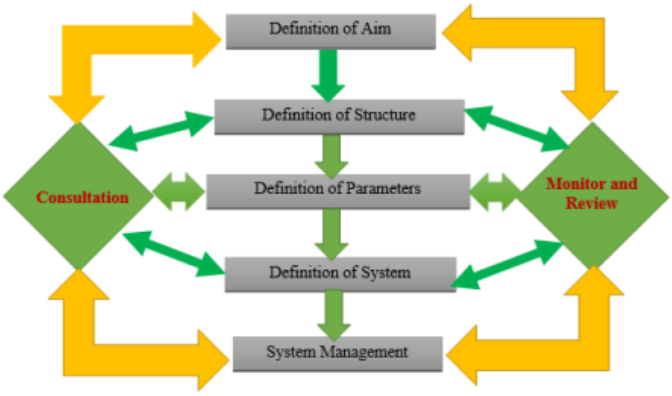

Figure 4 *Emergency planning process* [8]

Overall objectives of the Emergency Plans are:

1. To establish and maintain an EP for all potential emergencies at the Waste Management Facility resulting in potential containment failure;
2. To provide a method of controlling and minimizing injury to personnel, detrimental damage to the environmental and damage to property in the event of a significant incident;
3. To ensure site based personnel are trained and prepared to respond to incidents in an effective manner;
4. Awareness at onsite personal of their responsibilities in the event of an emergency.
5. Preserving safety of personnel during an incident;
6. Continuously review and improve the EP in-line with recommendations arising from debriefs and reviews;

3.8 Proposed plan for closure aftercare and monitoring

Guidelines for environmental management and planning activities to close the MWF are set out in Article 94 of the Law on Mineral Resources (Official Gazette of Republic of Macedonia, No. 136/12, 25/13, 93/13, 132/13) and other international standards. Plans for closure, rehabilitation, monitoring and after-care include technical, environmental and economic elements. The operator of MWF after decommissioning should provide in minimum:

- monitoring of physical and chemical stability of the MWF and to reduce any negative impact on the environment, particularly of surface and groundwater,
- maintenance of monitoring and measuring devices in good/proper conditions,
- maintainance operational lingering overflow channels.

Closure planning for mine waste facilities should be firmly based in developing a robust set of closure criteria. The framework for closure planning presented in Figure 5 shows an iterative process that tests factors of the design against closure criteria. During each step of this process, conservative measures should be incorporated so that risk is minimised. This may include the selection of conservative parameters during numerical modelling procedures to ensure the predicted results are for the “worst-case scenario” [10].

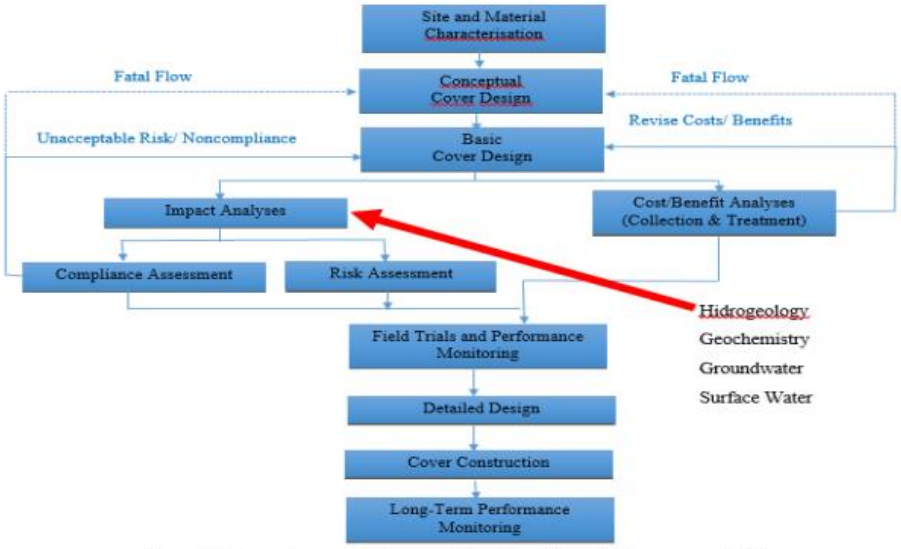

Figure 5 *General cover system and final landform design process* [10]

The rehabilitation should be aligned with regulatory requirements, specific aspects of the site, the mine policy and best industrial practice, which includes:

- Protecting the health and welfare;
- Achieving the agreed objectives for land use after closing;
- Geotechnical stability of the mine;
- Improving the visual landscape by minimizing the transport of sediment, erosion and potential harmful environmental impact;
- Protection of the quantity and quality of water and
- Protection of air quality.

4. CONCLUSION

Proper waste disposal is crucial in achieving sustainable development of extractive industries, and development and implementation of MWMP should provide for:

- Mine Waste Management without harming human health and without using processes or methods which could harm the environment, especially without risk to water, air, soil, fauna and flora, without causing inconvenience with noise or odours and without negative impacts on the landscape or protected areas and habitats;
- Implementation of necessary measures to prohibit the abandonment, un-safe disposal or uncontrolled mine waste storage; and
- Mine operators should take all measures necessary to prevent or reduce as far as possible any adverse effects on the environment and on human health, as a result of the waste management processes in short or long term perspective. This includes managing any type of waste facility during operation and after its closure, prevention of major accidents involving this facility, as well as limiting the impact on the environment and human health.

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