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Guideline on the rehabilitation of open-pit coal-mines in Mongolia (GROM)

Strengthening environmental protection requirements for the rehabilitation of areas devastated by coal-mining in Mongolia

GUB

LMBV

Lausitzer und Mitteldeutsche Bergbau-Verwaltungsgesellschaft mbH

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Project: Strengthening environmental protection requirements for the rehabilitation of areas devastated by coal-mining in Mongolia

Guideline on the rehabilitation of open-pit coal-mines in Mongolia (GROM)

by

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The responsibility for the content of this publication and photos lies with the authors.
Image on the front page: Open-pit mine Sharyn Gol (P. Denke 2018)

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Abstract: Guideline on the rehabilitation of open-pit coal-mines in Mongolia (GROM)

Rehabilitation of areas devastated by mining, especially coal-mining in Mongolia support the Sustainable Development Goals (SDG) of the United Nations, especially SDG 15 combating draught, land degradation and desertification. Rehabilitation measures support the concept of land degradation neutrality (LDN).

This technical guideline outlines the principles and practices of mine rehabilitation, with emphasis on generating ecological and economic viable solutions that last. The principles described apply to open-pit coal-mining in Mongolia´s semi-arid regions. The guideline is framed around the operational sequence in mining operations, i.e. legal basis, planning, operations and mine closure. Particular emphasis is given to the rehabilitation of natural ecosystems and replacement and compensatory measures.

These recommendations are intended for managers at the operational level, but they may also be useful for environmental officials, competent authorities, non-governmental organizations, students, of people with a general interest in the best practices associated with rehabilitation of open-pit coal-mines. Parts of the recommendations could be useful for open pit mining on other minerals in Mongolia. The goal of this work is to improve the mining industry's environmental performance.

Kurzbeschreibung: Richtlinie zur Sanierung von Kohletagebauen in der Mongolei

Die Wiedernutzbarmachung von bergbaulich devastierten Gebieten, insbesondere des Kohlebergbaus in der Mongolei, unterstützt die Ziele der Vereinten Nationen für eine nachhaltige Entwicklung, insbesondere die SDG 15 zur Bekämpfung von Dürre, Bodendegradation und Desertifikation. Maßnahmen zur Wiedernutzbarmachung unterstützen das Konzept der Landdegradationsneutralität (LDN).

Diese technische Richtlinie beschreibt die Grundsätze und Praktiken der Bergbausanierung mit dem Schwerpunkt auf der Entwicklung ökologisch und ökonomisch tragfähiger und nachhaltiger Lösungen. Die beschriebenen Prinzipien gelten für den Tagebau in semiariden Regionen der Mongolei. Die Richtlinie ist um den Ablauf im Bergbaubetrieb herum gestaltet, d. h. Rechtsgrundlagen, Planung, Betrieb und Stilllegung eines Tagebaus. Besonderes Augenmerk wird auf die Wiederherstellung der natürlichen Ökosysteme sowie auf Ersatz- und Ausgleichsmaßnahmen gelegt.

Diese Empfehlungen richten sich an Manager auf operativer Ebene, können aber auch für Umweltbeamte, zuständige Behörden, Nichtregierungsorganisationen, Studenten und Personen mit einem allgemeinen Interesse an den besten Praktiken im Zusammenhang mit der Sanierung von Tagebauen nützlich sein. Teile der Empfehlungen könnten für Tagebaue für weitere Mineralien in der Mongolei nützlich sein. Ziel dieser Arbeit ist die Verbesserung der Umweltleistung der Bergbauindustrie.

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ARD	Acid Rock Drainage
AG Boden	Team soil - Federal Institute for Geoscience and Natural Resources
BDFE	Soil bulk Density
CEC	Cation Exchange Capacity
CV	Coefficent of Variation
EC	Electric Conductivity
FAO	Food and Agriculture Organization, a organisation of the United Nation
GIS	Geographic Information System
GPS	Global Positioning System
IUSS	International Union of Soil Sciences
LDN	Land Degradation Neutrality
MNS	Mongolian Standards – General Technical Requirements
PAWC	Plant Available Water Strorage Capacity
PM	Particular Matter
PPE	Personal Protaction Equipment
SAC	Soil Air Capacity
SDG	Sustainable Development Goals
SOM	Soil Organic Matter
SOP	Standard Operation Procedures
SWSC	Soil Water Storage Capacity
WRB	The **W**orld **R**eference **B**ase is the international standard for soil classification system endorsed by the International Union of Soil Sciences
UBA	German Environment Agency

Summary

Modern mining activities have great impact on the environment but also on the social and economic situation. The Mongolian Government are aware of these impacts and regulates the mining activities on different levels.

A missing link between the legal regulation and the activities on-site are technical guidelines. Technical guidelines convert abstract laws into concretely applicable guidelines for action and allow the supervisory authorities to monitor the work carried out in a meaningful manner.

Coal-mining is a growing part of the Mongolian mining industry and the by far most important energy source. Therefore, mining projects which are fully planned from the beginning to their end in some decades are crucial for their impacts on the economic, social and natural environment. But also existing coal mining needs practical recommendations to minimize negative impacts on the environment and optimize the operating expenditures to fulfil the legal commitments

For the implementation, the Guideline on the Rehabilitation of Open-pit Coal-mines in Mongolia explains international standards and gives practical recommendations and examples on the different fields of the rehabilitation work in open-pit coal mining.

Any rehabilitation in any kind of mining has to deal with the impacts on water, the effects of the water onto the mine during its active phase and in the post-mining phase and the impacts on the soil.

Soil, as overburden and as future material for re-cultivation, is at the centre of this technical guideline. Furthermore, different possibilities of re-cultivation are described as well as methods to avoid erosion and dust.

The suitability of different parent material for rehabilitation purposes is described.

The survey of the future mining area is a legal obligation, fixed in the Mongolian Law on Sub-soil. Two methods for soil survey of the undisturbed area in front of the mine and of the dumped material are described in detail.

The determination of the pre and the post mining situation is an obligation fixed in different Mongolian laws (e.g. Mining law draft, Environmental Assessment Law). The technical guideline names methods of the evaluation and description.

Replacement and compensation measures are meaningful if a re-cultivation on-site is not possible. Methods and approaches are named.

Templates for cost planning and examples of different acceptance certificates completes the Guideline on the Rehabilitation of Open-pit Coal-mines in Mongolia.

Zusammenfassung

Der moderne Bergbau hat große Auswirkungen auf die Umwelt, aber auch auf die soziale und wirtschaftliche Situation. Die mongolische Regierung ist sich dieser Auswirkungen bewusst und regelt die Bergbauaktivitäten auf verschiedenen Ebenen.

Ein fehlendes Bindeglied zwischen der gesetzlichen Regelung und den Tätigkeiten vor Ort sind technische Richtlinien. Technische Richtlinien wandeln abstrakte Gesetze in konkret anwendbare Handlungsrichtlinien um und ermöglichen es den Aufsichtsbehörden, die geleistete Arbeit sinnvoll zu überwachen.

Der Kohlebergbau ist ein wachsender Teil der mongolischen Bergbauindustrie und die mit Abstand wichtigste Energiequelle. Daher sind Bergbauprojekte, die von Anfang bis zu ihrem Ende in einigen Jahrzehnten vollständig geplant sind, entscheidend für ihre Auswirkungen auf die wirtschaftliche, soziale und natürliche Umwelt. Aber auch der bestehende Kohlebergbau benötigt praktische Empfehlungen, um negative Auswirkungen auf die Umwelt zu minimieren und die Betriebskosten zur Erfüllung der gesetzlichen Verpflichtungen zu optimieren.

Für die Umsetzung erläutert die Leitlinie zur Wiedernutzbarmachung von Tagebauen in der Mongolei internationale Normen und gibt praktische Empfehlungen und Beispiele zu den verschiedenen Bereichen der Wiedernutzbarmachungsarbeiten im Tagebau.

Jede Wiedernutzbarmachung in jedem Bergbau muss sich mit den Auswirkungen auf das Wasser, den Auswirkungen des Wassers auf das Bergwerk während seiner aktiven Phase und in der Phase nach dem Bergbau sowie den Auswirkungen auf den Boden befassen.

Der Boden als Abraum und als zukünftiges Material für die Rekultivierung steht im Mittelpunkt dieser technischen Richtlinie. Darüber hinaus werden verschiedene Möglichkeiten der Rekultivierung sowie Verfahren zur Vermeidung von Erosion und Staub beschrieben.

Die Eignung verschiedener Ausgangsmaterialien für Wiedernutzbarmachungszwecke wird beschrieben.

Die Erkundung des zukünftigen Bergbaugebietes ist eine gesetzliche Verpflichtung, die im mongolischen „Sub-Soil Law“ festgelegt ist. Zwei Methoden zur Bodenuntersuchung des ungestörten Bereichs vor der Grube und des Haldenmaterials werden ausführlich beschrieben.

Die Bestimmung der Situation vor und nach dem Bergbau ist eine Verpflichtung, die in verschiedenen mongolischen Gesetzen festgelegt ist (z. B. Entwurf eines Bergbaurechts, Umweltbewertungsgesetz). Die technische Richtlinie nennt Methoden der Bewertung und der Beschreibung hierzu.

Ersatz- und Ausgleichsmaßnahmen sind sinnvoll, wenn eine Rekultivierung vor Ort nicht möglich ist. Es werden Methoden und Ansätze benannt.

Vorlagen für die Kostenplanung und Beispiele für verschiedene Abnahmebescheinigungen vervollständigen die Richtlinie zur Wiedernutzbarmachung von Tagebauen in der Mongolei.

1 Preamble

The "Guideline on the Rehabilitation of Open-pit Coal-mines" (GROM) addresses mine rehabilitation, targeting managers at the operational level, environmental officers from the authorities, and public regulators as main audience.

It outlines the principles and practices of mine rehabilitation, with emphasis on generating ecological and economic viable solutions that last. The principles described apply to open-pit coal-mining in Mongolia´s semi-arid regions. The handbook is framed around the operational sequence in mining operations, i.e. legal basis, planning, operations and mine closure. Particular emphasis is given to the rehabilitation of natural ecosystems and replacement and compensatory measures.

Environmental managers of mining companies should be able to adapt this information to site specific situations when planning a rehabilitation strategy. Landscape design for rehabilitation requires a holistic view of mining operations, where each operational stage and each component of the mine is part of a plan which considers the complete life cycle of a mine, i.e. planning, operations and final use of the site. On the other hand, environmental staff should be able to assure the quality of executed rehabilitation work and to discover deficits.

Due to a wide range of different types of mining companies varying in size and ownership, the GROM pursues targets that can be reached by all companies through state of the art technology. It provides hints how to reach these targets. However, these are not meant to be construed as a legal requirement.

This technical guideline was elaborated by the engineering company G.U.B. AG and the German state owned rehabilitation company LMBV mbH. It reflects as well discussion results with Mongolian experts, in particular the Ministry of Environment and Tourism, and German experts of the Federal Environment Agency (UBA).

Best practice examples from Mongolia and Germany were evaluated and considered. The EU Mining Waste Directive (2006/21/EC) as well as re-cultivation guidelines from major mining countries were also considered. Especially guidelines from Canada, Australia, China, USA and further best practice guidelines of the EU on different topics were checked.

Key factors that need to be considered in pre-mining studies include legal requirements, climate, topography, regional geology, soils and community views. Community views are clearly most important in deciding the final land use as they are the most likely site users. Their knowledge and expertise are invaluable in understanding the socio-economic pre-mining context and producing politically sustainable re-uses.

The Guideline on the Rehabilitation of Open-pit Coal-mines shall support the Sustainable Develop-ment Goals of the United Nations, especially SDG 15 combating drought, land degradation and desertification. Rehabilitation measures support the concept of land degradation neutrality (LDN).

2 General requirements

2.1 Principles

Mining plays an important role in promoting economic and social development, but has potentially serious negative impacts on the human and natural environments. Mining companies are challenged to restore the often huge areas of land destroyed or affected by mining. Local communities and authorities are challenged to develop sufficient framework conditions for this rehabilitation work.

To promote ecological rehabilitation and climate-smart mining land management and to coordinate rural development after mining has ceased, spatial planning must pursue an integrated approach. Balancing land use is at centre stage. The following enumeration portrays all basic aspects relevant for planning the re-use of mining heaps and dumps:

- Cross-coordination with all relevant laws, regulations, policies, technical standards and programs so as to determine reasonable rehabilitation goals – responsibility is with Mongolian government / Aimag government / authorities;
- Design of actions according to local and regional conditions and existing land use types taking account of infrastructure, farming, herding, forestry and grassland conditions in relation to hydrolo-gy, topography, soil properties and geology – responsibility is with mining companies, local authori-ties and provincial governments;
- Configuration of economically viable and environmentally compatible engineering measures in relation to the local landscape, its natural environment and topography so as to meet the re-use objectives – responsibility is with mining companies;
- Adherence to the unity of economic, ecological and social benefits (sustainable use of land resources) so as prioritize nature conservation where and whenever feasible – responsibility is with local and provincial authorities;
- Preservation of bio-diversity by gradually integrating ecological recovery processes in post-mining rehabilitation projects taking full account of soil, water and other environmental resources as well as the local / regional cultural heritage so as to control soil erosion, prevent secondary pollution and to garner support of the local population – responsibility is with mining companies.

2.2 Definitions

- Abandoned mine: means a mine or mining plant whose current or former mining license holder or mining plant operation license holder has terminated mineral mining and mining plant operations and has abandoned the mine or mining plant; (acc. Article 4,1,1 draft of Law of Mongolia on Mining 2017)
- Closure plan: means the document meeting the requirements of Article 59 of Law on Mining that identifies measures to be taken by the holder the mining license or the mining plant

operation license from the start of its operation to control and manage potential risks that may negatively affect health and safety of people directly affected by the mine or mining plant operation and to ensure chemical and physical stability in the operational environment; (acc. Article 4,1,7 draft of Law of Mongolia on Mining 2017)

- Dam: means an engineered structure designed to retain or confine water and or/waste within a pond; (acc. Article 3,11 EU Directive 2006/21/EC)
- Disposal: means the collection, sorting, transport and treatment of waste as well as its storage and tip-ping above or underground

  means the transformation operations necessary for its re-use, recovery or recycling; (acc. Arti-cle 1, b EU Directive 75/442/EWG)
- Dump: means backfilled waste-rock and overburden material into the excavated pit in distinc-tion to heap. The term “dump site” includes dumps and heaps.
- Hazardous Waste: means waste which displays one or more of hazardous properties listed in Mongolian guidelines; (adopted acc. Article 3, 2 EU Directive 2008/98/EC)
- Heap: means an engineered structure designed for the deposit of solid waste on the surface. (acc. Article 3,10 EU Directive 2006/21/EC)
- Inert waste: means waste that does not undergo any significant physical, chemical or biological transformations. Inert waste will not dissolve burn or otherwise physically or chemically react, biode-grade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm human health. The total leachibility and pollutant content of the waste and the eco-toxicity of the leachate must be insignificant, and in particular not endanger the quality of surface water and /or groundwater; (acc. Article 3,3 EU Directive 2006/21/EC)
- Mineral deposit: means mineral concentrations that has been formed on the surface or in the subsoil resulting from geological evolutionary processes, where the quality and proven reserve is economically feasible to mine by production methods; Article 3,1,5 Law of Mongolia on Minerals 2012)
- Mineral resource or mineral: means a naturally occurring deposit in the earth´s crust of an organic or inorganic substance, such as energy fuels, metal ores, industrial minerals and construction miner-als, formed by geological evolutionary processes, but excluding water; (adopted acc. Article 3,5 EU Directive 2006/21/EC and Article 4,1,1 Law of Mongolia on Minerals 2006)
- Pond: means a natural or engineered facility for disposing of fine -grained waste, normally tailings, along with varying amounts of free water, resulting from the treatment of mineral resources and from the clearing and recycling of process water; (acc. Article 3,3 EU Directive 2006/21/EC)

- Post-closure stage: means a time period after implementation of measures included in the closure plan, during which results of the rehabilitation, re-cultivation and other measures specified in the closure plan shall be reviewed and monitoring aimed at ensuring chemical stability and physical stability; (acc. Article 4,1,44 draft of Law of Mongolia on Mining 2017)
- Re-cultivation: collective term for technically and materially complex measures for the restoration of landscape ecosystems, which were impaired or destroyed by massive interventions as a result of human economic activities. Top priority of re-cultivation is to restore the capacity of the landscape ecosystem to enable planned subsequent use of the affected area. Re-cultivation is in this guideline a part of the overall rehabilitation process, focussing on measures to enhance the biological func-tions for the planned subsequent use.
- Rehabilitation: means the treatment of the land affected by a waste facility and or excavation voids filled with waste according to definition in bullet waste facility, in such a way as to restore the land to a satisfactory state, with particular regard to soil quality, wild life, natural habitats, freshwa-ter systems, landscape and appropriate beneficial uses; (acc. Article 3,20 EU Directive 2006/21/EC)
- Site: means all land at a distinct geographic location under the management control of natural or legal person responsible for the management of extractive waste; (acc. Article 3,28 EU Directive 2006/21/EC)
- Tailing: means the waste solids or slurries that remain after the treatment of minerals by separation processes (e.g. crushing, grinding, size-sorting, flotation and other physic-chemical techniques) to remove the valuable minerals from the less valuable rock; (acc. Article 3,9 EU Directive 2006/21/EC)
- Unpolluted soil: means soil that is removed from the upper layer of the ground during extractive activities and that is not deemed to be polluted under the Mongolian law; (adopted acc. Article 3,4 EU Directive 2006/21/EC)
- Waste: means any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force; (acc. Article 1, a EU Directive 75/442/EWG and 2008/98/EC)
- Waste facility: means any area designated for the accumulation or deposit of extractive waste, whether in a solid or liquid state or in solution or suspension. Such facilities are deemed to include any dam or otherwise structure serving to contain, retain, confine or otherwise support such a facili-ty, and also to include, but not limited to, heaps and ponds, but excluding excavation voids into which waste is replaced, after extraction of the mineral, for rehabilitation and construction purposes; (acc. Article 3,15 EU Directive 2006/21/EC)

3 Determining the pre and post mining situation

3.1 Objectives

Remodelling the overall appearance of post-mining landscapes according to the above principles has strategic and practical implications on promoting the development of a low-carbon economy. In addition, large scale mining activities aggravated the deterioration of the vulnerable ecological environment in semi-arid regions which is not resilient to natural disasters. It is crucial to make plans and improve the devastated ecosystems for keeping the mining on the rails and ensuring sustaina-ble development. The following aspects are pivotal for designing climate-smart land-utilization after rehabilitation:

- the geo-technical stability of the dump sites, slopes and berms;
- a self-sustaining water balance and good quality of groundwater and surface waters;
- the concept of a sustainable, multifunctional and diverse land-use;
- design of rehabilitation measures (biological and technical engineering) for disaster prevention and risk control;
- a layout of road, irrigation and drainage systems in relation to the requirements of the chosen land-use types;
- the proper management of scrapped-off topsoil and fertile soil substrates during intermittent storage (e.g. location, cover crops like leguminous plants) for optimal re-use.

Prior to actual rehabilitation works, all projects must be thoroughly evaluated in terms of cost, but also in regard to their social and environmental impact.

3.2 Planning stages

Planning for post-mining rehabilitation – as a matter of principle – proceeds over various stages and is firmly grounded on spatial planning specific to the particular regional circumstances. The following list provides an overview:

- Data collection: compilation of relevant basic information according to pre-formulated land-use targets in relation to socio-economic, ecological and environmental conditions;
- Design: determination of re-cultivation obstacles in relation to the selected land use type / pattern and the required engineering measures (machinery, equipment, biological means);
- Re-cultivation: detailed plans for specific sites with a focus on soil improvement, erosion prevention and after-use goals;
- Monitoring: on-time and on-site supervision of each process step according to prescribed (engineering) quality standards and flow diagrams;
- Acceptance of rehabilitation project upon completion: inspection of documentary proof and facilities of local competent authorities (office check) as well as actual achievements according to prescribed quality standards, such as physical and chemical soil properties,

farm / forest land-use pattern, biological engineering and protection of water bodies (field check);

- Compensation: In cases where a re-cultivation on-site is not feasible, because of harsh ecological conditions on the dump site, or it is totally disproportionate, compensation on other degraded sites or next to villages and settlements shall be realized. On such compensation sites the same approval and control process fixed in the relevant laws should executed. Chapter 12 explain in more detail.

3.3 Relation between various plans

This technical guideline in practice will involve plans at two levels, in terms of spatial planning, which will focus on balanced spatial structure and optimized service function of the rehabilitation area, and rehabilitation plan which will pay more attention to planning stages and sustainable development.

Spatial planning

- Regional planning: overall blueprint for integrating mining and rehabilitation projects into regional economic, social and environmental development according to applicable policies and regulations;
- Land use planning: integrated arrangement of land use, land development, land consolidation and land protection from overall and long term perspective, for macro control on total amount of mining land and specific land use;
- Water conservation and irrigation: framework for surface water discharge and treatment in re-cultivation areas;
- Infrastructure: framework for aligning all civil engineering works in rehabilitation areas (e.g. village renewal, rural road construction and maintenance, pipeline network, electricity, telecommunications) with the overall infrastructure development;

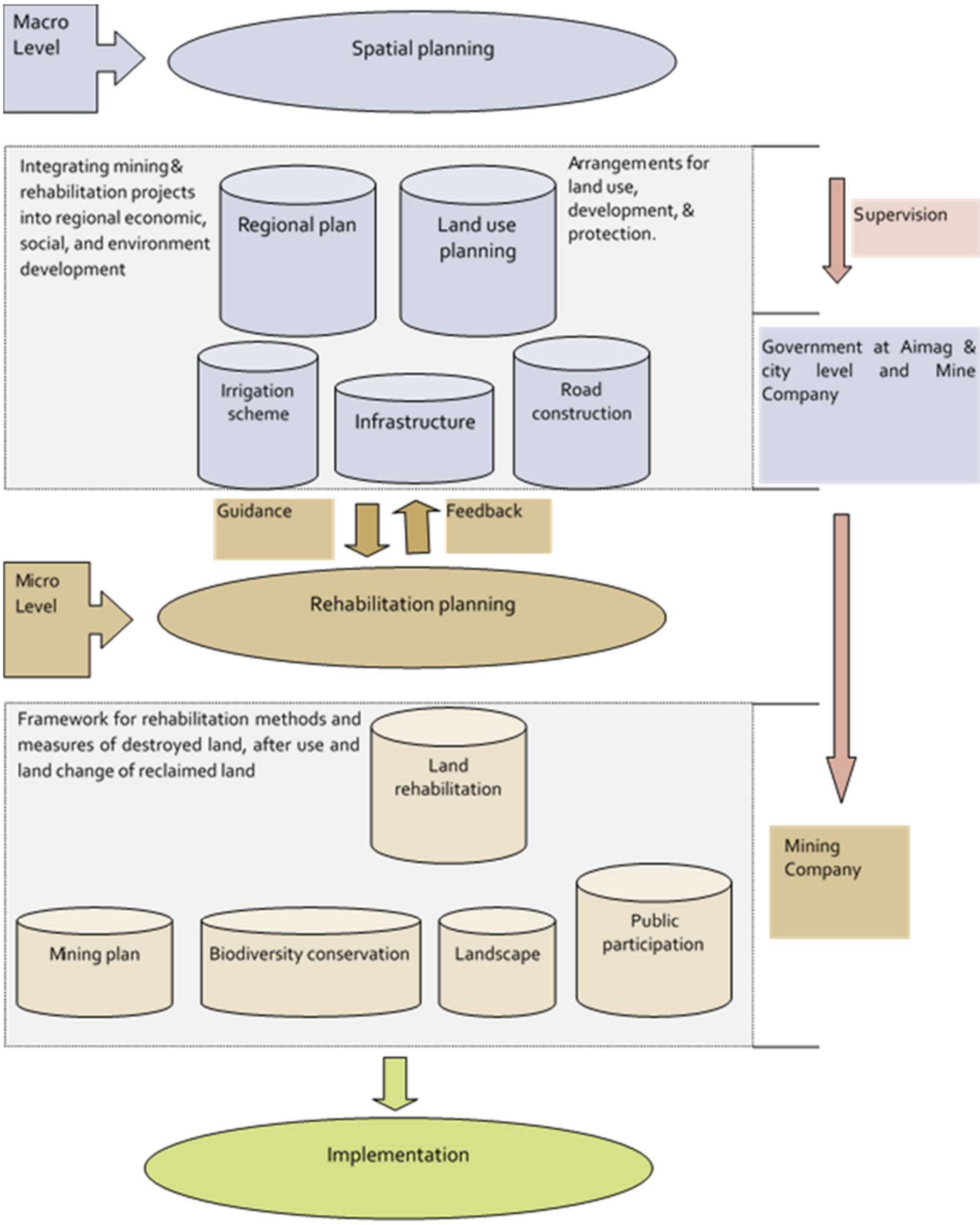
Rehabilitation planning

- Land re-cultivation: determination of land use and land use change for public interest to adjust and solve specific issues in a complex circumstance;
- Public participation: coordination of all social and administrative activities to solve the specific issues of mining and post-mining rehabilitation projects for the whole public interest;
- Mining: delineation of production and living areas strictly based on environmental impact assessments (EIA), specifying the particular norms of resource development in the landscape (e.g. reducing visual and environmental impacts during mining operations);
- Biodiversity conservation: identification of risk-prone areas (biodiversity, ecological corridors, soil / ground / surface water resources) sensitive to pollution caused by mining activities;

► Landscape: rehabilitation of abandoned mining land into a land form in harmony with surrounding landscape through land re-use program including reduction of possible visual and environmental impact during mining operation.

Central government is responsible for national interest while provincial government is responsible for provincial interest. City/county government is responsible for its interest while mining enterprise is responsible for its interest in mining site. Each level of government (enterprise) has to elaborate its own plan. Lower level government (enterprise) is supervised and monitored by higher level government (enterprise) for developing plans. Land rehabilitation activities have to be addressed in respective plans. Considering that there are many uncertain factors which will limit or impact the implementing of plans, it is allowed to keep some indicators dynamic balanced between different levels for achieving overall goals. Figure 1 shows the planning stages and their relationship in between.

Figure 1: Relation and dependencies of the different planning stages



4 Suitability of overburden and soils for rehabilitation purposes (Biological rehabilitation)

4.1 Principles of soil rehabilitation

- Open-pit mining thoroughly disturbs the structure of rock and soil and enormously damages the ecological environment and land. The success of soil reclamation is directly related to the quality of soil substrates or parent materials and the effectiveness of reclamation works. Therefore, soil rehabilitation, namely creating the optimum physical, chemical and biological conditions to promote biological growth and restore soil productivity, is at the core of land restoration. It is likewise the foundation of reshaping landscapes, promoting vegetation growth and reducing soil erosion.
- The overburden or cap-rock layers are one of the important factors that determine dump stability, subsidence (particularly uneven subsidence on large dump site) and erosion risks. Their chemical and physical properties affect vegetation recovery on the dump. It is significant to acquire the stratigraphic sequence of the lithology, its physical and chemical properties for land restoration works in the future. This is an important precondition for the separate extraction and dumping of valuable and fertile soil substrates and the creation of homogenous soil covers.
- The division between mining activities connected to the extraction process, including dumping of the overburden and a separated re-cultivation following afterwards led to negative consequences and constraints on the re-cultivation part. To overcome these constraints requires additional operating expenditures like staff, machinery, material and late completion of the project results. Considering the later re-cultivation in all phases optimize the operational expenditures and led to greater success.

4.2 Topsoil handling

Best materials for reclamation purposes are in descending order: topsoil, subsoil and parent materials like loess (Table 1).

Generally, topsoil is the upper most surface layer with the highest amounts of nutrients and organic material. The seed of plants are also concentrated in the topsoil, and 80 -90% of the roots of cultivated plants are concentrated in this layer. Normal thickness of topsoil is 5 - 25 cm. On arable land, it is the layer regularly worked with tillage equipment. Its separate handling and application on the dump sites has top priority. The topsoil piles should not be higher than 2 maxima 3 m (MNS_5916:2008 max 5 m) and should be covered with vegetation. A slight seeding of local plants is sufficient.

4.3 Suitability of overburden and soils

If topsoil material is not removed and stored separately and finally returned to re-cultivation sites, the top-layer of the dumped soil substrates has to be enriched with nutrients and organic material. One possible method for enrichment with organic material is to seed adopted local grass and herb species. A slight but repeated grazing and leaving the manure fastens the development of organic material on the re-cultivation site.

Table 1: Suitability of parent materials for soil rehabilitation and reclamation on dumps

Legend: ++ best; + good; +/- acceptable; - low

soil property	Parent material			
	topsoil	loess	laterite	Kastanozem (top-soil)
pH -value	++	++	++	++
Nutrient contents	++	+	+	++
Nutrient storage	++	+	+/-	++
Water holding capacity	++	++	+/-	++
Soil texture	+	+	+/-	+/-
Acidification	++	++	++	++
Contaminants	+-	++	++	++

The reasons why loess parent material can directly be used for dump coverage are as follows:

- loess is free of toxic substances and available in large quantities after stripping of overburden;
- there is no significant difference in nutrient content and leaching behaviour between topsoil and this parent material;
- raw loess weathers easily and its productivity can exceed that of the original topsoil by rational fertilization.

Weathered coal, containing humic acid, might be an acceptable addition in the substrates used for reclamation purposes. It is found in the overburden of the coal seams. Its portion in the parent materials for soil reclamation should not be more than 3 to 5 mass-% (d. m.) It may improve some physical and chemical properties of the substrates forming the final cover of the dumps (e.g. water holding capacity, soil density and cation exchange capacity) depending on its formation conditions, structure and chemical composition. Well and homogenously distributed particles (particle size less than 2 mm) are more effective than few bigger particles in irregular distribution. The coal may also contain nutrient elements favourable for plant growth. On the other hand, the C/N-ratio of the coal is high and its microbial decomposition very low with a high demand of available nitrogen. Nitrogen may be immobilized or adsorbed as NH_4^+ to high extensions thus impeding good plant growth and causing high demands for nitrogen fertilization. The coal may also contain sulphides causing acidification and lime requirements. Therefore, a prerequisite for the use of coal or substrates with coal additions is the analysis of the coal to define the maximum mass content in the re-cultivation layer and needs for further soil treatment (fertilization, liming).

On the other hand, overburden with lot of marl, limestone and calcite caking is unsuitable for re-vegetation and restoration purposes. Attention should also be paid to toxic heavy metals and radioactive elements found in some overburden.

To improve infertile soil material and to enrich it with nutrients, soil material can be mixed with compost, sewage sludge or other organic material, provided such material is free of heavy metals and pathogens.

Waste materials like fly ash, rubble, street sweeping and sewer deposits may be used as subsoil layers in specific cases after analysing their hazardous components, if harmful leaching into the dump and emissions into ground- and surface waters can be excluded.

Generally, waste material shall only be used in the rehabilitation processes, if the value for re-cultivation is higher than disposal elsewhere and if environmental risks are not higher than without using the specific waste material.

In mining areas where rock with high nutrients distributes, the rock should be broken into graded gravel with particles no larger than 50 mm. Simulated experiments can be carried out upon start of mining production, so as to grasp the appropriate grading value and to assess extent and speed of soil formation through weathering, leaching or Aeolian deposition of nutrients.

4.4 Soil survey and evaluation

- The characterisation of materials normally comprises mineralogical, physical, mechanical and chemical analyses. Generally, this is the onus of the mining enterprise and the administration authority in charge of Environmental Protection.
- Table 2 provides an overview of the required methodologies and prescribed technical standards in Mongolia.

Table 2: Standardized data collection for soil and overburden surveys before mining

Item	Parameter	Unit	Standard measuring method
Physical and mechanical Properties	Bulk density	g/cm^3	
	Texture	-	
	Slope gradient	°	Gradiometer
Chemical Properties	Elemental analysis (P, K, Mg, Ca, S,...?)	g/cm^3	
	Total nitrogen	%	
	pH value	-	
	Organic matter	%	
	Plant available potassium	mg/kg	
	Plant available phosphorus	mg/kg	
	Salinity	%	
	Carbonates		
	CEC	m·e/100g	
	Mercury	ppm	
	Cadmium	ppm	

Matrix contamination	Lead	ppm
	Chromium	ppm
	Copper	ppm
	Zinc	ppm
	Nickel	ppm
	Arsenic	ppm
	Sulphides	ppm

5 Survey of mine sites and sites to be mined

5.1 Objectives

Mine site survey has two directions. First, the knowledge of the upfront of the mine, the area that will be mined in future. This is the future overburden and the knowledge of the upper soil meters is a prerequisite for a successful mass-management which consider the mandatory re-cultivation measures. Second, the survey of the dumped material itself.

Juvenile mine substrates are anthropogenic raw soils with unique properties and a set of growth limiting factors. Generally free of recent organic matter (humus), they have a negligible biological activity. A lack of plant-available nutrients, especially nitrogen and phosphorous, is common. In the case of high acidification potential, heavy metal contamination or strong soil compaction mine sites may remain barren of vegetation, sometimes even for decades ("lunar landscapes"). Furthermore, raw soils and dumped waste rock partially have a high susceptibility to erosion and unfavorable mechanical properties in respect to dump and slope stability, in some cases requiring special measures to guarantee geotechnical stable landforms.

However, driven by the process of re-vegetation and cropping (biological rehabilitation) mine substrates underlie high soil dynamics and pedogenic processes over time. Yet, from the ecological point of view, restoring fully sustainable and productive soils and ecosystems is a long-term, quite challenging task taking several decades.

In this context, the following recommendations provide a consistent, harmonized and reproducible methodology on mine site surveys according to national and international standards and best practice. Although special focus is on loess, kastanozem and cernozem coverage systems of hard coal open-cast mining in semiarid and arid Mongolia, they outline general principles for mine soil examination on other post-mining sites all over the country. Thereby, the recommendations should (i) support ongoing rehabilitation efforts, (ii) lead to a better understanding of ecological processes, (iii) shape a quality management system but also (iv) improve concepts and tools, for example by a contemporary site-adapted land use or innovations in rehabilitation technologies.

As table 3 illustrates, a proper soil evaluation is a prerequisite not only for site-adapted land use options, but also any soil engineering.

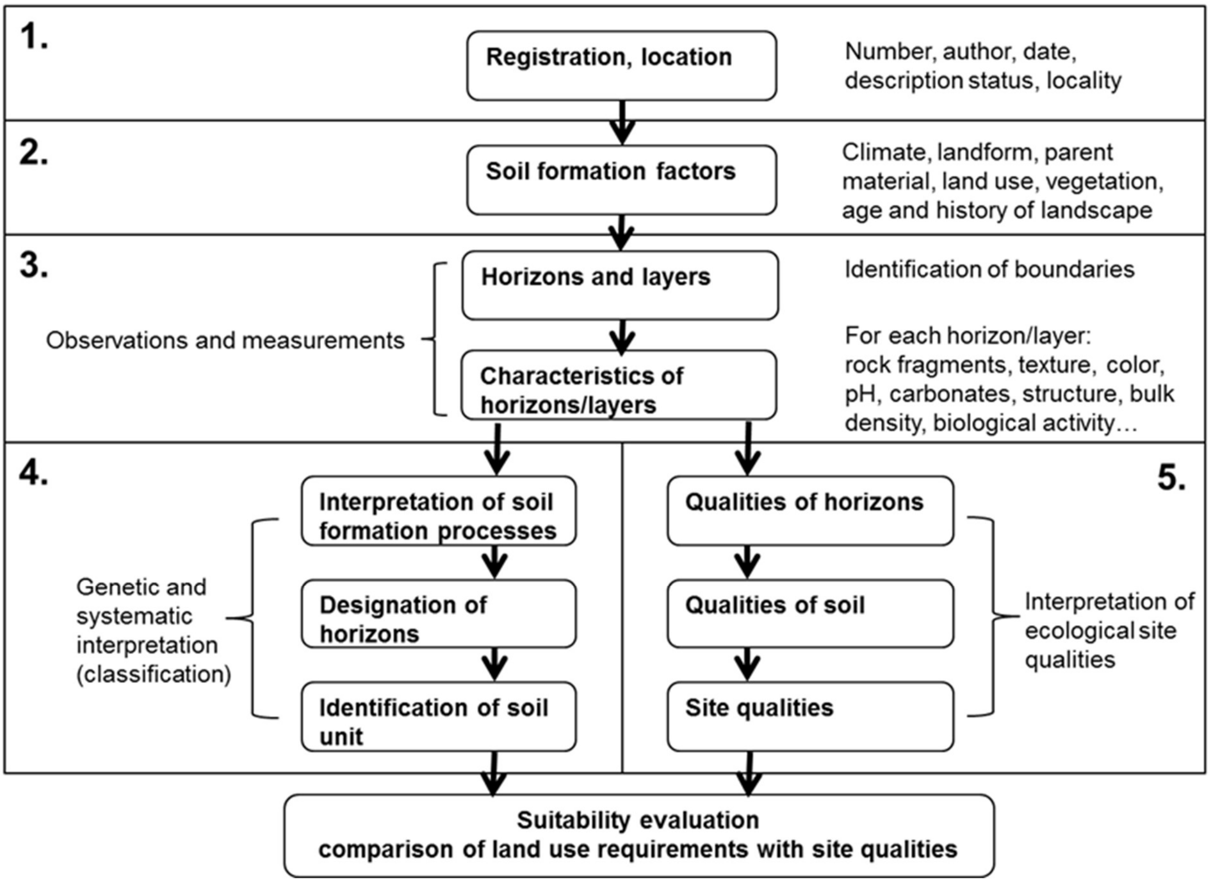
Table 3: Soil evaluation before excavation and after dumping

Procedures / Technologies	Objectives
Geological survey	Exploration of *overburden* sediments, substrate *mass calculation*, projection of dumps and heaps
Mining, transport and dumping	*Selective extraction and dumping* of fertile soil substrates, creation of homogenous soil covers as possible
Shaping and drainage	Soil *erosion control* and *slope stabilization*
Mine site survey	Evaluation of *mine soil properties and fertility*, deduction of land-use options, amelioration and reclamation technologies
Soil improvement or coverage	Creation of *favorable preconditions* for developing soil functions, especially regarding biomass production
Revegetation and cropping	Promoting the development of soil functions, reaching the sustainable site potential by *"biological reclamation"*

Hence, evaluation of basic soil properties and fertility is essential for the determination of soil (function) target values and land expectation values, which have to be reached by subsequent biological reclamation and site management. Such measures are humus formation and accumulation in the topsoil by initial cropping, application of organic soil conditioners (e.g. compost, manure, municipal sewage sludge or bio-char) and further soil treatment (e.g. high amounts of plant residues). However, since mine soil dynamics are quite high in the initial stage, it turns out rather difficult to predict the long-term ecosystem behavior on cause-effect relationships and thus the final success of reclamation. That´s why an objective soil assessment based on function-related analytical soil parameters is essential (Figure 2).

The process of soil description, classification, site quality and suitability evaluation

Figure 2: Principles of soil description, classification and site quality evaluation (WRB Guidelines for Soil Description 2006)



A target-oriented mine site evaluation system should produce an overall site characterization with special respect to plant growth-limiting (key) soil properties and functional indicators. Moreover, it has to be practicable in field application, compatible to national and international reference (ISO) methods but also cost-efficient (Figure 2). Both, the intensity of soil survey as well as investigated properties have to be adjusted to the site-specific obstacles in reclamation. Finally, the soil evaluation leads to site-adapted recommendations for a sustainable land use management, with special respect to a turnover of nutrients and water that promotes plant growth.

Besides, the documentation of the initial soil properties provides basic data for a long-term soil monitoring on permanent plots and soil fertility prognoses to assess the site yield potential. This is essential to determine soil sensitivity to impacts of management (e.g. tillage, fertilization) and environmental effects such as air pollution (e.g. carbon dust deposition) or deflation. Moreover, soil evaluation and mapping may serve various other purposes, such as supporting many ecological studies like carbon stock and biodiversity assessments or research on climate change impacts on soils (see Mongolian standards MNS 5914:2008, MNS 5915:2008 MNS 5917:2008).

Demands on an accurate mine-soil evaluation system:

- Practicable and easy to handle
- Compatible to international standards
- Harmonized sampling and analytics

- Standardized procedures
- Reproducible and consistent results
- Target oriented and cost efficient
- Soil target values
- Determining growth limiting factors
- Basic soil information / key parameters
- Overall site characterization

5.2 Methods and contents (example from Germany and experiences from other countries)

Sampling involves the selection from the total population of a subset of individuals upon which measurements will be made; the measurements made on this subset (or sample) will then are used to estimate the properties of the total population. Sampling design involves the selection of the most efficient method for choosing the samples that will be used to estimate the properties of the population. The sampling design defines how specific elements will be selected from the popula-tion, and these sampled elements form the sample population (Pennock D. & Yates T. 2006).

In the context of soil survey and evaluation of areas that will be mined or post-mining substrates, the sampling design and the chosen sampling method have to produce re-producible results of the interesting soil / substrate properties. That means it is sufficient to concentrate the effort on reliable results of these properties named in table 5.

Sampling design

The sampling design depends on the variation of the topography (e.g. hillside, wet depressions, flat areas, etc.) and the expected heterogeneity of the soil or substrate. It depends also on the needed accuracy and the whished confidence of the results.

- Accuracy - refers to the amount of deviation on either side of the mean for the sampling area. For example, if the true value for nitrate N in the sampling area is 10 mg/kg, an accuracy of plus or minus 20% means that the mean of the sample values lies between 8 and 12 mg/kg soil.
- Confidence - as the number of cores changes, the chance that their mean will fall within certain limits of accuracy also changes. Even with a large number of cores, there is a chance that the mean value could fall outside the range of accuracy desired. For example, for a 90% confidence level, using ten sets of samples, one of the mean N values would probably fall outside the desired accuracy limits while the other nine would be inside the limits.

Although many types of sampling designs exist only two main types (random and systematic) are commonly used in the soil and earth sciences.

In simple random sampling all samples of the specified size are equally likely to be the one chosen for sampling. In stratified random sampling, points are assigned to predefined groups or strata and a simple random sample chosen from each stratum. The most commonly used sampling design for many field studies is systematic sampling using either transects or grids.

The following figures 3 a - d give examples of different sampling designs.

Figure 3 a-d: Common sampling designs in soil evaluation (after: A guide to soil sampling - APSIM 2019)

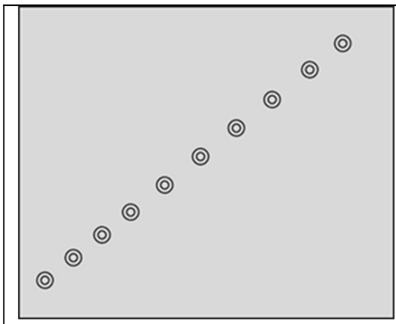
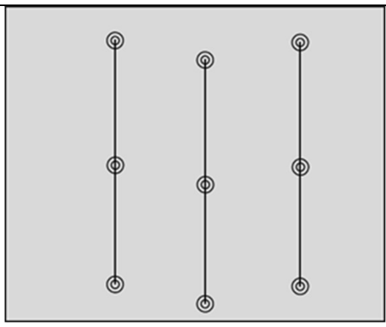
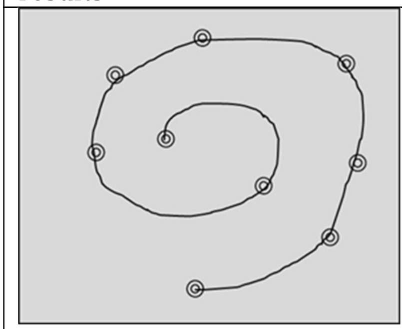
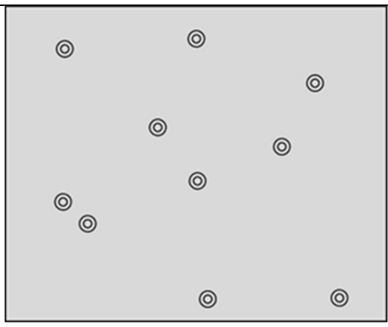
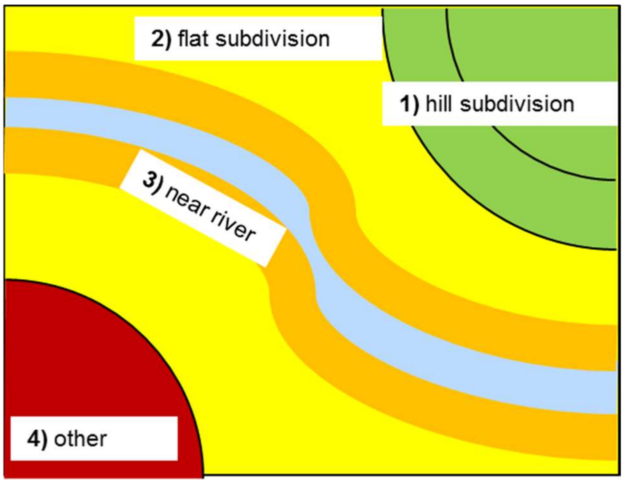
 Pattern for sampling a single soil-type Figure 3a	 Parallel lines in single soil-type Figure 3b
Set a line across the diagonal of the subdivision and take samples at equal points along the line. This pattern allows a subsequent identification of the location, which may help in the interpretation of results.	A pattern of parallel lines enables two or more sets of bulked samples to be taken and the location of sampling lines readily identified for later reference.
 Circular pattern for sampling a single soil-type Figure 3c	 Random pattern for a single-soil type Figure 3d
A circular pattern could cover subdivision variability more effectively than a diagonal line, but it is more difficult to later identify those areas within the subdivision from which individual sets of bulked samples were taken.	Random sampling across the subdivision covers variability but it is difficult to later define where individual samples were taken.

Figure 4: Subdivision of sampling area in respect to morphology and land-use



The different morphology of the sampling area, its land-use and other known differences need to be respected in the planning of the sampling design (Figure 4).

A necessary and important step in the planning stages of a soil survey project is to determine the number of samples required to achieve some pre-specified accuracy for the estimated mean. Estimates of the coefficient of variation (CV) for different soil properties are widely available, and are summarized in Table 4.

Table 4: Variability of Soil Properties (after Pennock D. & Yates T. 2006)

Legend: a Adapted from Wilding, L.P. and Drees, L.R., in L.P. Wilding, N.E. Smeck, and G.F. Hall, (Eds.),

Pedogenesis and Soil Taxonomy. I. Concepts and Interactions, Elsevier Science Publishing,

New York, 1983, 83–116.

b Adapted from Mulla, D.J. and McBratney, A.B., in M.E. Sumner (Ed.), Handbook of Soil

Science, CRC Press, Boca Raton, Florida, 2000, A321–A352.

Coefficient of variation CV			
Low	**Moderate**	**High**	**Very high**
(CV <15%)	**(CV 15%–35%)**	**(CV 35%–75%)**	**(CV 75%–150%)**
Soil color and value a	Sand content a	Solum thickness a	Nitrous oxide flux b
pH a	Clay content a	Exchangeable Ca, Mg, K a	Electrical conductivity b
A horizon	CEC a (Cation Exchange Capacity)	Soil nitrate N b	Saturated hydraulic conductivity b
Thickness a	% BS a (Base Saturation)	Soil-available P b	Is b
Silt content a	$CaCO_3$ equivalent a	Soil-available K b	
Porosity b	Crop yield b		
Bulk density b	Soil organic C b		

Table 4 shows that for most of the relevant soil properties the coefficient of variation is low or moderate with exception of the properties of nutrients and salinity. That means that the main information about the quality of the soil is achievable with a moderate sampling design as given in the German example. The sampling design should base on a geo-referenced map (GPS) to locate the sampling points accurately.

Collecting samples:

The material from the sampling points of one separated subdivision has to be transferred to the homogenization container. Each sample should have approximately the same volume. Samples of the different depths have to be transferred separately to different homogenization containers. These containers must be marked with the necessary data (date of sampling, subdivision, depth, sampling equipment, numbers of sampling points). Samples from bigger subdivisions should be divided into different bulked samples in the case of fertilization decisions. If it is an evaluation of the soil of the area that will be mined, just one homogenized sample for each subdivision may be enough. The samples then have to be transported to a specialized soil laboratory.

Sampling equipment:

Two different proven methods are applied,

- Digging with a spade or similar equipment,
- Drilling boreholes with (I) a hand-driller (hand-auger) (Figure 5) or (II) a machine-driller for deep underground sampling.

Information of the physical soil parameters including soil-water and soil-air (porosity), the different soil-horizons (A, B, C) and the chemical property is needed for 60 (100) cm depth for re-cultivation purposes. It is the main biological active zone and the zone of the highest density of plant roots. Commonly used sample depth combinations are 0 to 15 cm and 15 to 60 cm, or 0 to 30 cm plus 30 to 60 cm. However, if the soil nutrient of interest is expected to be stratified by depth, as with water-soluble highly mobile nutrients, potential cation exchange capacity (CEC) and the acidification potential, then additional sampling increments up to 100 cm would help ensure accurate recom-mendations. To ensure that a uniform volume of soil is taken through the full depth of each sampling increment samples should be collected using soil probes and augers designed for this purpose. A wedge-shaped sample like that collected using a spade will not give consistent results. All probes should be kept clean and rust free. Avoid contamination at all stages of sample handling. There are many distributors for soil-sampling kits in the internet available.

Figure 5: Typical soil-auger (photo: Robin Simmen, Cornell University)

German example:

For the routine mine soil mapping and the up scaling of point information to spatial average a geo-referenced raster scanning with Pürckhauer-soil core sampler / geo-sampler (Figure 6) is provided in Germany. Such a geo-sampler costs about 600 $ (www.buerkle.de). Correspondent to the expected soil heterogeneity, the regular mapping grid should be 50 m x 50 m to 50 m x 100 m, in case of quite homogenous coverage material 200 m x 200 m is sufficient. Boreholes are 1.5 cm in diameter and 100 cm in depth (Figure 6 and b).

Basic morphological and other diagnostic soil criteria are recorded by a brief core characterization following FAO Soil Classification Scheme (2006) and / or German Soil Mapping Guide 5 (AG Boden 2005). The data set contributes to a definition of soil types which are verified according to diagnostic criteria and analytical data obtained at site representative soil profiles. By simple drilling, the following set of soil-related parameters can be assessed:

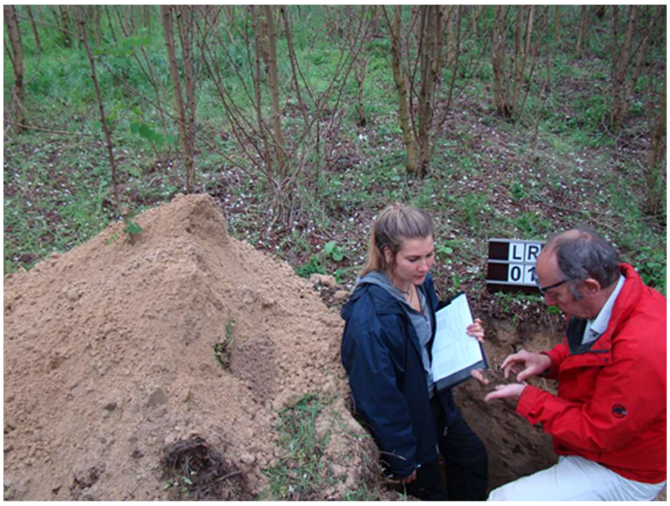
- Layer / horizon boundaries, soil colour
- Parent soil material (bedrock), geological stratum
- Particle size distribution, texture of fine earth
- Humus and carbonate ($CaCO_3$) content
- Coal and other additions (e.g. artefacts)
- Field soil pH ($CaCl_2$)
- Degree of soil compaction and cementation
- Hydro-morphism

One reference soil pit (100 cm depth) for every 3 to 5 ha geo-referenced mapping section or observation plot should be characterized and analysed in detail. The soil profile pit description and coding of key attributes is according to FAO Guidelines for Soil Description (2006) and / or German Soil Mapping Guide 5 (AG Boden 2005). Both compatible guiding principles guarantee for an accurate field investigation and characterization of soil genetic horizons / substrate layers within the major rooting zone. The pedological characterization is completed by sampling according to the identified horizons (Figures 7 and 8). The basic mandatory site and soil attributes are listed in Table 5 (see also MNS 2305:1994).

Figure 6: Geo-sampler or core-soil-sampler after Prof. Pürckhauer

Figure 7: Transferring the different soil depths (0 - 30 cm, 30 - 60 cm 60-100 cm) in bowls for evaluation in the field (photo: LMBV 2006)

Figure 8: Typical situation of mine soil profile description and sampling, characterization of initial soil properties, here some years after natural succession (photo:Schlenstedt 2018)



For soil typology and classification, the International Soil Classification Principles according to WRB (IUSS Working Group, WRB 2006) and / or German Soil Mapping Guide 5 (AG Boden 2005) are suggested. The following scheme outlines workflow and further steps to be taken in mine site survey:

Workflow in mine site survey

- Step (1): Borehole and field profile descriptions are checked to find references to basic soil-forming processes (e.g. darkening of topsoil indicating enrichment with organic matter, browning of topsoil indicating weathering of parent material) leading to a horizon / layer designation.
- Step (2): Horizon / layer designation and analytical data are checked whether certain soil characteristics correspond with WRB (IUSS Working Group WRB 2006) and / or German Soil Mapping Guide 5 (AG Boden 2005) requirements, regarding diagnostic horizons or layers, soil properties and materials.
- Step (3): Described combinations of diagnostic horizons / layers, soil properties and parent materials are compared with WRB and / or German Soil Mapping Guide 5 Soil Classification Systematic (latter allows a more precise description of mine soils with respect to requirements of reclamation).

Further steps in mine site survey

- Step (4): Development of a specific mine soil classification procedure for dumps of coal mining (regional, national) in Mongolia, by description, analysis and grouping of reference soil profiles (e.g. Eastern German Mine Site Classification System), creation of a mine soil data base
- Step (5): Establishment of a standardised site quality assessment system, principles for the deduction of site index (fertility) and land units from soil observation, analytical data and cropping performance, prognoses of sustainable crop potential (productivity, yield stability,

quality), therefore applied soil and yield monitoring in permanent plots on different, quite typical reclamation sites all over the country

- Step (6): Implementation of mine survey guidelines (regulations) in the reclamation process, definition of minimum requirements for sampling and reports, specific manual and criteria for sampling, assessment and analysis of mine soils, training programs in mine soil reconnaissance and mapping, on-going improvement of methods and measures.

The mine soil description is completed by digital photographic recordings, illustrating (i) the geomorphology and vegetation of the surrounding area and (ii) the soil profile wall (before and after cleaning). For soil profile photography, a bicoloured centimetre scale is helpful. If needed, the horizons are gently outlined and special aspects of soil formation are accentuated (e.g. mottles, cracks, coarse fragments, matting of roots, application of ameliorants et cetera). Appendix A.2 is an example of a soil description in the field on a re-cultivated dump site.

5.3 Substrate analysis and evaluation

Borehole and field profile descriptions may be complemented by lab analysis of soil samples. Analytical data should be obtained by international reference methods in applied soil analytics (e.g. according to FAO 2006, Cools & de Vos 2010). Ideally, they are also synchronized to national analytical standards and data collected already. All laboratories involved in mine soil analysis have to use the same reference methods, mainly following ISO standards (Table 5).

Table 5: Key laboratory parameters of mine soil evaluation and ecological evidence (see also MNS 3310:1991)

(based on FAO 2006, Cools& de Vos 2010, TI Institute for World Forestry, supplemented)

Parameter classification	Key parameter	Ecological relevance and effects
Acidity	pH, iron sulphides (FeS_2), (acidification potential)	Acidification status, mineral weathering intensity and rates (Al, Fe, S), plant nutrient uptake
Salinity	Soil electrical conductivity (EC)	Salinity stress and salt tolerance, plant water and nutrient uptake, site productivity
Exchange characteristics	CEC, BS, exchangeable cations and acidity, $C_{t,}$ soil organic matter (SOM)	Acid-buffering properties, base status, plant available mineral nutrients
Macronutrients	N, P, K, Mg and Ca(total content and plant available fraction)	Growth limiting nutrients, nutritional imbalances, calculation of nutrient stocks

Contaminants	Heavy metals (e.g. Pb, Cu, Zn, Cd, Cr, Ni,…), As, B...	Phyto- and Eco toxic effects, hazardous, limiting food production
Soil physical and mechanical parameters	Particle size distribution (soil texture), content of coarse fragments	Estimation of plant available water, susceptibility to water and wind erosion
	Bulk density (BD_{fe}), pore size distribution (pF 1.8),soil air capacity (SAC)	Index of compaction, aeration, limiting rooting, water infiltration and drainage
	Soil water retention (SWRC), plant available water storage capacity (PAWC)	Water fluxes and storage, estimating irrigation water need (IN), timing of water application
	Strength and compressibility, particle size distribution, plasticity of fine-grained materials, SWRC and water conductivity	Geotechnical stability of dumps and slopes, deduction of additional measures (drainage, biological engineering)

1) Chemical analysis comprises soil reaction (pH), salinity (EC), cation exchange capacity (CEC), buffering properties, carbon content, soil organic matter (SOM) and macronutrient availability (N, P, K, Mg, Ca). If reasonable, special soil contaminants (e.g. heavy metal pollution, harmful organic compounds; total contents and mobile fractions) and soil acidification potential (e.g. pyrite (FeS2) weathering) should be taken into account (optional parameters).

2) Mandatory soil physical parameters are soil skeleton, texture (7 classes), soil bulk density (BDfe), soil water storage capacity (SWSC), plant available water storage capacity (PAWC), air capacity (SAC) and porosity (pore size distribution) and by this conductivity. In case of additional ge-otechnical evaluation analysis of strength and compressibility, plasticity and water conductivity should be carried out. Such evaluation will be based on further information about dump geom-etry and slope design (e.g. gradient and form) as well as climate data (especially rainfall and evaporation).

However, the measurement of soil water is quite time-consuming and requires profound laboratory expertise. Optional, both soil water retention curve and hydraulic properties can be derived from surrogate data, such as soil texture and compaction using Pedotransfer-Function-Models (e.g. Rosetta-NRCS, USDA).

Mine soil substrate mapping is essential for any land use planning and reclamation. A consistent classification scheme has to consider both, soil quality requirements for a sustainable post-mining land use but also engineering or reclamation procedures.

The results of the soil survey and evaluation are essential for the deduction of site-adapted land use options, soil amelioration measures (e.g. liming, sub-soiling) and reclamation technologies (e.g. choice of plant species, tillage, fertilization, planting schemes, tending strategies, crop rotation and management).

5.4 Soil survey and mapping report

For each soil mapping plot the results of soil evaluation are reported in a Soil Survey & Mapping Report, summarizing and visualizing the investigated site and analysed soil profiles (Figure 9). Thus, the account lists the main results of the soil survey and provides site specific information (location, orientation, slope angle etc.), analytical data of soil profiles, a fertility appraisal / index of land quality (e.g. Figure 10), the deduction of soil types in spatial distribution (e.g. Figure 11) and recommenda-tions on a sustainable post-mining land management.

Figure 9: Mandatory contents of the Soil Evaluation & Mapping Report

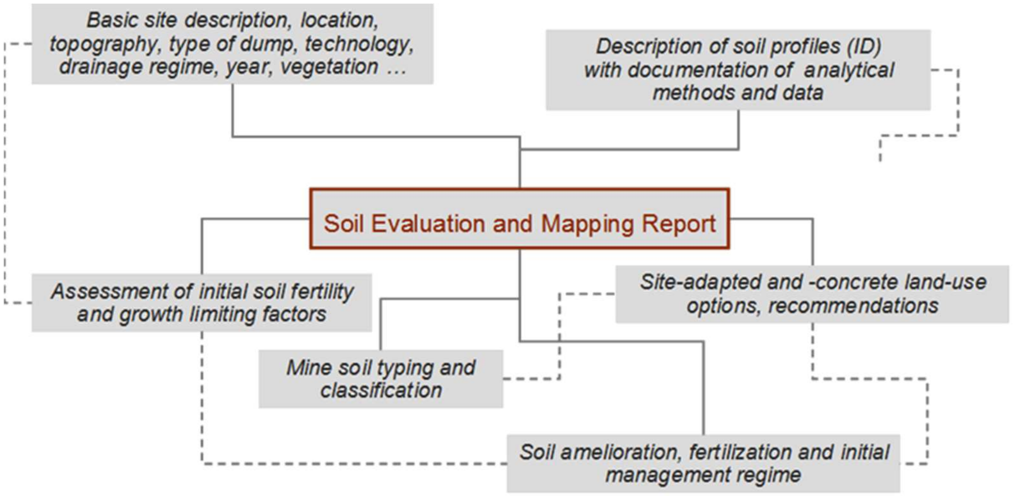


Figure 10: Mapping of pH-distribution (0-100 cm soil depth) as a mandatory criterion of soil fertility (Example from a German report)

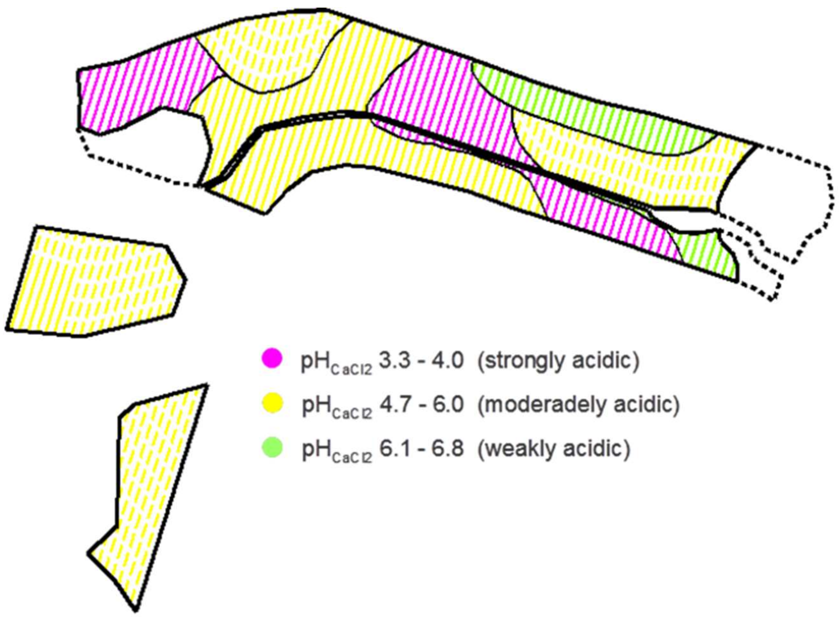
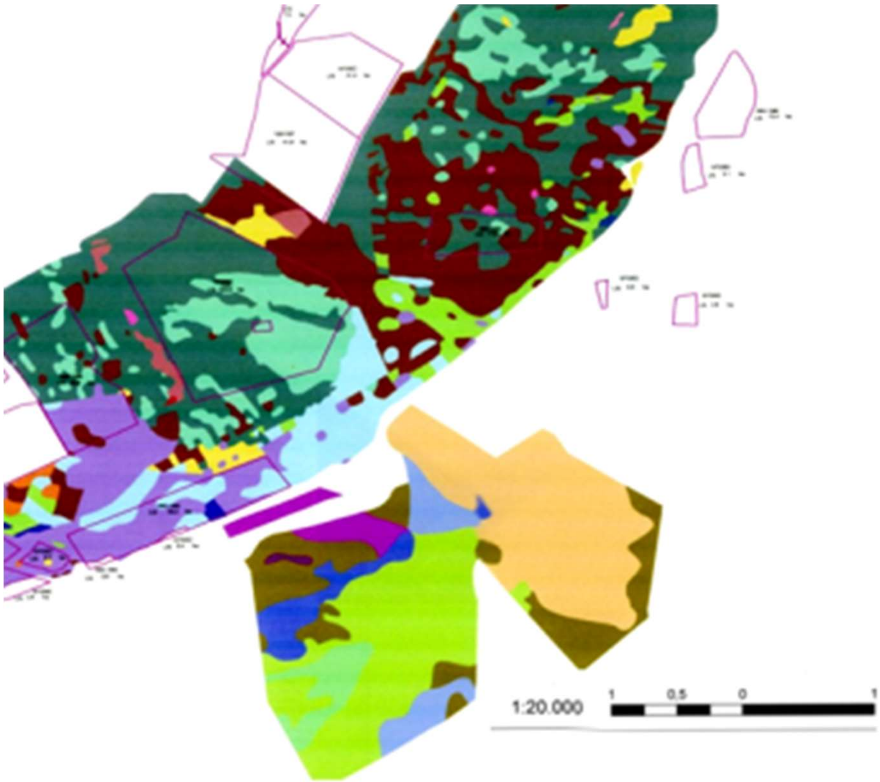


Figure 11: **Mine soil mapping at landscape scale (1:20,000), coloured patches reflecting different mine soil types (Example of Welzow Mine in Germany)**



6 Design of dumps in respect to after-use (Geological Rehabilitation)

6.1 Principles

"To hand over [the site] to the local government administrative authority that issued the permission, after rehabilitating the land that was damaged in the course of using subsoil to ensure its safety and in a way that [the site] can be used again"

(The Law of Mongolia on Sub-soil (1989) Article 20. 4. The basic rights and duties of users of subsoil)

The appearance of the post-mining landscape is characterized decisively by its relief. Heaps and dumps are more than just storage of not needed or not useable material. They have to give space for nature and for necessary after-uses like agriculture and forestry. Mining heaps and dumps have to fulfill a production function for food and wood and have to stabilize the ecological situation of the land affected by mining. Once the final surface with a particular slope inclination has been shaped, the future flow-direction of surface water and the collection of rain water are pre-designed. Also, the exposition to the main wind-direction and the intensity of solar radiation on the future fields and forests are defined by the dumping process. Therefore, the geometry of dump sites has an eminent influence on the development potential of the post-mining landscape. As long lasting manmade construction the geotechnical stability is of crucial importance. Dumping processes based on geotechnical calculations and geotechnical reports after dumping are proven methods for sustainable and economic dump designing.

The timely planning of the landscape and the implementation of measures as planned is of high importance for reaching low-carbon goals also in the after-use planning.

The geometry of the heap / dump surface has an evident influence on:

- Geotechnical safety,
- Susceptibility to erosion by wind and water,
- Aesthetics of the post-mining landscape,
- Economic after-use,
- Biotope-diversity and thereby diversity of species,
- Possible self-ignition of the dump site.
- The rehabilitated area should be harmoniously embedded into the surrounding terrain so as to allow non-eroding drainage of surface water. Ground slope is a function of rock stability, and must in general not exceed 18 - 20° (25°) (see MNS 5917:2008 water saturated 25%, open-pit 18 % 10.5 10.7 and guideline A138).

Mining machinery should be employed in landscape remodelling / dump site shaping (e.g. levelling, backfilling) whenever possible to reduce cost and energy consumption of the landscape design work.

6.2 Spatial and temporal design

The construction of heaps / dumps in open-pit mining follows a specific spatial and temporal design planning.

Material from different excavation points is transported to the future dump site. Gangue material from the different working faces in the underground in contrast is transported and dumped as a mixture of different materials. In general, the material from open-pit mining should be backfilled in the same succession as they have been in their undisturbed geological strata whenever it is possible.

The foundation of the future heap should be of solid material.

6.3 The management of tailings and waste-rock

The management of the residues generated at mining operations, typically presents an undesired financial burden on operators. Typically, the mine and the mineral processing plant are designed to extract as much marketable product(s) as possible, and the residue and overall environmental management is then designed as a consequence of the applied process steps.

The choice of the applied tailings and/or waste-rock management method depends mainly on an evaluation of three factors, namely:

- cost
- environmental performance
- risk of failure.

6.4 Key environmental issues

The main environmental impacts from tailings and waste-rock management facilities are impacts associated with the site location and related land take as well as the potential emissions of dust and effluents during operation or in the after-care phase. Furthermore, bursts or collapses of tailings and/or waste-rock management facilities can cause severe environmental damage – and even loss of human life.

The bases for the successful management of heaps, dumps and tailings and waste-rock are a proper material characterization, including an accurate prediction of their long-term behaviour, and a good choice of site location whenever possible. (EU-Mining-Waste-Directive 2006).

Emissions:

Effluents and dust emitted from heaps, dumps, tailings and waste-rock management facilities, controlled or uncontrolled, may be toxic in varying degrees to humans, animals and plants. The effluents can be acidic or alkaline, and may contain dissolved metals, as well as possibly natural occurring organic substances such as humic and long-chain carboxylic acids from mining operations. The substances in the emissions, together with their pH level, dissolved oxygen content, tempera-ture and hardness may all be important aspects affecting their toxicity to the receiving environ-ment.

Usually a mine, together with the mineral processing plant and the tailings and waste-rock facilities, will only remain in operation for a few decades. Mine voids (not part of the scope of this work), tailings and waste-rock however, may remain behind long after the mining activity has ceased. Therefore, special attention needs to be given to the proper closure, rehabilitation and after-care of these facilities.

The most important aspects in management of tailings and waste-rock, despite the choice of the site locations, are the consideration of failure modes of heaps and dams, the relationship between tailings characteristics and tailings behavior and the acid rock drainage (ARD) potential (EU-Mining-Waste-Directive 2006).

6.5 Heaps / Dumps

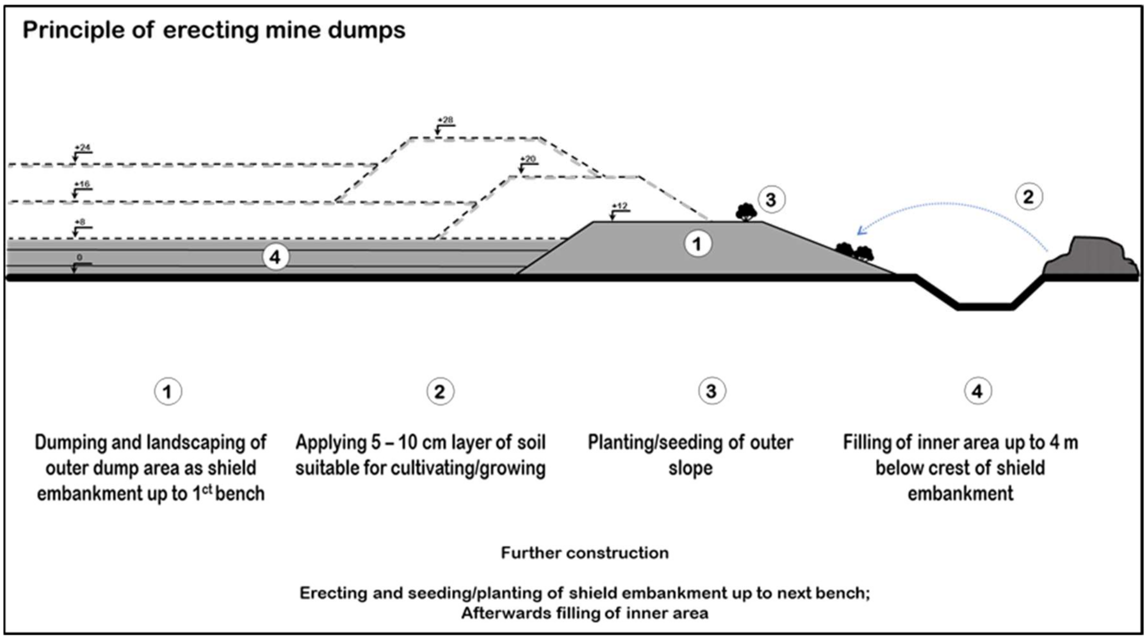
Water is by far the most likely cause of instability in a tailings or waste-rock dump sites and for the soil underneath the dump site.

Therefore, anything that tends to increase or decrease the amount of water or pore pressures in dump sites and its foundations is a potential source of weakness. Particular attention is given to drainage around the heap in order to prevent the flow of groundwater into the heap and to prevent ponding of water at the toe. On sloping ground, drains are usually constructed near the uphill side of the facility. For calculating the capacity, the following factors are taken into account:

- catchment area uphill of the drain
- existence of springs
- agricultural drains
- natural surface water flows which will be interfered with by the heap.
- All dumping processes shall be in accordance to the existing national Mongolian Standards. The following describes advanced methods and explain the reasons (see also MNS 5918:2008 & MNS 2015 0330 and guideline A-138).

Figure 12 shows an example of a tailing heap construction with coarse material from hard-coal mining in Germany. It is an efficient and cost-saving method which allows also landscape-modeled heaps.

Figure 12: Schematic drawing of tailings heap construction source: adapted after: "BREF contribution", DSK, 15.4.2002.



Construction of a tailing heap

Principally, tailings are dumped onto the heaps in layers. The thickness of layers' ranges from 0.5 to 4.0 m. Compaction is achieved by way of the trucks' rolling wheels and via vibration rollers to reduce, as much as possible, penetration by oxygen or precipitation into the heap body and, thus, minimiz-ing or even preventing the generation of ARD by pyrite oxidation.

The following steps should be carried out:

- At the beginning of preparatory works, recovery of the grow-able / fertile topsoil from the entire ground area should be carried out.
- The permeability / impermeability of the future base of the tailing heap have been checked and areas with high permeability need to be sealed, for example with compacted tailing material of adequate quality.
- Construction of a drainage system with a ditch running along the heaps toe collecting the surface run-off and transporting it to a water collecting pond.
- For documentation and evaluation of the effects resulting from the impacts on the groundwater cycle system, a groundwater monitoring system should be installed, using precipitation measurements as well as surface water and groundwater surveillance. For this purpose, observation wells are needed. This set of measures allows the operator to discuss possible changes in groundwater composition with experts at any point and to rapidly initiate necessary measures.

The following information should be collected in front of the construction of a tailings heap:

- water management:

  hydrologic study, including a groundwater model

  drainage concept for the tailings heap's surface

  plan of a hydraulic/subsurface drainage system in the heap's rim area

  study of the hydro-chemical processes in the drainage system, with respect to operation

- safety

  compensation measures for balanced water management, retention and discharge of precipitation and leachate emanating from the tailings heap

- dumping:

  dumping plan, including essential calculations on structural stability and subsidence

  expert opinion on fire protection during the dumping phase

- emissions, pollution:

  expert opinion on emissions and pollution of dust

  expert evaluation on noise emissions and pollution into surrounding neighbourhood

- environmental impact study:

  impact of the tailing / heap / dump on flora and fauna and surface water

- regional development plans:

  regional development plans for constructing a landscaped earth structure including

  modelling and re-cultivation plan

- recreation (if planned):

  control of recreational activities

- re-cultivation / greening:

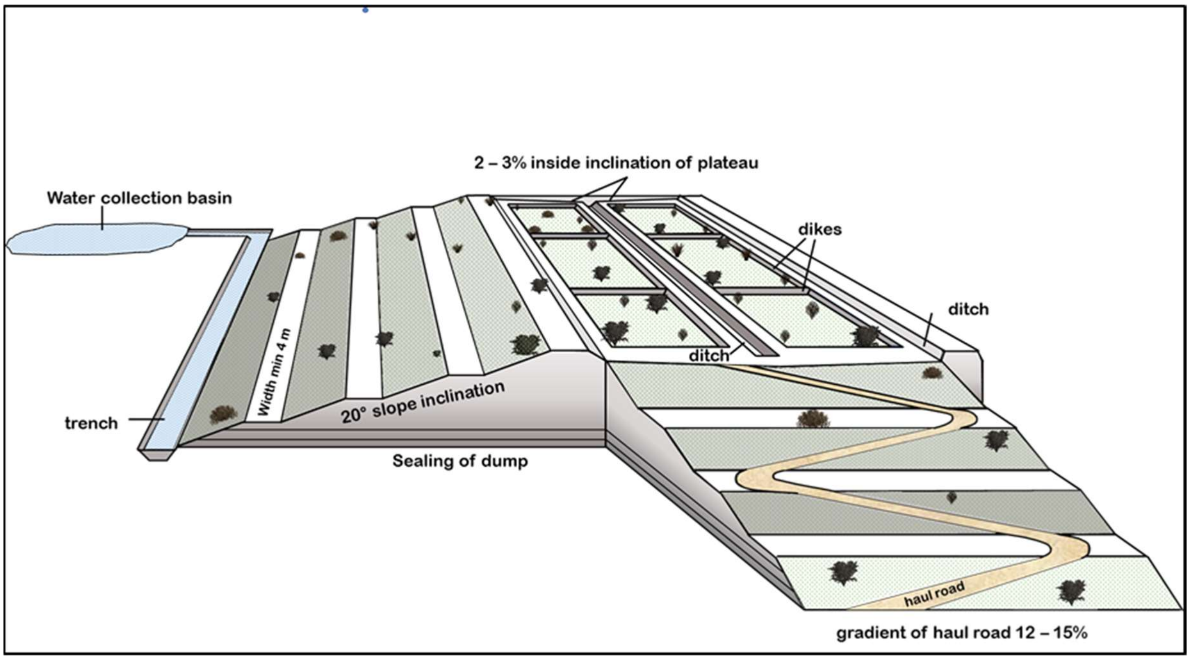
  transition of plants.

Figure 13 shows an idealized heap construction. Mining-Waste dump sites consist mainly of gangue-material impairing successful establishment of a vegetation cover. Therefore, waste rock material should be utilized by strictly adhering to the following principles:

- Dense compaction of the dumped material with caterpillars on evenly spaced strips (e.g. every 3 – 5 m in accordance to the material) during the dumping process;

- General inclination maximum 1:4 (roughly 25%);
- Division of slopes by intermediate berms every 30m;
- Covering of gangue-material with fertile soil e.g. loess-topsoil, kastanozem-top-soil;
- Construction of a drainage system during the dumping process.

Figure 13: Schematic drawing of tailings heap construction source: adapted after: "BREF contribution", DSK, 15.4.2002.



The gradient of the haul-roads should not steeper than 12 - 15% to prevent destruction impacts of the trucks. The management of water and wind on dump sites are essential factors for the stability and possibility for any after-use. Rainfall is the only natural water source on dump sites. It is a precious good. But it can be also the source for erosion. Dividing the plateau of heaps into different sectors, divided by dikes and a surrounding ditch let the water percolate into the fertile part of the heap and prevent water erosion. Between every slope and berm should be also a ditch to prevent water from running down-hill uncontrolled.

6.6 Backfilling of overburden and waste rock into mining pits

Dumps will eventually create areas with economic after-use, especially agriculture and forestry but also nature conservation. Therefore, unfertile or hazardous material shall be deposited in the deeper parts of the mining pits and thoroughly compacted according to the land-use direction. Contact of that material to groundwater and seepage must be precluded by all means possible. The whole dump shall be compacted during the dumping process in accordance to prescribed geotechnical safety standards. Fertile soil shall be dumped in the upper 2 m of the final dump. This material should not be compacted by heavy machinery. The slope angle between different dumps should be at most 1:3 to 1:4 (roughly 30 to 25 %) while the flat areas should receive a slight counter-slope of 2 %.

Amount, availability, transport and quality of the overburden are the limiting conditions of safe dump design. Therefore, a reliable forecast of velocity and direction of strip-mining is necessary to calculate the usable overburden masses and their specific qualities. The relevant data from the technical department are the basis for any design work.

Dump construction starts right at the beginning of dumping and must not be postponed to the end. A unified planning of excavation, mass-transport, intermediate storage of top-soil and dumping optimizes the efficiency of needed funds, low-carbon approaches and future land-use.

6.7 Dump site management and stable slope geometry

The geotechnical stability of heaps, dumps and slopes shall be calculated by experts in accordance to official regulations, an indispensable prerequisite for dump design and dumping process. The stability of dumps depends on general factors such as material, particle size, cohesion of particles, water content of the dump, weight, length of the slope, inclination of the slope and re-cultivation factors such as soil permeability and vegetation cover.

A dump consists of platforms, slopes and berms, each part offering different options for re-cultivation and after-use. Overburden masses shall be handled in relation to the specific requirements of the planned after-use (e.g. agriculture, forestry, tourism) and the natural surroundings.

Platform

The platforms are most suitable for agriculture and forestry. For ease of future management and reduction of earthworks, the platform should be divided into squares surrounded by ridges of 0.5 - 1.0 m height to store the rainfall water. The usable water depends on soil permeability and annual precipitation. Agricultural fields should be, therefore, protected by afforestation with draught resistant plants perpendicular to the main wind direction. The squares are connected by roads. Ditches collect surplus water for use in fire-ponds on the platform or outside discharge away from the heap.

Platforms shall have an inward slope (2 % maximum) to prevent water erosion along the heap shoulders. Such platforms have a different micro-climate as compared to hill-top-platforms. In general, the usable water capacity is higher and wind exposition lower. Plants with higher water demands are possible in general.

Berms

Berms are small platforms inside the slope system. Berms interrupt the slope and reduce the general inclination of a slope. By this the slope stability is increased. On berms control-roads for the slopes are essential. Road-side channels collect excess water from the slopes.

Slopes

The geo-technical stability and the available space for dumping in relation to after-use determine slope length and inclination. For agriculture, slope angles shall be less than 20°along the heap's outer edge while angles for afforestation shall not exceed 35°.To increase stability, slope design shall emulate the natural topography. Control of surface-water run-off is eminent. Grids made of natural material like branches on the slope and water retaining ridges on the slope face (embankment edge) are part of the slope stabilizing system. Plants (shrubs and trees) should be planted on steeper slopes in triangular form of 4 – 6 m so that plants along up-hill rows are spaced in between two plants along down-hill rows (Figure 14 & 15).

Figure 14: afforestation of slopes, triangular form

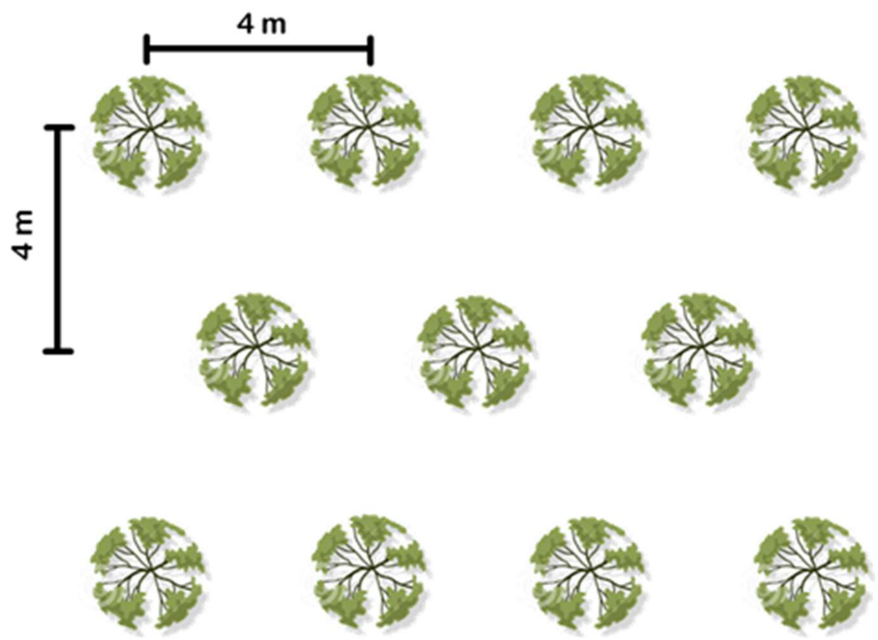
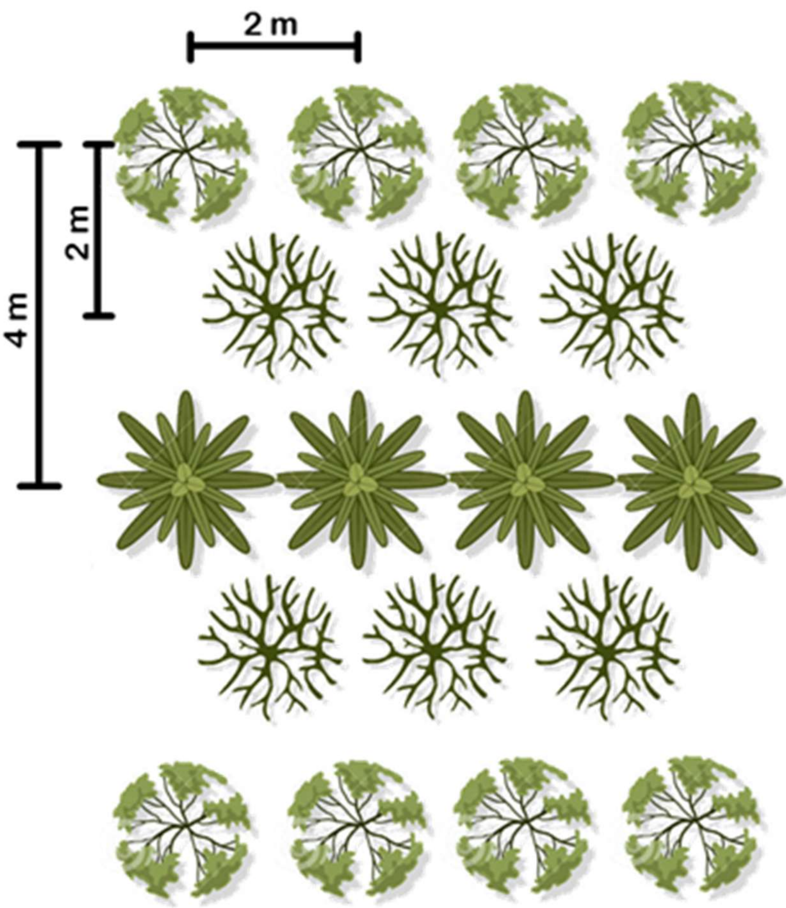


Figure 15: Planting pattern on dump slopes alternative: mixed stand and more densely planted



Mining schedules and dump site parameters are illustrated by Tables 6 - 10.

Table 6: Main technical characteristics of strip-mine engineering

No.	Index Name	Units	Index
1	Main technical characteristics of strip mine		
1.1	The average length of the surface state	km	
1.2	The average breadth of the surface state	km	
1.3	The area of the surface state	km^2	
1.4	Maximum depth of mining	m	
1.5	Terminal slope angle	°grade	
2	Construction period		
2.1	Construction period		
2.2	Commissioning of the project		

Table 7: Area of land damaged by mining

Time interval	Original land use	Area	Ownership
		m^2 / ha	

Table 8: Dump site parameters

Items	Units	heap			dump
		1	2	etc.	
Eventual dump site elevation	m				
Coefficient of volumetric expansion					
Final stable slope angle	°grade				
Bench slope angle	°grade				
Minimum working width of flat plate	m				
Dump site-capacity	Mm^3				
Maximum number of dump steps					

Table 9: Area of land occupied by heaps

Time interval	Original land use	Area	Ownership

Table 10: Area of land required for storage of stripped top soil

Time interval	Original land use	Area	Ownership

6.8 Surfaces and inclination in agriculture and forestry

The overarching goal is to create a post-mining landscape with a high potential for land use especially agriculture and forestry, including biological carbon-dioxide sequestration.

In case of agricultural re-cultivation, the area should be accurately leveled with a minimum inclination of 1:200 (0.5 %) to allow surface water run-off as well as mechanization and a maximum inclination of 7 % to avoid soil erosion by water.

For forestry, leveling is not necessary so far, as long as relief differences are not higher than 0.5 m. The slope angle should not exceed 1:4 (25 %) to allow mechanized tending and harvesting.

Substrate freshly dumped or uncultivated is exposed to wind, rain and sunshine. Erosion by wind and by water is highly likely for any dumped, poorly structured material. Inclination angle and slope aspects directly influence the susceptibility to erosion. Before a dump site is covered with plants or artificial material, the dumping design should hasten soil development and prevent unplanned water accumulation as well as uncontrolled surface run-off. Small dams in a checkerboard pattern divide the slope into small patches, thus, allowing rainfall to infiltrate quickly into the soil. Depending on the inclination, dam-spacing should be 100 to 20 m horizontally and 20 m vertically. This approach reduces velocity of surface water run-off and sedimentation to a minimum. Additional water collection channels and basins next to access-roads lead surplus water to the bottom of the heap. Berms and roads should be constructed with a counter-slope to the inclination of the heap (approx. 2%).

As a matter of principle, only water which cannot be retained by infiltration should be drained from the dump site.

Design and capacity of the drainage system should be such, that it can handle periodically occurring surges from heavy rainfall over a short period of time or from snow-melt, even a "hundred years" event. As a rule, the water absorption and retention capacity of the cultivated soil increases with the cohesiveness of the soil improved by vegetation cover.

6.9 Special case: Slopes to the working phase and future construction sites

Slopes and berms next to the working phase cannot be recultivated finally. They need an intermedi-ate erosion protection system to reduce water and wind erosion and, thus, dust emissions. These areas should be covered by grass and herbs. Successful methods are construction of the embank-ment with fascines and seeding casting or hydro-seeding. Small amounts of fertilizer promote the success.

6.10 Inspection protocol

Appendix A.1 is an example of the inspection protocol used in the East-German lignite mining industry for the finalization of all dumping processes as prerequisite for the subsequent rehabilita-tion steps.

7 Soil rehabilitation and improvement on raw dumps and heaps

7.1 Principles

Dumping substrates such as parent material may be unfavorable for the development of fertile soils, impeding plant growth, microbial activity and other soil functions. Such substrates are often characterized by compaction, low or high pH-values, lack of humus and/or high contents of pollutants. If these conditions do not disappear by natural processes of soil formation or regular soil tillage in a short time, based on systematic soil analysis, special technologies of soil improvement have to be applied, taking account of economic and technical limitations.

7.2 Soil management and conservation measures

In order to get the best results of sustainable soil rehabilitation, usually the best quality soil or parent material with favourable physical and chemical properties should be selected. Extreme compaction must be avoided by restricting the movement of heavy machinery for transport and leveling, especially when soils are near saturation point. Substrates with high silt contents like loess are very susceptible to compaction.

Soil conservation measures in open-pit mining also involve separate topsoil and subsoil stripping, stockpiling and backfilling. Stockpiles can be established temporarily in mined-out areas or on waste rock piles. Stockpiles should be built in layers and be protected by retaining walls. A grass cover will conserve them and retain the soil´s nutrients.

The amount of soil stripping depends on the thickness and quality of the top- and subsoil. As a matter of principle, only fertile soils are stripped and separately stored. When too thin, uneven in texture or too poor in nutrient content, they are usually not reserved for later rehabilitation work for economic reasons. Vice versa, when of superior quality (e.g. abundant organic content), such soils make excellent rehabilitation material. On arable land, the solum is commonly stripped down to 0.5 meters. To reach high and enduring productivity on the dump sites at least 1 m of fertile soil is required on arable land, 2 m are recommended in respect to a high yield potential for a big spectrum of crops.

In order to avoid long-term storage, and the concomitant danger of nutrient loss and compaction on the intermittent soil stacks, the stripped soil should be distributed on the reclaimed land as soon as possible.

Especially wet clay and silt soils are prone to compaction. Hence, soil transportation, dumping and leveling of such materials with heavy machines during the rainy season must be reduced to an unavoidable minimum.

The soil should be spread in a thick layer. In General, on the planed surface, the movement of heavy equipment must be minimized and strictly confined to predefined and appropriately demarcated transport routes. Vehicles must shuttle back and forth along the same route. On compaction-prone areas, the ground must be loosened up before the next layer is added. When installing the top layer, all wheeled traffic should be banned, respectively rely on tracked vehicles and/or long-arm excavators only.

7.3 Amelioration

Compaction

As a consequence of soil compaction, bulk density is high and soil porosity low. Especially the coarse pore volume is reduced, leading to poor aeration and retarded water infiltration. Plant growth is impaired due to poor water and nutrient supply as well as resistance to root penetration. Bulk densities in topsoil should be less than 1.60 g/cm3. Tillage down to a depth of 30 cm may be done by conventional agricultural implements. Below the tillage depth (20 to 30 cm), soil bulk density should not exceed 1.75 g/cm3. Compacted subsoil has to be loosened by technical means. Deep loosening down to 60 - 100 cm requires special equipment and generates high cost. Whatever technology is being deployed, the working of wet soils will do more harm than good. After deep tillage or rotation, such soils are very susceptible to re-compaction, and have to be protected by establishing deep-rooted plants (e.g. alfalfa, sweet clover) and exclusion of any traffic during the first 3 years after the soil treatment.

Acidification

In waste rocks of coal mining, the weathering of pyrite often causes acidification that limits plant growth. Soil acidity may promote the solubility and mobility of aluminum, iron and other phytotoxic heavy metals. Soil-pH can be adjusted by liming to achieve target pH-values (measured in KCl or $CaCl_2$) of 5.0 - 5.5 for forestry and 6.0 - 6.5 for agriculture, in order to guarantee very favorable growth conditions for revegetation and soil biota. The lime requirement has to be defined by special methods considering the long-term acidification potential of the sulfides, e.g. by an “acid-base-balance” (Katzur & Haubold-Rosar 1996). Besides lime, ashes with a CaO-content of at least 10 % (dry weight) may be used, if they have low contents of harmful components like heavy metals and their application does not cause a contamination of the environment. The liming agents should be mixed with the sulphurous and acidic soil substrates to a depth of 1 m. In case of afforestation on coarse textured soil materials or the establishment of grass- and bush land, the amelioration depth may be reduced to 60 cm (trees and bushes) or 30 cm (grass and herbs). For afforestation, the amount of lime or ash should be calculated for a depth of 1 m, even if the incorporation depth is only 60 cm, assuming a leaching of carbonates with the seepage water and thus a liming effect in the deeper subsoil zone. The spreading of the needed amount of lime can be calibrated and controlled by an inspection protocol. Appendix A.3 gives an example.

Humus and nutrient deficiencies

Most mine sites and waste rock or parent material dump sites have low amounts of nitrogen, phosphorus and sometimes other macro-nutrients. A solution to this problem is to add certain amounts of mineral fertilizers that are adapted to site conditions and the prescribed after-use. Adding organic fertilizers will provide a slow release of nutrients by mineralization and contribute to humus accumulation and therefore carbon sequestration. Using organic materials like compost and bio-char will increase the contents of humus-like matter.

7.4 Cultivation of site improving plants

Biological measures are an important part of the rehabilitation work. Plants can indirectly create environmental and economic benefits and their establishment is an essential activity to restore soil fertility and biological productivity as well (see MNS 5918:2008).

Selection criteria

The selected plants should have the following properties:

- strong ability to adapt to unfavourable soil and climatic conditions;
- ability to fix nitrogen (leguminous plants)
- intensive and deep root system, fast growth and low mortality rate and
- producing high amounts of organic residues for humus accumulation and thus carbon sequestration in the developing soils.

Especially in the early stages of land re-cultivation, the vegetation should have a strong resistance to drought and nutrient deficiencies. The usage of plants with high water consumption (e.g. grain crops) should be reduced to an unavoidable minimum. The plants should have high water use efficiency and be well adapted to the regional rainfall distribution throughout the year. Astragalus adsurgens, Avena sativa, Caragena spec., Hippophae rhamnoides Medicago sativa, Pinus tabulaeform-is, Potanina mongolica, Prunus armeniaca, Prunus pedunculata, Salsola laricifolia, Spirea aquilegifolia, Robinia pseudoacacia, Ulmus pumila, Vicia faba and have all proven useful in in semi-arid areas like northwestern China and Mongolia in terms of efficient water use, frost-hardy, and poor soils. The following plants are recommended for different purpose:

- Economic shrub growing areas: Prunus humilis, Prunus armeniaca, Pinus tabulaeformis, Amorpha fruticosa, Ligustrum lucidum and Syringa oblata;
- Herbage re-cultivation areas: Caragena spec., Medicago sativa and Bromus inermis.
- Farmland in crop-growing regions: Avena sativa, Zea mays and Vicia faba.

Vegetation configuration

The layout of the plant community should be grass /shrub/ tree combinations in space and the combination of short / medium /long-living plant species over time. All these combinations should reflect the local social, ecological and economic benefits.

Cultivation techniques

Plant cultivation should focus on herbaceous species (especially leguminous grasses). No-tillage or minimum tillage techniques should be practiced, coupled with stubble and straw mulching to reduce soil moisture loss. For small re-cultivation projects, the application of organic manure, phosphorus and potassium fertilizer or local materials, e.g. fly ash without critical contents of contaminants could be tested to improve soil fertility, as well as water and fertilizer holding capacity of the soil.

8 Agricultural and forest re-cultivation aftercare

8.1 Agriculture

Goals

The main purpose of agricultural re-cultivation is to promote soil fertility as a condition for sustainable productive land use. Safeguards are as follows:

Dumping of suitable soil or soil substrate on the dump or heap surface at a depth of no less than 1 meter;

- General minimum inclination of 0.5 % (1:200) for draining surplus water from agricultural plots without the risk of water erosion;
- Connection of plots with ditches to drain surplus water from the area;
- Measures against wind erosion, e.g. by suitable land-use patterns, shelter belts
- Amelioration and fertilization in accordance to the soil evaluation report;
- Crop rotation leaving plant residues to improve humus accumulation;
- Minimum soil tillage if there is no strong compaction.
- Analysis of site conditions

Soil preparation

The quality of the soil coverage determines yield potential and stability, soil carbon storage, and is, thus, the key in climate-smart agricultural re-cultivation.

The original soil is preferred as covering substrate on coal mining dump sites. If this material is not available in sufficient quantity, immature soil parent material like loess with a thickness of at least 1 meter from the surface after natural settlement, free of polluting materials and with a gravel content below 10%, can be taken instead. If topsoil is available, it should be used as the top cultivation layer on the dump site with a thickness up to 30 cm. Strong soil compaction should be loosened to a depth of 0.5 to 1,0 meter. PH $CaCl_2$ target values should range from 5.5 to 7.5, the salt content should not exceed 0.2 %. Organic fertilizers (e.g. manure) should be used to improve topsoil structure and quality.

Species selection

The plants chosen for crop-rotation have to fulfil the following requirements (see MNS 5918:2008):

- Good growth on the initially nutrient and humus poor raw soils with low microbial activity;
- Enrichment of the soil with recent organic matter (preferably narrow C/N-ratio) to stimulate nutrient turnover;
- Deep rooting to improve soil structure and water conductivity;
- High tolerance against desiccation, heat and pathogens.

To improve fertility of raw soils, a first crop rotation of 5 years (see Table 11) is recommended. The plants themselves should be able to improve soil fertility in a short time (principally legumes) and should be tolerant of low soil fertility.

Generally, a mixture of dominating Alfalfa (Medicago sativa) and selected grasses is recommended as standard combination for improving soil structure and fertility. Alfalfa should have a proportion of 40 – 50% during the rotation while grain should have one of 25 – 35 %. The accrued straw and hay shall be chaffed and used as green manure.

Fertilization

Supplying field crops with nutrients at the right time, quantity and quality is decisive for successful agricultural re-cultivation. The following factors are essential in relation to the regionally prevailing weather and climate conditions:

- Nutrient exchange capacity in the rooting layer;
- Nutrient requirement of selected agricultural crop / crop combinations;
- Total nutrient up-take by selected crop(s);
- Nutrient removal by harvest and effects of previous crop(s);
- Application rates of organic fertilizer(s);
- Controlling of soil acidity.

Site-compatible fertilization is one of the most climate-smart actions in the re-cultivation process. Therefore, the evaluation of the nutrient level and requirements should be done seriously.

Table 11: Example of average mineral fertilizer demand for selected crops on a loamy sand or silt (par-ent material without humus)

Crop rotation	Year of cultivation	Crop type	N per ha	P per ha	K per ha
Lucerne-Naked Oats / Potato-Bean	1-3	Lucerne	70-110	60-100	80-120
	4	Naked Oats (*Avena nuda)* / Potato	110-140	60-100	120
	5	Beans	80	170	150
Astragalus-Naked Oats / Potato-Bean	1-3	Astragalus	70-110	60-100	80-120
	4	Naked Oats / Potato	110-140	60-100	120
	5	Beans	80	170	150

Melilotus-Naked Oats / Potato-Bean-Corn	1-2	Melilotus suaveolens	70-110	60-100	80-120
	3	Naked Oats / Potato	110-140	60-100	120
	4	Beans	80	170	150
	5	Corn	120	-	-

Green manure can be applied directly on the harvested area in most cases. To minimize nutrient losses by erosion, mixing of the nitrogen fertilizer with the upper layer is recommended.

Acceptance certificate

Agricultural land re-cultivation control usually consists of a rehabilitation project test and a preliminary ecological restoration test three years after project acceptance. Inspection and evaluation are as follows (see Table 12 for overview):

- random sampling to check the quality of the rehabilitated land, commonly on 5 to 10% of the inspection area;
- items to be inspected include feasibility report, design document, implementation plan and local background information of the rehabilitation project;
- parameters of on-site inspection include the overall layout, backfill area, soil thickness, dump site geometry (slope, relief), bulk density of overburden, soil pH, salinity as well as irrigation and flood control facilities;
- items and parameters of ecological inspection include soil fertility improvement and crop planting reports. Parameters of on-site inspection include crop vigor, soil organic matter, pH, nutrient status, toxic and hazardous substances in crops;
- evaluation of the inspection results includes completeness of documentation, and degree of compliance with established requirements (e.g. toxic and hazardous substances, soil fertility).

Table 12: Test items and methods for restored agricultural land

No.	Item	Unit	Method
1	Area of soil material cover	ha	trigonometric survey (e.g. GPS)
2	Thickness of soil material cover	m	multi-point soil auger sampling
3	Surface roughness	m	ground measurement method
4	Soil bulk density	g/cm^3	ring knife, wax seal method
5	Soil organic matter	%	test of soil organic matter
6	Soil gravel content	%	sieving
7	Soil alkalinity / acidity	pH	Electrode method
8	Crop yield	kg/ha	Field Measurement
9	Grass yield	kg/ha	Measured quadrat, calculation
10	Planting density (reforestation)	plant/ha	Measured quadrat, calculation

8.2 Forest and grassland re-cultivation

Goals

Revegetation is the foundation of land re-cultivation and is crucial to its success. Post-mining rehabilitation projects not only strive to reconstruct the original ecological environment, but also to balance environmental, economic and ecological values that should preferably deliver better structure and higher benefits than the original land-use.

Natural Factors

In Mongolia´s semi-arid mining areas, there is adequate illumination; temperature varies greatly between day and night, which is conducive to the accumulation of organic matter. But obstacles persist that inhibit plant growth and development, such as water scarcity, high annual precipitation variability and uneven distribution, strong winds in spring and risk of drought. Taken together, all these factors hasten evapo-transpiration especially during the extremely cold winters which greatly limit the choice of plant species for land re-cultivation projects.

Engineering Factors

Open-pit coal mining dump sites are extremely challenging environments for land re-cultivation projects. The following factors provide an overview:

- compaction of dump site platform surfaces increases their bulk density, prevents rainwater percolation and can trigger sheet erosion of the top soil on a large scale;
- variously textured dump site surface materials may trigger gully erosion especially on the dump site slopes;
- mining operations such as blasting and transportation produce dust that settles on plant leaves blocking their stomata which in turn reduces respiration and photosynthesis, inhibits plant growth and may – in severe cases – even lead to death.

Species selection

Open mining destroys all the original vegetation. Under the environmentally harsh and ecologically fragile conditions of Mongolia, natural succession of plant communities is slow. To accelerate vegetation recovery, it is paramount to screen for pioneer species suitable for the establishment of resilient plant communities.

Pioneer species are generally characterized by a high tolerance to frost, desiccation by drought, wind and snow damage, waterlogging and alkalinity, and importantly availability of large amounts of propagation material. The following selection criteria apply:

- fast growth to quickly cover large areas and to reduce surface runoff, conserve water, and prevent soil and wind erosion;
- strong rooting system to reduce soil erosion and to improve friability of the often compacted top soil layers on mining dump sites;
- pest and disease resistance including to dust pollution to decrease mortality rates;
- nitrogen fixation and easily decomposable litter with a narrow C/N ratio to improve soil fertility;

- employment of propagation material of multiple provenances to ensure high survival rates and to reduce biological (e.g. pests) and non-biological risks (e.g. desiccation) inherent with mono-cultures;
- economic value to reflect the locally pursued rural development goals.

As a matter of fact, it is hard to find one species that meets all of these conditions. Key is to match the individual requirements of the selected species with site conditions. The following considera-tions apply:

- Herbaceous species are low cost solutions for quickly creating soil cover over large areas. Examples are Allium anispodium, Allium mongolicum, Astragalus adsurgens, Agropyron cristatum, Bromus inermi, Dontostemon spec., Elymus dahuricus, Leymus secalinus, Leymus racemosus Medicago sativa, Melilotus suaveolens and Onobrychis vicaefolia, (see Table 13 below). Being annual plants, however, their life cycle is short, their rooting system shallow and they do not produce a layered canopy to speak of.
- Shrubs are perennial and characterized by denser crowns and rooting systems and more litter production all of which effectively contributes to soil and water protection. Examples are: Caragana korshinskii, Elaeagnus angustifolia, Hippophae rhamnoides, Rhus typhina, Salix cheilophila (see Table 13).
- Trees are the most effective agent in land restoration projects, due to their longevity, pronounced rooting systems and their ability to create layered canopies which effectively provides rainwater interception. However, most species – especially poplars – require a minimum of 400 mm rainfall per year. Obviously, under semi-arid conditions, trees can only be managed under the best of circumstances, if e.g. planted in micro-catchments on the dump site platform or along the lower third of dump site slopes, where they profit from surface run-off. Examples are: Pinus tabulaeformis, Robinia pseudoacacia or Ulmus pumila (see Table 13).

Planting Density

- In semi-arid areas of Mongolia, water is the single most important growth-limiting factor of plant life. Raising the water storage capacity of the soil and optimizing water use is crucial for any re-cultivation project. Planting density, hence, determines more than any other management decision survival / mortality rates in the field. There is a trade-off between type of after-use and site conditions. Planting density must, hence, take account of locally prevailing climate and geomorphological conditions, especially slope aspect or exposition. The following general considerations apply:
- wide plant spacing at high altitudes and latitudes where temperature and rainfall are low and soils often barren;
- successively wider spacing along a south-north transect from (in that order) the Loess Plateau and intermediate farming-pastoral zone in the North to the grassland and desert areas in the South;

- dense spacing in protection (e.g. soil & water) and production (e.g. timber) forests;
- wide spacing for most light-demanding and fast-growing trees with straight trunks, good self-pruning properties, broad crowns and robust root systems, as opposed to dense spacing for shade-tolerant and slow-growing trees with poor self-pruning properties, narrow crowns and compact root systems.

Table 13: Recommended planting densities of selected plants on Loess and Kastanozem in semi-arid areas

Herbaceous plants	Seed quantity (kg /ha²)	Woody plants / shrubs	Seedling number (n / ha) (initial stocking after 5 years)
Bromus-inermis	15-20	Larix-gmelinii	2500-1000
Agropyron-desertorum	15-20	Pinus-tabulaeformis	9500-3300
Elymus-dahuricus	20-25	Pinus-sylvestris	6600-3300
Elymus-sibiricus	25-30	Picea-asperata	6600-4500
Elyymus-chinensis	40-50	Platycladus-orientalis	9900-4500
Festuca-arundinacea	15-20	Robinia-pseudoacacia	5000-1700
Lolium-perenne	15-20	Ailanthus-altissima	3300-1100
Onobrychis-viciifolia	60-75	Fraxinus-chinensis	6600-4500
Coronilla-varia	5-10	Populu-salba-var. pyramidalis	4500-2000
Medicago-sativa	12-15	Populus × xiaohei	3300-1400
Astragalus-dsurgens	3-5	Elaeagnus-angustifolia	5000-2500
Melilotus-suaveolens	15-20	Hippophae-rhamnoides	6600-3300
Vicia-amoena	25-35	Caragana-korshinskii	9900-5000
Glycyrrhiza-uralensis	45-60	Amorpha-fruticosa	9900-5000
Isatis-indigotica	45-60	Salix-cheilophila	6600-3300
		Ulmus-pumila	3300-1500
		Forsythia-suspensa	6600-3300
		Xanthoceras-sorbifolium	6600-2500
		Lycium-chinense	9900-4500

Selection of plants

To increase survival rates after planting, respectively reduce mortality and investment, the following principles shall be applied in combination or alone as the local situation dictates:

- Species/site-matching: selection of plants whose physiological and ecological properties comply with local site conditions, i.e. mostly pioneer nitrogen-fixing plants with robust rooting and self-propagation properties, capable of quickly producing biomass and resilient allelopathic behaviour. Comparison with natural plant communities and their species composition on neighbouring undisturbed sites may provide guidance when establishing artificial ecological communities;

- Sustainable development: the composition of plants should – in the long run – be able to generate ecological, economic and social benefits required by rural development goals at the particular location.

8.3 Vegetation types

According to the land use direction, the following "land-use configurations" are conventionally distinguished: pure high-forest, pure shrubbery, mixed grass-shrub, grass-tree, shrub-tree and combinations thereof. Mixed forest-grass combinations are favoured over other combinations for their proven environmental protection and disaster reduction efficacy.

Whatever the overall rehabilitation goal, be it community adaptation or environmental protection, shrub-grass combinations should be favoured as base for further admixtures with trees and herbs. Even though the water demand of shrubs is higher than grassland, their hardiness to low tempera-tures and their strong regeneration capabilities make them superior to herbaceous vegetation under the extreme unfavourable environmental conditions of Mongolia´s semi-arid areas.

8.4 Re-Vegetation techniques

Afforestation is usually based on mixed stands so as to achieve greater ecological, economic and social benefits. Establishment methods include direct seeding, generative propagation by seedlings or saplings and vegetative propagation by cuttings.

Shrubs, such as Caragana korshinskii, Hedysarum fruticosum var. mongolicum and Ceratoides latens, and grass species lend themselves to direct seeding. Trees on the other hand are commonly planted by seedlings or saplings, site conditions permitting. Vegetative propagation can be used for afforestation, provided the chosen tree species have strong sprouting abilities, local site conditions permitting.

Grass species can be sown alone or mixed with others. When mixed pastures are established, seed quantities of each species are slightly less than when sown alone. For instance, sowing two species together requires only 70% to 80% of the seed amount of either when sown alone. When three species are sown, two species from the same family would require only 35 - 40% for either and the third species 70 - 80%, respectively when sown alone. If two species each of Poaceae (true grasses) and Fabaceae (leguminous plants) are used, seed requirements are 35 - 40% for either when sown alone. The seed amount of species with weak competitiveness can be increased by 25- 50%.

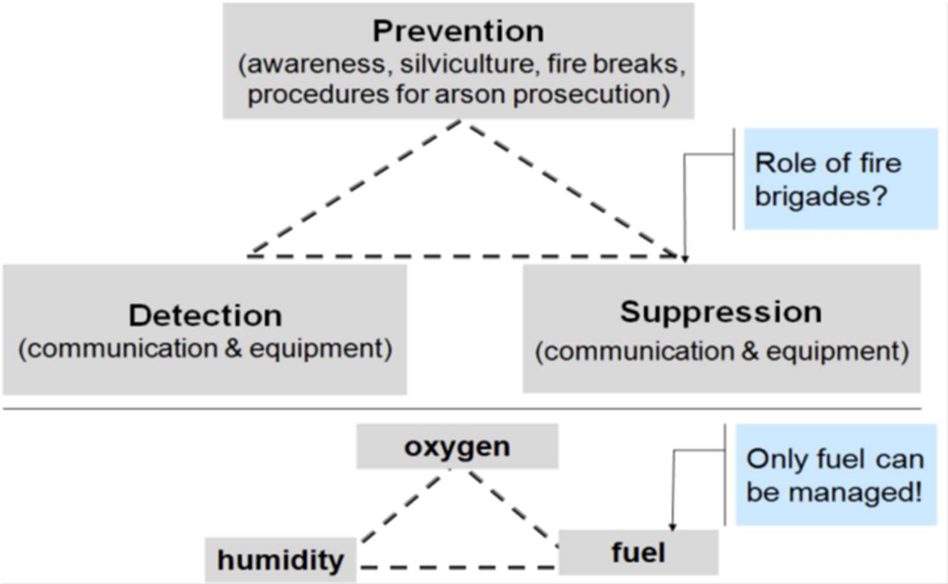
8.5 Management principles

When managing re-vegetation projects on post-mining land, managers must take account of the following considerations:

- Frost protection: The average annual temperature on the mining areas is very low, with winter extremes as low as minus 30º Celsius for weeks. To insulate young woody plants from freezing, seedlings and saplings can be planted sunken in the soil, the above-ground parts of seedlings / saplings can be wrapped with plastic film or cloth, and the planting area can be covered with coal ash (chemical contents permitting).

- Fertilization: Re-cultivation projects usually cover large areas, making the use of inorganic fertilizer a costly undertaking. Hence, preferred methods are the planting of green manure crops, nitrogen-fixing plants, and retaining litter (leaves, dry twig lets) on the ground.
- Pruning and tending of woody plants: Pruning can be applied as a means to reduce water consumption and excessive nutrient uptake. In high forests, thinning operations can be employed for the same purposes while at the same time increasing stand stability. However, there is a trade-off between thinning degree and stand stability. Obviously, too heavy thinning would open the canopy, expose remaining trees to (snow) storm damage as well as neutralize the soil & water protection and biodiversity conservation functions of closed forest stands. To avoid losses, the managers of mining re-cultivation projects should seek proper silvi-cultural advice from competent authorities.
- Low carbon approaches: When aiming at climate change mitigation, the manager must discriminate natural (type of carbon sinks) and social conditions (type of extant land-use). This distinction is essential, for it determines the possible management interventions. The most obvious one in the vicinity of mines is hillside closure from unregulated grazing and/or introduction of rotational grazing systems on grasslands to facilitate natural succession. This intervention relies on native species that are already adapted to climate change. It does not require investment in re-vegetation, but high investments in social networking with concerned communities and possibly incentive mechanisms for adopting new grazing or other land-use types. In contrast, afforestation on dump sites is the costliest and managerially most demanding intervention, but will increase carbon stocks so as to (partially) compensate carbon emissions from mining. Spatial planning is decisive, because it ultimately controls– in any region – location and size of industrial, mining, forest and farming lands. Spatial plans may also specify particular land husbandry methods, such as planting green manure crops and minimum-tillage farming so as to increase soil organic matter (SOM). As a rule, managers should involve competent land-use planning agencies incl. land consolidation, before embarking on land re-cultivation projects in earnest.
- (Forest) Fire Control: Under semi-arid conditions, vegetation is always at risk of being destroyed by fire, whether of natural causes, neglect or arson. Fires risk turning (woody) vegetation from carbon sink to source. Fire control is invariably based on a clear-cut chain-of-command and the active management of bio-physical factors (Figure 16). Emphasis is always on prevention, especially in areas with rudimentary access and nearby population centres. Suppression is the last resort – when it burns, the system has failed.

Figure 16: The (forest) fire management triangles



8.6 Acceptance certificate

The process is divided into two phases, as shown below.

Completion acceptance

- Documentary proof (complete technical archives);
- Fiscal proof (use of funds according to prescribed auditing standards).
- Evidence in the field
- Engineering and management according to prescribed quantitative and qualitative standards;
- Quality of land re-cultivation (according to prescribed standards, e.g. top soil depth, slope gradient, gravel content).

Late acceptance

- Geological hazard assessment (soil, water loss, slope stability);
- Re-cultivation results (survival rate, canopy density, vegetation coverage);
- Late quality of facilities, the breakage of supporting facilities.

9 Re-cultivation aspects for the reuse of heaps and dumps

9.1 Principles

Dump sites in vicinity to villages or towns or recreational areas should be structured in such a way that they are able to fulfill manifold functions in the long term and prevent damages to the dump-systems themselves and the surrounding environment. The main productive function on dump sites is the production of food on arable land and plantations. Greened areas, hedge-rows, small ponds and other near-nature structures are necessary measures in the food production. They are the habitats of predatory birds and insects against food-production endangering animals like insects, mice and rabbits. Therefore, such areas should be established regularly next to and surround of agricultural areas. In the following some proven techniques are described.

9.2 Cover crop and grass planting

The main function of cover crops is threefold, i.e. (i) erosion control and reduction of dust pollution; (ii) improvement of soil fertility and nutrient cycling through biological means and (iii) protection of woody seedlings. This depends on site conditions, such as exposure to villages, infrastructure or to neighboring nature conservation sites and the re-cultivation schedule. If for instance a site is exposed to wind and rain and shall not be re-cultivated within the next 5 years, then it shall be covered by intermediate sowing.

Four principle sowing methods are available:

- manual broadcasting;
- mechanized sowing;
- hydro-seeding (terrestrial or airborne) and
- sowing combined with mulching.

The site is ready for after-use, when all necessary geotechnical stabilization works on the dump site (leveling, compaction and surface shaping) are concluded. If it is an intermediate sowing for erosion control, direct sowing is possible. For successful projects, the selected site should be at least moderately fertile and be regularly watered during the first three weeks after sowing.

Seeding by hand (broadcasting) is the preferred method for small areas. A seed mixture with drought-tolerant grasses and herbs like Achillea millefolium, Arrhenatherum melatius, Bromus erectus, Campanula patula, Centaurea scabiosa, Daucus carota, Festuca ovina, Festuca rubra, Knautia arvensis, Linum spec. or Poa pratensis is recommended at 20 – 40(60) kg/ha seed and incorporation into the substrate of 1 cm. Table 13 names further adopted species. In case of a first sowing on reforestation sites, the minimum quantities are enough.

On agricultural sites, mechanical drilling of seed mixtures is the most economical way. The drilling direction on slopes should be parallel to the contour to prevent gully formation by excessive surface water run-off.

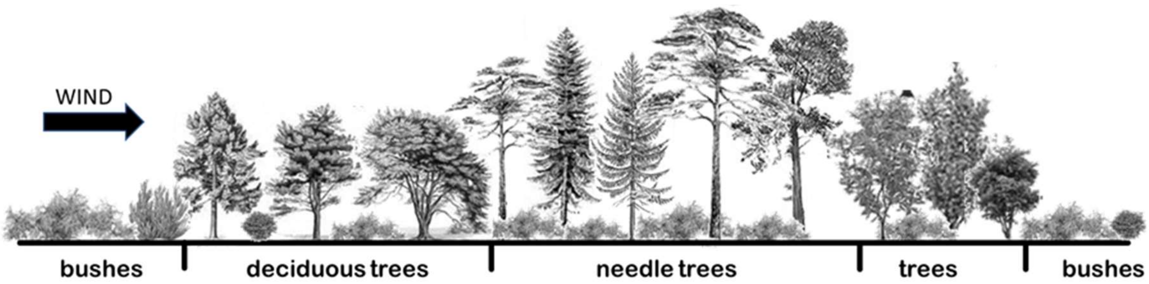
Hydro-seeding is suitable on steep slopes or large areas which cannot be worked by agricultural machinery, like open coal seams or geo-technically hazardous sites. Specialized companies can be contracted to this end. The seed-mixture should contain fertilizer, natural glue like wax, cellulose and water. The mixture is spread from a tank truck equipped with a stirrer, a high-pressure pump and a flexible pipe or from a tank suspended from a helicopter. Agricultural airplanes are too fast and not precise enough. The resulting coverage should be 2 - 5 cm deep and contain 5 – 15 g/m^2 of seedling material.

The most natural way of quickly creating ground cover is mulch-seeding with hay or cut grass. This method has several advantages. Mulch prevents erosion of the substrate, it shelters seeds and stores water and finally it transfers seeds and micro-organisms from the surrounding area onto the dump sites. In short, mulch-seeding fastens and stabilizes the re-vegetation process. Selection of donor sites and timing of mulch procurement are essential. Preferable donor sites are undisturbed grasslands with a high variety of regional plants. Best time for harvesting is when the seed of the grass and herb species are nearly ripe. In many cases, this coincides with July. The thickness of the mulch cover should be 5 – 7 cm. The mulching material can be distributed by agricultural machinery (manure spreader) or by hand.

9.3 Hedges and protection stripes

As a matter of principle, protection stripes should be designed in accordance to official spatial planning documents and to scientific experience. This includes the preservation and tending of all existing vegetation. Hedges around villages should ultimately be able to develop a large absorbing surface so as to comb dust from the air and reduce wind-speed. To do this efficiently, protection stripes should generally have a width of 15– 50 m and a height of over 10 m and a stepped profile (Figure 17).

Figure 17: Idealized profile of protection stripes



Structure follows functions. The following enumeration in table 14 provides an overview of some key features of protection stripes in relation to their particular function.

Table 14: Functions and structures of hedges and protection stripes

	Function	Structure, composition and lay-out
1	Dust filtering	• *Densely structured profile with straight canopy line;* • *prevention of jet-effects by level, straight canopy-line;* • *vertically diminishing porosity from ground to canopy of about 40 – 50 % to allow passage of wind;* • *steep flank perpendicular to main wind direction;* • *checkerboard layout of stripes with one side perpendicular to main wind direction;* • *on windward-side of stripe, wider spacing of planting rows and on down-wind side, closer spacing to reduce wind-speed and increase filtering;* • *preference to densely foliated plants with big leaves and dense branching pattern;*

2	Noise attenuation	• *same as no. 1 above plus:* • *evergreen conifers in center of stripe admixed with fast growing solitary tree species like poplars;*
3	Wind and frost protection	• *same as no. 1 above (smaller stripes possible);*
4	Erosion control	• *deep-rooting trees / bushes with quickly closing canopies (e.g. Robinia /Amorpha);* • *densely growing bushes like sea buckthorn (Hippophae spec.);* • *ground-covering, creeping plants like blackberry (Rubus spec.) and knotweed (Polygonacae spec.);*
5	Provision of aesthetic views	• *same as no. 1, but also as close stripes with evergreen conifers in center;* • *ornamental trees and bushes with showy flowers and conspicuous foliage along the seams of hedges;*
6	Bank protection of water bodies	• *establishment of rows of water adapted trees like alders and willows along natural water bodies and irrigation ditches;* • *maintenance of ditches (e.g. dredging) is essential to prevent clogging with sediments and subsequent bank erosion.*
7	Provision of habitats (birds, bees)	• *same as no. 4 above*

The planting pattern can be regular or irregular depending on the particular function and specialized goals. As a rule of thumb, a maximum spacing of 1m between plants and 2m between rows is recommended. Table 15 provides an overview of suitable plants.

Table 15: List of suitable plants for hedges and protection stripes

Plant type	**Examples**
Small-size bushes	Artemisia plants ; Medicago sativa; Hedysarum scoparium
Higher bushes	Caragana korshinskii; Hippophae rhamnoides; Salix cheilophila; Nitraria tangutorum
Trees	*Pinus tabulaeformis; Pinus sylvestris; Robinia pseudoacacia; Ulmus pumila; Willow; Platycladus orientalis; Populus alba var. Pyramidalis; Populus × xiaohei; Elaeagnus angustifolia; Larix gmelinii*

9.4 Natural conservation and ecological stepping stones

Sites, with natural succession of plant communities has the chance to unravel undisturbed (including soil genesis), are very important in mining areas. They help to restore natural habitats so important for wildlife conservation. Obviously, geotechnical stability of the selected dump site is a prerequisite for establishing conservation areas and eliminating all threats from neighboring villages or infrastruc-ture.

Dump sites set aside for nature conservation normally do not require special treatment, besides control of wind and water erosion. The larger they are, the better is the future recolonizing of wild plant and animal communities.

Ecological stepping stones – in contrast – are small installations between larger dump sites to particularly facilitate the return of animals that were absent during mining operations. They can easily be built at minimum cost. Successful examples are enumerated in table 16. These features should be incorporated in the design and shape of the dump and heaps as shown in figure 3.

Table 16: Ecological stepping stones – some examples

Type	**Features and use**
Small ponds	• *can be a part of the surface water collection system;* • *flat slopes on one side for easy access of animals;* • *tree cover to provide shade;* • *adequate water depth to prevent freezing to the ground during winter;* • *no consumptive or recreational use of any kind;* • *habitat for a variety of water-dependent fauna like fish, amphibians, dragonflies, birds and mammals;*
Rock cairns	• *collection of non-contaminated material like natural rocks, also clay bricks;* • *stapled in pyramidal shape with ground diameter of 3 - 5m and height of 1 - 2m; sides are exposed to various lengths of sunshine during the year, thus, providing different micro-climates;* • *habitat for poikilothermic animals like insects, reptiles and small mammals;*
Tree stump and root piles	• *stapled in rows with a ground width of 2 - 4m and height of 1 - 1.5m (higher staples would create unattractive views in the landscape) at user-defined lengths;* • *to be constructed right after compaction and levelling of dump sites incl. admixture of other wood waste, if untreated (piles will rot over the years);* • *habitats for a variety of birds, insects, reptiles and small mammals;* • *useful for wind erosion control as well as natural germination of plants.*

9.5 Agro-forestry and short-rotation forests

On dump sites, agro-forestry can help to improve the development of soils and fasten the productivity of arable land. Agro-forestry or agro-silvi-culture is an integrated approach of using the interactive benefits from combining trees and shrubs with agricultural crops. Trees and shrubs are conventionally planted in rows and a checkerboard pattern over the arable land.

The distance between tree-rows depends on site conditions and on the machinery that will be used on the arable land. Bigger agricultural machinery requires bigger field plots. Tree-rows should be aligned perpendicular to the main wind direction to reduce wind velocity. This decreases evapo-transpiration of soil and crops and wind velocity. The tree-rows should have a width of 6 - 12m or about 3 - 6 rows at a spacing of two meters. Poplars (Populus spec). and alders (Alnus spec.) are suitable or other fast growing species capable of coppicing that are not exacting in their site requirements.

Five to ten years after planting, the first outer row is cut followed by the removal of the next consecutive row the year after (rotational system). It will sprout by itself. The timber can be harvested. To prevent root competition between agricultural crop and trees, a strip of Lupinus spec between tree rows and arable land is very helpful.

9.6 Acceptance certificate

Apendix A.3 and A.4 provide examples of best practice from Germany.

10 Ecological Compensation

Replacement and compensatory measures on third places are international standard in re-establishing ecological functions if the impact on the balance of nature could not be compensated on the site itself.

Existing mine sites in Mongolia often has not a sufficient geotechnical stable construction and a lack of knowledge of the soil properties of the dumped material. A re-cultivation as described in the chapters 7 - 10, requires therefore mass-movement and soil-evaluation as a prerequisite on many dump sites. This hinders the legally requested rehabilitation measures.

According to the existing laws of Mongolia dealing with the mining and its ecological impacts, the post-mining sites have to fulfill the following attributes:

- no thread or adverse impact on the surrounding environment, especially by contaminated water fluxes and erosion by wind (dust),
- possible after-use,
- compensation of negative impacts during mining to local communities.

If the financial and technical burden prohibit the orderly preparation of the dump site for rehabilita-tion measures, it should be checked if the rehabilitation could be split into necessary measures on the dump site (e.g. water collecting, dust reduction) and measures to fulfill the further intended goals on a third site. Splitting up the measures lead to a more effective and sustainable use of the capital employed and the technological measures.

Ecological replacement and compensatory measures can be part of the concept of land degradation neutrality (LDN) and its implementation under goal 15 of the Sustainable Development Goals of the United Nations. Goal number 15 focuses on life on land, terrestrial ecosystems and their sustainable management and combat desertification, soil-degradation and the biodiversity loss. These measures could be integrated into a community driven natural resource management system.

Ecological replacement and compensatory measure in the vicinity of a community or stables and grazing grounds of the livestock could add a surplus in comparison to a low- to medium successful rehabilitation of a dump site.

Measures like protection hedges, restoration of degraded forests, restoration of degraded land and soil around communities and grazing areas or the reconstruction of irrigation systems are very useful and sustainable.

The establishment of the ecological replacement and compensatory measure shall be approved and documented and then the measure handed over to the local community or other local institutions for maintenance and use.

11 Infrastructure on rehabilitated areas

11.1 Planning principles

Rehabilitated dump sites need to have a functioning infrastructure in relation to the particular after-use like agriculture, forestry, human settlement or touristic view-points. Infrastructure planning is part of the general design planning of dump site construction and re-cultivation according to the planned after-use.

This includes foremost main access roads and drainage systems, but also special provisions e.g. for power line locations, drainage, water basins and other fire prevention facilities as well as building sites and view-points. All these facilities should be constructed during the final dumping and levelling process. They should be planned and constructed in such a way that the maintenance can be carried out easily and in an economic way. For instance, drainage trenches should be shaped such that they protect the dump site from erosion and geo-technical failures and can be cleaned with equipment accessible to the mining company. Roads should have an hourglass-shaped camber. Road spacing depends on berm lay-out. The distance between two berms should ideally be not more than 30m to ease maintenance and effectively control water erosion. As a rule of thumb, a road density of 15 – 30m/ha is recommended.

Roads disrupt on the other side forests, arable land and areas with specific functions for nature. These negative ecological effects have to be considered by planning the road system for the after-use. The negative ecological influence can be minimized by integrating the existing roads of the active mining into the post-mining structure. The width of the roads should also adapt to the registered traffic on the roads. If roads are shaded by trees from both sides, the negative ecological impact is minimized.

11.2 Construction of non-asphalted rural roads

Primary roads

These roads provide the basic network on re-cultivated dump sites for any kind of transportation. They give access to public roads surrounding the particular dump site. They should have a design capacity of < 40 tons regardless of truck configuration without receiving any damages. Figure 18 shows the typical scheme of such a road and the following list provides an overview of their required design features:

- axle load: 11.5 t per single axle;
- camber: bilateral transversal tilt of 2 – 3 % on either side of road's centre line
- (hour-glass profile); unilateral tilt of 6 % in curves (even profile);
- alignment: longitudinal tilt 8 % (10 %); if tilt exceeds 3%, cross chutes should be constructed at regular intervals to force surface water into drainage ditches (chutes and ditches need regular cleaning);
- curve-radius: 20 minima;
- travel speed: 40 km/h maximum;
- road width: 3.5 m minimum;

- 20 m before connection to another road, the road needs to be widened to 5 m;

  the same applies to curves with changing directions and a radius of less than 50 m.

  Road-bed: depending on base material, the depth of compacted roadbed material should be 20 (sand) – 50 cm (clay) with grain size 0/32 – 0/56 mm (usage of un-contaminated recycling material permissible).

- road surface: 6 – 10 cm compacted layer with grain size of 0/22 mm.

Byroads

- camber: as above;
- alignment: as above:
- travel speed: 25 km/h maximum;
- road width: 3 m;
- roadbed: constructed by levelling and compaction of the underground, without
- extra material input; on base material with higher loam and clay content, coarse calcareous material should be incorporated to reinforcethe roadbed.
- Control of axle load carrying capacity:
- Proof rolling: truck charged to maximum permissible load of 11.5 t per axle moves at walking speed over the road – there shall be no clearly visible deformations on road surface;
- Dynamic plate bearing test: in accordance to specified testing method.

Drainage

- It is important for the stability of the roads that they are dry. An appropriate drainage system is therefore needed. On dump sites, especially on heaps, a drainage trench on both sides of the road is needed to collect water from the uphill slope so as to prevent erosion on the downhill slope. The drainage system should be projected in relation to the expected maximum amount of precipitation; the planned after-use and the equipment accessible to the mining company.
- Two types of trenches have proven successful:
- V-shaped ditch

  Slope gradient 1:3, depth about 50 cm; slope sides can be reinforced with mats (coconut mat) and/or grassed and planted (best for lower amounts of drainage water);

- U-shaped ditch

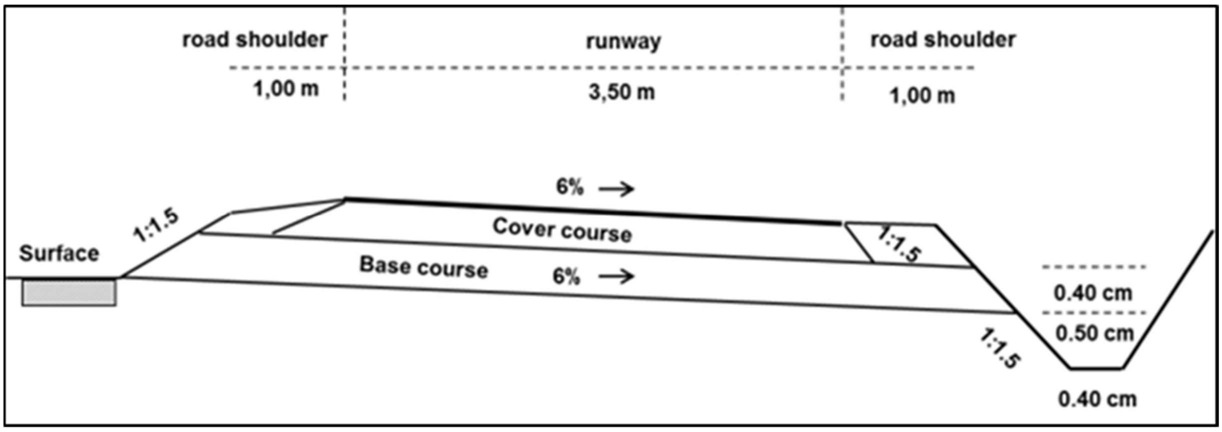
  Slope gradient 1:3, ground width 30 cm – 100 cm (depth unspecified); reinforcement as above whereby the bed can be reinforced with big stones to prevent erosion of the ditch bed.

Concrete trenches can be employed for tackling high amounts of surface water run-off, particularly at road intersections. They need generally more maintenance then bio-engineered ditches. Excess water should be collected in basins for irrigation, fire suppression and installation of small biotopes.

11.3 Road maintenance

Roads shall be maintained regularly to make the often considerable investment pay. They shall be controlled twice a year and funds shall be earmarked to this end. Erosion gutters, ruts or potholes forming on the road surface due to usage need to be fixed. The most economical way of road maintenance is with a grader. Material which is pressed to the side accumulating at the road banks shall be cleaned from organic material and filled back to repair the damages resulting from wear and tear.

Figure 18: Cross-section of standard rural non-asphalted road showing road surface (cover course) and roadbed (base course) (after German standards for rural roads and lignite mining)



11.4 Acceptance certificates

Protocols of the maintenance should include information of date of execution, exact length of road and ditches, used technology and material and information whether basic renewal of sections is necessary.

12 Erosion

12.1 Principles

Erosion is a geologic process by which soil and rock are removed from their original location by exogenic forces, and then transported and deposited elsewhere. This natural process can be accelerated by human activities such as agriculture, grazing of livestock, forestry and mining. According to the patterns of exogenic forces, erosion falls into the category of wind, water, gravity and mixture of water and gravity. For effective erosion control, it is necessary to analyse the causes and patterns of erosion and to focus preventive measures on the key erosive factors.

12.2 Wind erosion

Wind erosion is a major force in arid and semi-arid regions and during drought periods. Two main types are distinguished, i.e. deflation (translocation of loose particles by wind) and abrasion (wearing down of surfaces when struck by airborne particles). Deflation is divided into three categories, i.e. surface creep (rolling of heavier particles along the ground), saltation (lifting of particles into the air and bouncing across the soil surface) and suspension (lifting of very small and light particles into the air transported over long distances). The majority of wind erosion is caused by saltation (50 – 70 %), followed by suspension (30 – 40 %) and surface creep (5 – 25 %).

Origins

Wind flows over the soil surface, loosens and moves particles by pressure and lifting forces. The particle size determines the type of movement. While particles with diameters of 0.2 - 2 mm rollover the ground (surface creep) and those with diameters of 0.06 - 0.6 mm jump (saltation), smaller particles can become airborne over long distances (suspension). The predominant form of movement of particles is by saltation, a process that can either trigger an avalanche-like acceleration of displacement of soil particles or the destruction of soil aggregates (soil texture) or both.

Wind erosion of mineral soils starts at wind speeds exceeding 6 m/second (measured at 10m height) or exceeding 4 - 6 m/second desiccated soils (measured at 0.3 m height). The risk of wind erosion is particularly pronounced in regions with a negative water balance and strong winds prevailing from one direction over extended periods of time.

Damages

The removal of soil and its deposition elsewhere results in damages to land and vegetation, both on-site and off-site.

Visible damages range from dislocation of farming inputs (seeds, fertilizer, pesticides) to destruction of crops and physical impediments to soil tillage. Non-visible damages comprise on-site loss of nutrients and humus (soil organic carbon), off-site accumulation of pollutants by concentration of fertilizers and pesticides in deposition areas, diminishment of soil depth / rooting horizon including reduced water storage, filtering and buffering capacity, as well as revenue and income losses.

Prevention of wind erosion

A rough surface is more resistant to wind erosion than a smooth one, especially on loess soils with their high content of fine-grained silt. Since only particles can be moved with a diameter <0.6 mm, the stability of aggregates on the soil surface is of prime importance for the prevention of wind-erosion. This is especially important on barren agricultural land and dump sites that are not re-cultivated yet.

The best way to minimize wind erosion is to provide for permanent vegetation coverage. Coverage rates of 30 – 50 % are usually sufficient to this end. The following measures are recommended:

- avoid / shorten fallow periods through intermediate sowing, mulching or crop rotation;
- minimum-tillage including creation of rough surfaces on uncovered sites;
- intermediate sowing of grass seeds on topsoil storage area or area requiring second re-cultivation to control wind erosion;
- subdivision of large areas by wind breaks perpendicular to main wind direction.

12.3 Dust reducing measures for mass transportation of excavated material

Dust is one of the most significant problems of open-pit mining. Its reduction is necessary due to public health and environmental concerns. Besides cost considerations, the intelligent reduction of dust can lead to a significant reduction of CO_2-emissions, because water and energy consumption of the sprinkling systems for roads and galleries at mine perimeters and equipment maintenance can be decreased.

Dust is divided in two categories, i.e. coarse dust and fine dust with grain size < 10 µm (PM 10). The regular exposition to fine dust causes – especially when containing silicates – lung-diseases like pneumoconiosis and silicosis. Therefore, the wearing of personal protective equipment (PPE) is required for any employee working in exposed environments. Heavy equipment like trucks, excavators, loaders and caterpillars should have air-conditioned cabins.

To reduce dust efficiently, the whole process-chain of mining has to be analyzed for dust emission leaks:

- removal of overburden;
- loosening of overburden (drilling, blasting, stripping);
- crushing;
- moving of vehicles (trucks, bulldozers, excavators);
- transportation of masses including loading and dumping;
- intermediate storage of fertile soil
- levelling and compaction.

At each step, a reduction of dust formation and emission is possible. Most effective is the suppres-sion at specific points of dust formation, such as for instance fog-guns during stripping of overbur-den. Fog not only absorbs dust particles better than water droplets but also requires less water.

Rock blasting shall be done in such a way that the rock is only loosened so as to facilitate removal by excavators. On exposed blasting sites close to housing areas, the coverage of drill-holes with water-filled plastic bags (50 – 100 liters) is an effective means of dust suppression.

In open-pit mines with mass transportation by trucks (the method of choice in much of Mongolia), traffic on hauling roads is one of the main dust producers. The minimum Standard Operation Procedures (SOP) are (i) regular road cleaning by mechanized sweepers depending on weather conditions, i.e. when conditions are not windy and road surfaces are damp (dirty wet roads are slippery and accident-prone) and (ii) sprinkling of roads by water-trucks during dry weather spells. More advanced technologies are the usage of binding agents to seal the surface on unpaved roads. Common is an asphalt-cement mixture or organic-polymers and magnesium-chloride solutions; the latter two containing hygroscopic and coagulation agents.

The proper construction of hauling roads combined with effective dust suppression will:

- improve the work cycle and fuel efficiency;
- increase skid resistance as well as reduce rolling resistance and fuel consumption;
- decrease vehicle maintenance and extend tyre life;
- reduce the need for road sprinkling and - significantly - water consumption;
- when combined, all these measures lead to significant carbon-dioxide emission reductions.

Dumping processes on exposed areas must consider weather conditions. Dumping of dry materials during strong winds blowing into the direction of protectable natural and man-made features, such as conservation or housing areas, is not permissible. Before entering public roads, mining trucks shall be cleaned from dust and dirt in tire washing facilities.

Dust avoidance on uncovered sites

The formation of dust- and sandstorms (DSS) is a self-enhancing process. Therefore, a sequence of uncovered and protected sites, where wind cannot produce Aeolian sediments, helps to reduce dust emissions and save costs. The erosion by wind depends strongly on the erodibility of the substrate, the length of the slope or plateau, the exposition to main wind direction, the inclination of the slope and any protection measures on site.

To reduce the erosion by wind a substrate mixture of easy erodible materials with materials with higher surface tensions or coarseness (e.g. mixture of sandy material with loess or loam) is recom-mended as the top-layer if the surface will not be covered by vegetation soon.

A widespread practice on exposed areas is to temporarily cover the ground by hydro-seeding. The hydro-seed mixture usually comprises a combination of seed, fertilizer, wood- or paper-fiber mulch, water and a binding agent. As the sites cannot be watered, water storage components, like hygroscopic particles of organic-polymers, are added. The seed mixture should be adapted to dry conditions. Germination starts normally 7 – 14 days after sowing.

The temporal storage of fertile soil or of top-soil which will be used as final layer is a regularly used practice. Such storage stockpile should be covered with a grass and herb mixture as soon as possible to prevent erosion by wind.

The displacement of dust particles also depends on surface wind-speed. Rough surfaces can reduce wind-speed by 40 – 50 %. Rows of wooden or plastic fences around facilities and close to the mine perimeter can be employed to reduce wind-speed.

Acceptance certificate

The suppression of dust is an important on going task. The staff should be instructed regularly. These instructions should be part of the general instructions over the year. Dust avoidance is also an ideal target for competition and new ideas.

12.4 Water erosion

Common forms of water erosion on abandoned mining land are splash, sheet and gully erosion. Splash erosion is the first stage of the erosion process, followed by the two other types.

Splash erosion occurs mainly on newly re-cultivated land of open-pit mining dump sites, and on land subject to subsidence. The main characteristics are:

- splash destroys soil structure, thus, reducing infiltration and increasing surface run-off and flow intensity, especially on fine-grained loess substrates. Splash removes soil particles into rock crevices and gaps, especially on dump sites composed of unconsolidated coarse rock and gravel material;
- splash spatially concentrates toxic ions, such as mercury (Hg) or cyanide acids (CN), which might potentially cause the risk of polluting water and soil at the point of deposition.

On the other hand, splash erosion accelerates the weathering and disintegration of mud rocks (e.g. argillaceous shale, shale, gangue), thus, facilitating re-vegetation.

Sheet or surface erosion refers to the uniform movement of a thin layer of soil across an expanse of land devoid of vegetative cover. Soil particles are detached, go into suspension as run-off occurs and are deposited downstream where water flow velocity tapers out. Sheet erosion mainly occurs after dump site construction and during early stages of re-cultivation. Especially vulnerable are fine-grained loess substrates and freshly leveled, barren fields material without much surface roughness.

Rill and gully erosion always occur on dump site slopes. Extent and rate mainly depend on length and slope gradient as well as on relative location on the dump site slope. While rills commonly form on dump site shoulders and the upper third of the slope (generally less than 20 cm deep), deep gullies tend to develop on lower concave slopes. Rills can be restored by general cultivation measures, whereas gullies require major restoration works.

Suffusion erosion refers to the leaching of fine-grained material and deposition elsewhere. It occurs when silt and clay particles are trans located to macro-pores, ducts and crevices due to a hydraulic gravity gradient. This phenomenon is particularly pronounced on intermittently stacked and unconsolidated mining dumps and heaps.

Chemical erosion includes the migration of chemical ions caused by rainfall and surface runoff as well as solution of ions. In mining areas, the former type actually is the main form of surface contamination, including from industrial construction sites and other infrastructure development. Other types of erosion (e.g. landslides, stream channel erosion, tunnel erosion) are rare and not dealt with in this GROM.

12.5 Water erosion and dump site slope stabilization

Water erosion control is primarily a function of the regulation of surface water run-off and heap and dump site design. The process can be divided into two stages:

Landform reconstruction and seepage management

Natural hills differ from constructed heaps and dumps in a number of crucial ways. While heap and dump slopes are generally constructed in a linear profile, natural hill slopes are of diverse angle, length and surface texture and generally concave-shaped, which tend to capture erosion sediment on the slope. Natural hill slopes are protected from erosion by vegetation, rock and stones. Mining dump and heap slopes, on the other hand, are often covered with erodible fine-grained soils and an evolving re-vegetation cover with limited resistance to erosion.

Post-mining landscapes should, hence, mimic natural landforms as much as possible. Earthworks should aim to reconstruct similar distributions of slope angles and lengths, vegetation patterns to those that were in place prior to mining. The aim is to cost-effectively achieve a sustainable post-mining land use while managing the risk of environmental impact and limiting the need for maintenance of erosion control facilities. The following considerations and measures apply:

- A mining dump site closes off evaporation from the natural land surface, while allowing rainfall infiltration. Initially, rainfall infiltration may be dominated by flow along preferred pathways. A proportion of the rainfall infiltration will go into storage within the voids of the dump, ultimately emerging as seepage at its foundation.

- Due to its very low hydraulic conductivity, the initially dry heap / dump will store infiltration from rainfall. The wetting front will progress through the dump site as its ability to store water is exceeded, this occurring well below full saturation (about 25 % saturation for fresh, coarse-grained waste rock; up to 60 % saturation for weathered, well-graded waste rock). As the degree of saturation of the pores rises, the hydraulic conductivity and the ability to pass water will increase, too. The longer the dump site is left uncovered, the more it will wet up. Ultimately, the dump site will wet up to the point where there are continuous water pathways, allowing 'breakthrough' seepage from its foundation.

- Initially, percolation into the foundation is limited by the very low hydraulic conductivity of the unsaturated zone within the foundation. A wetting front will advance downwards, raising the hydraulic conductivity of the unsaturated zone and causing groundwater mounding, with any contaminants in the seepage able to reach the groundwater. The amount of rainfall infiltration into the pile can be restricted by sloping the top surface to avoid ponding and increase run-off. The outer slopes should be constructed of benign waste rock of sufficient thickness to produce clean run-off and seepage.

- The water stored within the heap / dump and prior to it being covered will continue to seep for many years, even though the placement of a top cover will significantly reduce further infiltration into the dump site. 'Store/release' cover systems have shown to limit infiltration to one per cent of average annual rainfall, and perhaps up to five percentages of unseasonal high annual rainfall events. Seepage from the toe and percolation into the foundation (accompanied by the transport of contaminants) will diminish over time as the waste rock drains and loses hydraulic conductivity.

- For the side slopes of the pile, no sustainable, low-percolation cover system has been developed. The side slopes of most piles will remain prone to infiltration during heavy or continuous rainfall. It is, therefore, essential that they be constructed using benign waste rock of sufficient width to ensure clean run-off and seepage.

Re-vegetation

Techniques used for vegetation establishment are designed to fulfill long-term rehabilitation objectives. The objectives are designed to establish particular agreed land uses, mostly with native vegetation for conservation, but also with water quality protection, grazing, timber production and recreation. Often, the aim is to establish multiple compatible land uses.

In general, establishment of vegetation on sloping areas is expected to reduce erosion due to reductions in run-off and in sediment detachment. The extent to which vegetation meets that expectation, however, is a function of a number of factors, including climate, vegetation type, and soil properties. Vegetation can provide large increases in infiltration through surface protection from raindrop impact (a cause of surface seal formation), through reductions in soil water content, improvements in soil structure and structural stability, and by creation of stable macro-pores in the soil. Surface protection is largely associated with contact cover (at soil surface) and canopy cover (above soil surface) becoming less effective as canopy height increases. Changes in soil structure and creation of stable macro-pores are influenced by rates of organic matter return to the soil and root activity.

Some vegetation communities typically those with a significant component of grass produce high rates of contact cover. In comparison, vegetation communities dominated by trees or shrubs can tend to have much lower levels of contact cover and are particularly susceptible to erosion during initial establishment.

In planning rehabilitation, it is important to identify whether vegetation is a major factor in erosion control and, if so, to determine what aspects of vegetation are critical for slope stabilization and at what stage in the rehabilitation process. If rehabilitation relies on vegetation for erosion control, then there is typically an initial window of risk that should be closed as quickly as possible. In that case, species such as grasses that give rapid initial cover can be crucial and may also be important for site stabilization following disturbances such as fire. Vigorous grass growth can hinder establishment of trees, but this is routinely managed by forestry organizations using a combination of weeding and thinning. There may also be potential to selectively place materials that favor either grass or trees to achieve the desired balance.

In general, a balanced ecosystem will contain all of the species required to provide a range of ecosystem services. Trees and shrubs are crucial components of most native ecosystems, but their contribution to erosion control particularly at some stages of the rehabilitation process may be minimal. The following considerations and measures apply:

- Rainfall interception and storage by plants: the most effective and economic measure to reduce soil and water loss is the rapid establishment of vegetation. In the early stage of re-cultivation, a combination of trees, shrubs and grasses can be used.
- Rainfall infiltration and soil storage: root development and litter production can increase soil porosity and improve soil structure.
- Water drainage and storage by engineered solutions: roads are actual catchment areas leading to dangerous spatial concentrations of surface run-off. Hence, road-side ditches need to be connected to drainage ditches on the dump site’s slope.

12.6 Gravity erosion

Gravity erosion, also known as mass movement, is the geomorphic process by which soil, sand, regolith, and rock move downslope, largely under the force of gravity, but frequently affected by water and water content as in submarine environments and mudslides.

In mining area, dump sites are usually large and loose deposits, common forms of gravity erosion include hole-erosion, debris slide, slope slide, collapse and fall rock and rock slide.

Gravity erosion is closely linked with water erosion as water will accelerate gravity erosion. Therefore, controlling water erosion is a key factor to prevent gravity erosion.

- Dividing platform and slope of dump site into separated units will avoid formation of surface water runoff. In each separated unit, berms or ridges can be built in relation to the natural surroundings to break up the confluence area.
- Ditches shall be built on the key route where runoff comes together to prevent damage to ridges caused by rainstorm. The location of drainage system shall be determined by topography and flow rate of runoff.
- Both ecological and engineered solutions shall be used to control erosion during the first 2 - 3 years of vegetation restoration.

12.7 Mixed erosion

Mixed erosion refers to a special erosion pattern which forms under the force of gravity and water impulsive force, sometimes known as debris flow erosion. It may be divided according to the type of solids contained, into 3 classes: rock flow, mud flow and debris flow.

Both ecological and engineered measures can be used to prevent debris flow erosion.

- Proper combination of grass/shrub/tree should be employed for vegetation restoration where the risk of debris flow erosion occurs.
- Retaining dam can be adopted to control solid staff and runoff of debris flow.
- Artificial building/structure can be built to drain/guide debris flow and minimize the damage.

12.8 Construction of slope drainage

Soil amelioration

In Mongolia’s arid and semi-arid regions, the groundwater is deep, with a low permeability, unsaturated zone above. Streams are predominantly ephemeral, underlain by a perched underground stream in sand or gravel bed, which itself is underlain by an unsaturated zone above the groundwater table. The base of the underground stream is effectively sealed by fine sediments, delivering limited water to the unsaturated zone beneath and maintaining its unsaturated state and very low permeability. If this were not the case, all surface water would rapidly percolate to the groundwater table, which has ample porosity to store it.

Dump site covers should mimic the function of ephemeral streams, with a storage layer in the upper part underlain by a sealing layer to limit percolation into the underlying mine wastes. This will ensure they remain unsaturated and of low hydraulic conductivity. The following considerations and measures apply:

- The platform of dumps and heaps shall receive a reserve slope of 2 – 3 %. A drainage channel shall be constructed along the perimeter of the platform, protected by trapezoid-shaped retention walls at the platform's outer rim to prevent erosion on the side slope from surface runoff.
- The surface of platforms is often compacted due to the deployment of heavy equipment. To increase rainfall infiltration (if wanted), the top layer should be mulched, loosened by ripping and be covered by soil with a large water retention capacity, such as loess / marl. The best way is to improve dumping technique to avoid serious compaction. The bulk density of soil should be less than 1.4 g/cm^3.

12.9 Acceptance Certificate

Erosion control engineering shall be checked for acceptance according to completion criteria that have been developed in conjunction with stakeholders as part of the mine closure plan. Each inspection lot shall be in accordance with the guidelines for the corresponding quality standards project.

13 Water treatment

13.1 Principles and aims

Problems with mine drainage generally develop when precipitation, surface water, seepage water or groundwater enter mine sites and come in contact with primary and secondary minerals under toxic conditions. "During contact with those minerals, the water may dissolve components of the ore and rock-forming minerals. Most of the processes involved and controlled by the EH-pH conditions at the water-mineral contact. If even relatively small amounts of disulphides, as pyrite or marcasite, oxidize and dissolve, the acidity formed can dissolve other water contaminants. Because metal or coal deposits are so diverse, the metals and the composition of mine water are unique at every mine site. Commonly carbonate minerals are present and neutralize (buffer) the acid, leading to neutral or even alkaline mine water, which might be still harmful to surface and ground-waters in a catchment area" (Wolkersdorfer, 2008).

Therefore, the chemical properties shall be analyzed and compared to the limits set by the government. Waters exceeding the limits should be collected and treated.

Therefore, mineralogical analysis is a useful aid in characterizing overburden, waste rock or waste dump sites, as it can identify the presence and nature of potentially acid-producing sulfides, which can seriously affect plant growth directly through low pH values, or indirectly through creation of excessive soluble metal concentrations.

- Mine site materials include ore, benign and reactive waste rock, cover materials and soils. Limiting environmental impact from land disturbed by mining and coal processing and achieving sustainable mine site re-vegetation depends on the propensity of the reconstructed surface materials to support plant growth, in terms of their water-holding capacity, their geochemistry, and their microbiological attributes.
- Typically, the strata overlying the groundwater table have been exposed to atmospheric oxygen and are oxidized, while the strata underlying the groundwater table have been denied access to oxygen and are prone to oxidation on exposure to the atmosphere. Sulphides from below the groundwater table will oxidize to sulphates on exposure, resulting in a drop in pH and the dissolution of metals at lowered pH-value.
- The benign, oxidized materials first encountered in open-pit mining (at shallow depth above the water table) should be used to encapsulate the typically sulphidic materials later excavated (at depth below the water table). The oxidized waste rock should be used to construct base and side encapsulations in advance to contain the reactive waste rock.

13.2 Treatment of slope water in cleaning plants and Acid Mine Drainage

Sedimentation basin

The easiest way of a water treatment is a sedimentation basin in which the contaminated water stays for a defined time. By gravimetric sedimentation the solids that are not dissolved settles at the ground of the basin. The basin has to be dredged after a while. No chemicals are needed and only a low investment is necessary and with low operating costs. This type is feasible for small to medium water fluxes and wide spare of land that can be occupied for the settling ponds. The treated water can be used as operating water.

Artificial wetlands

Artificial wetlands or constructed wetlands are an alternative solution to treatment plants for acid mine drainage. They use natural processes for water neutralization, thus, reducing some dissolved substances in the water by specialized plants. Generally, they are not equipped with a technical infrastructure. They work with the hydrological gradient. Collected water enters the plant, remains a specific time and flow out into the river without any pumping. The artificial wetlands are designed basins which are filled with materials, e.g. limestone, manure and different plants. Toxic and anoxic conditions can alternate. The dissolved substances of the water come into close contact with the suspended material. The substances change their status (species) and can be incorporated by the plants. Periodically the plants are cut and deposited.

Artificial wetlands are suitable for smaller amounts of relatively stable water quantity and quality conditions. If high water fluxes or changing water qualities have to be treated, artificial wetlands are no solution.

Technological plants / Mine water treatment plant

A technological plant requires high investments, trained staff and for this a water treatment is necessary by operational needs of the company or as a mandatory plant in the official approval process of the mining operation.

Typically mine drainage is treated in technological plants. For the investment decision the following parameters shall be defined:

- Water quantity per unit (e.g. m^3/h)
- Content of hazardous ions
- Limits to be meet
- Use of chemicals for the treatment process
- Which types of waste / sludge will be produced
- Deposition of waste / sludge
- Electric power demand
- Expected operation time
- Investment costs
- Operating costs per unit (e.g. Tugrik / m^3 treated water).

Ideally the operating time should be exceeding the running time of the mine. Regularly acid mine drainage is not only a problem during mining operation but also after closing down of all activities for a certain time.

Service water, used for dust reduction on roads should be collected in the road-side channels and transferred to a settling basin in front of a treatment plant. The inflow into the basin should be equipped with a rack to collect waste like plastic bags, wood, stones in front of the basin. The settling basin should have such a size that the coal-dust and other minerals are able to settle down. The settling takes normally several hours.

Sewage treatment plants shall be built in mining areas to dispose of sanitary sewage. The water shall be recycled or discharged according to the Mongolian sewage disposal standard.

14 Calculations: cost planning/determination of costs

14.1 Principles and aims

Rehabilitation is an integral part of the mining process. It is not a separate process. Therefore, all costs assigned to the rehabilitation are one part of the overall costs of the mining and have to be covered by the price of the product.

Some costs are costs which can be assigned to the exploration phase or the mining phase or the rehabilitation phase. In this GROM it is defined that costs of pre-studies, environmental studies, directly related planning and designing costs are part of the rehabilitation costs.

Rehabilitation services are calculated accordingly to the planned after-use.

All services and the necessary need of material to establish the site shall be recorded.

Re-cultivation services are part of the rehabilitation and starts after the complete finishing of dumping, securing and rough levelling of a mine site or after the complete removal of former industrial sites. The costs include all manpower, material (e.g. fertilizer, seed, plants, construction material for channels and roads, etc.), maintenance (e.g. flood control, combating drought, pest management and fire control) and the cost per hour of technical equipment used. The rehabilitation project on a specific site ends when all goals are fulfilled and the approval is finished. Therefore, as rehabilitation work last usually several years, the calculation has to sum-up all steps in between.

The mine site survey is an important base for calculation estimations on a specific site.

The following lists show typical work that should be mentioned.

14.2 Cost planning

Rehabilitation cost planning should be part of the annual planning. Table 17 shows an example of parameters and situations for a typical dump site:

Table 17: Calculation parameters

No	Parameter	Annual / regular measures	One time / extraordinary measures
0	Transport and dumping of fertile soil		X
1	Mine site survey		X
2	Fine levelling of site		X
3	Amelioration		X
4	Soil fertilizing / improving		X
5	Seeding / planting		X
6	Fertilizing		
7	Tending / protection measures	X	
8	Road construction		X

9	Channel construction		X
10	Maintenance of infrastructure	X	
11	Measures for nature protection	X	X
12	Documentation	X	
13	Pre-studies		X
14	Planning phase (partly)	X	X
15	Environmental studies		X
16	Water treatment (erection of plant)		X
17	Water treatment	X	
18	Dust avoidance	X	

14.3 Determination of costs

For the calculation existing national standard lists shall be used. If they do not exist for the specific goal, market prices or fixed internal costs should be the basis. It is necessary to name the chosen bases.

The calculation shall be done always with the same base (ha, m^3, litre, etc.)

Calculation templates

Below are some templates for cost calculation, see tables 18 - 22.

Table 18: Total cost estimation for rehabilitation

No	Name	cost (Tugrik)	rate (%)
1	Engineering construction		
2	Equipment		
3	Other cost		
4	Monitoring and maintenance		
(a)	Monitoring for rehabilitation		
(b)	Maintenance		
5	Budget reserve		

Table 19: Unit price estimation for engineering construction

No	Name of engineering	unit	quantity	Unit price of direct cost	Unit price of direct engineering cost	Measures cost	Indirect cost	profit	tax	Comprehensive unit price
1	Soil amelioration									
A										
(a)										
……										
2	Re-vegetati									
(A)										
(a)										
……										
3	Auxiliary									
(A)										
(a)										
……										

Table 20: Cost estimation for engineering measures

No	Name of engineering measures	unit	amount	Comprehensive unit price (Tugrik)	Total (Tugrik)
1	Soil amelioration				
(A)	Backfilling				
(1)	Backfilling ground fissure				
……					
(B)	Topsoil removal				

No	Name of engineering measures	unit	amount	Comprehensive unit price (Tugrik)	Total (Tugrik)
(1)	Top soil disposal				
……					
(C)	Leveling				
(1)	Dump site leveling				
……					
(D)	Slope works				
(1)	Terracing				
……					
(E)	Ecological and chemical works				
(1)	Soil improvement				
……					
(F)	Clean up				
……					
……					
2	Re-vegetation				
(A)	Forest re-cultivation				
(1)	Tree planting				
……					
(B)	Farmland protection				
(1)	Tree planting				
……					
3	Auxiliary project				
(A)	Irrigation and drainage				
(1)	Canal				
……					
(B)	Micro-irrigation				
(1)	Pipe line work				
……					
(C)	Pumping well				
(1)	Well drilling				
……					
(D)	Hydraulic structure				

No	Name of engineering measures	unit	amount	Comprehensive unit price (Tugrik)	Total (Tugrik)
(1)	Culvert				
……					
(E)	Rain collecting				
(1)	Sedimentation basin				
……					
(F)	Drainage system				
(1)	Trench				
……					
(G)	Transmission line				
(1)	Installation				
……					
(H)	Road works				
(1)	Walking path				
……					
Grand total					

Table 21: Cost estimation for equipment

No	Name of equipment	Unit	Quantity	Unit price Tugrik	Total
1	Valve/start-stop apparatus				
(a)	Gate flap				
……					
2	Equipment for irrigation and drainage				
……					
Grand total					

Table 22: Cost estimation for other items

No	Items	Billing base	Rate %	Amount Tugrik
1	Preliminary work	Engineering construction cost		
(a)	Pre-study	Engineering construction cost		
……				
2	Construction supervision	Engineering construction cost		
3	Final acceptance	Engineering construction cost		
(a)	Project acceptance			
……				
4	Management fee	Engineering construction ＋ Preliminary work ＋Construction supervision＋ Final acceptance		
Grand total				

15 Documentation

15.1 Principles, aims and tasks

Documentation of all relevant steps, their successful processing and open tasks left for future execution is an integral part of the modern internal quality management according QM ISO 9001.

The documentation system uses different systems, beside paper the E-Systems like databases and Geographic Information Systems (GIS) are getting more important. Documentation is not needed only inside the mining company but also for research and design institutes and finally for the public authorities.

The documentation mentioned here is related only to the rehabilitation process on individual dump sites and connecting work like water collecting and treatment. Examples of documents (protocols and records) are given in the appendixs.

The responsibilities for the documentation process, the working steps which should be documented and the schedule, should be described in **an internal Standard Operating Procedure (SOP) of the single mining company**.

The aim is to document all working results which have relevance for downstream operations (e.g. dumping for rehabilitation, water treatment for release into river), all

working results with high financial contribution, as basis for approval processes to public authorities and for the after-use of third parties (e.g. amelioration and fertilization of an arable land).

The documents can be reports of external experts, proved bills from landscape gardening companies or documents elaborated from the different departments of the mining company itself.

15.2 Finalization acts of the individual area

The following shows a detailed example from a German coal mining Company. The idea behind this kind of documentation is to prove and guarantee that all planned work has been fulfilled successful-ly.

Content and structure of a Résumé act of the individual area:

- Basics
- Records of the planning of the company
- Records of the measurement
- Records of the current use of the area
- Acceptance protocols
- Inspection protocol – Rehabilitated area
- Data of dumped material, dumping technology, geotechnical stability and hydrology
- Data of measurement (heights, inclination and material thickness of final dumping)
- Acceptance protocol for amelioration (pH, compaction)

- Acceptance protocol for successful culturing (arable area, forest, etc.) including measuring data
- Protocols of regularly tending
- Performance records
- Records of planning for specific site
- Records for the project- and capital planning
- Forest-plans, culturing plans
- Records of dumping of suitable materials
- Records of reaching planned dump site design (analyses of planning/current status)
- Record of mine site survey (soil evaluation report)
- Records of amelioration work (work documentation, amounts, results)
- Records of cultivation (work documentation, seeds, fertilizer, results)
- Records of tending work
- Records of used materials for amelioration and culturing
- Type of lime (delivery note, material safety data sheet)
- Type of seeds, planting material (delivery note, qualification)

16 Approval of results by authorities

16.1 Aims and principles for acceptance inspection of land rehabilitation projects

The purpose of land rehabilitation acceptance inspection in Mongolia (see State Law of State Supervision and Inspection 2010) is to check the completion status of land rehabilitation objectives in order to ensure the optimal balance and consistency of ecological, economic and social benefits. Mine rehabilitation acceptance inspection includes project and results acceptance inspection. While project inspection needs to be done upon its completion, appraisal of results needs to be conducted after the project has passed acceptance. During effect acceptance inspection as last step, the ultimate objectives of ecological rehabilitation and sustainable land use shall be ascertained.

16.2 Types of acceptance inspection and requirements

Mine rehabilitation acceptance inspection is mainly divided into three phases: annual, intermediate and final acceptance inspection. Among them, the project acceptance inspection will be carried out throughout the entire rehabilitation cycle. Project acceptance inspection can be divided into individual project acceptance inspection and rehabilitation unit inspection. Mining waste dump site rehabilitations are generally accepted as a rehabilitation unit.

The annual inspection shall be conducted upon completion by the land rehabilitation obligor according to the implementation schedule; the intermediate inspection shall be conducted upon completion according to the progress of annual rehabilitation works; the final inspection shall be conducted upon completion of all rehabilitation tasks according to the rehabilitation objectives specified in the land rehabilitation scheme and the results of intermediate inspections.

Inspection cycle

- Annual inspection: to check the completion of rehabilitation objectives of the current year based on the annual implementation scheme;
- Intermediate inspection: Generally, once every five years. If the duration of the rehabilitation project is shorter, annual and final inspections are permissible. Before the completion of each rehabilitation phase, the rehabilitation obligor shall apply to the competent land and resources authorities for organizing acceptance inspections of intermediate effects and review of funding as well as capital settlement of rehabilitation accounts. After successful completion of the inspection on effects and expenditure, the remaining funds can be directly released for the next rehabilitation phase.
- Final inspection: The land rehabilitation obligor shall, upon completion of all rehabilitation tasks according to the land rehabilitation scheme and (potential) intermediate land rehabilitation plan, apply to competent land and resources authorities for final acceptance inspection.

Project management

- Individual projects: to be conducted upon completion of the individual project. Subsequent amendment of the individual project is not allowed, unless the individual project has received and passed acceptance inspection. Individual inspection can be conducted any time during the project's duration. Such inspection shall be signed off for confirmation on acceptance by the design, construction and the supervising company as well as the land rehabilitation obligor. The confirmation notes for individual project acceptance inspection, signed off by the above-mentioned companies, shall be kept and serve as basis of an appendix to rehabilitation unit acceptance inspection.

- Rehabilitation units: to be conducted after all individual projects have been completed by the rehabilitation company provided they meet all specified quality requirements and acceptance inspection reports are available for each individual project. All confirmation letters for acceptance inspection shall be kept and serve as basis of and appendix to final acceptance inspection.

Organization of acceptance inspection

- Competent land and resources authorities shall be in charge of the organization, implementation and evaluation of land rehabilitation acceptance inspection. The inspection team shall include personnel from the competent land and resources department, along with personnel from other departments, land re-cultivation experts and relevant stakeholders.
- The acceptance inspection team shall make clear suggestions on evaluation of acceptance inspection. The team's conclusions shall be signed for confirmation by each of its members. In case any member has reservations on the conclusions, such opinions shall be explicitly specified in the documentation and signed by the person/s holding such opinion/s.
- Suggestions on addressing the problems found during acceptance inspection shall be proposed by the inspection team. The team leader shall have the last word in disputes. If more than half of the team members do not agree with the decision of the team leader, such a scenario shall be reported to the acceptance inspection organization unit for decision in a timely manner.

16.3 Main content of land rehabilitation acceptance inspection

In accordance to Mongolian Mine Closure Regulation (draft 2018)

Annual inspection

- Preconditions

  All individual rehabilitation projects of the current year must be completed. Confirmation formalities for individual project acceptance inspection are fulfilled and self-inspection has been done.

  Annual rehabilitation funds have been deployed as planned.

  Documentation and material are adequate and complete.

- Documentary basis

  Land rehabilitation scheme (tabular statement);

Annual implementation plan;

Project design, budget report, applicable regulatory stipulations and technical standards;

- Required material

Survey report of annual land rehabilitation acceptance inspection;

Annual land rehabilitation blueprint;

Summary of annual land rehabilitation supervision;

Construction and supervision contracts, agreement on fund supervision and annual financial statements;

Confirmation notes for individual project acceptance inspections, monitoring reports on soil and water quality and evidence for land ownership;

- Inspection procedures

The land rehabilitation obligor shall apply to competent land and resources authorities for acceptance inspection and submit required materials for annual land rehabilitation acceptance inspection.

The acceptance inspection team shall be established. Such a team shall be set up by the acceptance inspection organization unit according to relevant requirements for organizing an acceptance inspection team.

Inspection shall be conducted at the rehabilitation project site. On-site selective examinations shall be conducted among individual projects.

The acceptance inspection team shall organize as hearing involving the land rehabilitation obligor, the construction / supervising/ design companies and the final accounting company. Meanwhile, required materials for annual acceptance inspection will be reviewed and relevant archival documents will be checked at the meeting.

The acceptance inspection team will discuss and form a clear opinion on the annual land rehabilitation acceptance inspection.

Conclusion on the annual land rehabilitation acceptance inspection will be drawn and opinions on approval of acceptance inspection will be issued.

- Goal and scale of inspection

Reviewing the Survey Report on Annual Land Rehabilitation Acceptance Inspection, Summary of Annual Land Rehabilitation Supervision and Agreement on Land Rehabilitation Fund Supervision, Financial Statement on Annual Land Rehabilitation Funds, Record Drawings of Annual Land Rehabilitation and other relevant materials.

Checking completion status of individual projects, rehabilitation unit and annual rehabilitation objectives;

Checking construction progress and quality of annual rehabilitation projects;

Auditing of annual land rehabilitation funds;

Checking the organization and management of land rehabilitation and implementation of rules and regulations;

Reviewing public participation;

Checking pending issues of land rehabilitation of previous year;

Checking whether land rehabilitation projects are suitable for normal operation and functioning as designed.

- ► Intermediate inspection

1. Preconditions

All annual rehabilitation tasks specified in the Intermediate Rehabilitation Plan have been completed and all project quality requirements have been met.

Intermediate rehabilitation funds have been deployed as planned.

Documentations and materials are adequate and complete.

2. Documentary basis

Analogous to annual inspections above, complemented by the following:

Intermediate implementation plan and design of intermediate project;

Survey report on acceptance inspection of current phase incl. inspection application;

3. Required Material

Analogous to annual inspections above, complemented by the following:

Survey report on intermediate inspection

Intermediate Land Rehabilitation Blueprint and Record Drawings of Land Rehabilitation

Summary of Intermediate Land Rehabilitation Supervision;

4. Inspections procedures

The basic procedures are analogous to annual inspections outlined above.

The focus is on intermediate aspects of the inspection cycle.

5. Goal and scale of inspection

Scope and scale are analogous to annual inspections outlined above, with a focus on intermediate aspects of the inspection cycle, complemented by:

Reviewing the maps of the current land use before and after the completion of intermediate rehabilitation tasks and check the area of the rehabilitated land.

Checking the land ownership.

- Final inspection

1. Preconditions

All rehabilitation projects have been completed and all the project quality requirements have been met.

Overall rehabilitation funds have been deployed as planned.

Documentations and materials for the overall acceptance inspection are adequate and complete.

2. Documentary basis

Analogous to annual / intermediate inspections above, complemented by the following:

Design of overall project and budget report;

Survey report on intermediate acceptance inspection for current phase and reply for acceptance inspection application;

3. Required materials

Analogous to annual inspections above, complemented by the following:

Survey report on overall acceptance inspection;

Layout plan of overall project, land rehabilitation blue print and design sketch;

Summary of overall supervision;

Financial statement on overall funding;

4. Inspection procedures

The basic procedures are analogous to annual / intermediate inspections outlined above.

The focus is on the overall and final aspects of the inspection cycle.

5. Goal and scale of inspection

Goal and scale are analogous to intermediate inspections outlined above, with a focus on the overall and final aspects of the inspection cycle, complemented by: Reviewing the Maintenance & Administration Plan of Land Rehabilitation and Hand-over Plan.

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A Appendix

Appendix A.1 Inspection protocol - Mining re-cultivation (dumping)

Appendix A.2 Soil description - example

Appendix A.3 Calibration protocol (Amelioration with lime)

Appendix A.4 Rehabilitation Protocol – planting trees / vegetation

Appendix A.5 Inspection protocol - Rehabilitated areas

Appendix A.6 Example Soil Description according to German Soil Evaluation Method

A.1 Inspection protocol - Mining re-cultivation (dumping)

Date:

Area details:

Mine: ……………………….. Target after-use: (e-g. Agriculture)………………………..

Plan area: (planned size on map…………………) local area: (e.g. dump area south-east 3.2)

General data of realization mining re-cultivation:

Dumping technology: ………………………………………………..

Dumping machines: …………………………………………………

Origin of overburden: ………………………………………………..

Estimated quality of overburden: (e.g. loamy sand)……………..

Period of time of dumping: …………………………… Period of time of leveling: …………………...

Planned targets / realization

	Target	Actual	Comment
Size of dump area (ha) ……….	………..	………………………………………..	
Altitude of dump area (m asl)	……….	………..	………………………………………..
Inclination	……….	………..	………………………………………...
Thickness of culture soil (m)	……….	………..	…………………………………………
Quality of substrate (category)	……….	………..	…………………………………………

Geotechnical Assessment

………..

Stipulations / Instructions

………..

Special site properties

………..

Area inspection

Yes No Date Head of inspection commission………………………

Representative of mine ………………………………..

Transferred to mine map system by Surveyor ………………………………………………...

A.2 Soil description – example

Profile description in field:

Sample number	39W		
Date	25.05.2018		
Soil formation	Loose raw soil (syrosem) of very slightly gravelly - medium sandy dumped sand over gravelly, coal containing weak loamy dumped sand.		
Location	Lusatian mining area, southwest from town Lübbenau, on western part of the bank lake		
Relief position	Gently sloped western exposed hillside, from former open pit Schlabendorf		
Climate	Continent-influenced climate, average temperature 9,1 °C, precipitation 570 mm,		
Land use	Succession, precursory woodland stadia mainly Robinia pseudoaccacia and Pinus syl.		
Humus form	Initial litter layer,		
Horizon	L	+0,5 -0	Loose leaf-litter and needle litter
	jAi	0 – 0,5 cm	Very slightly gravelly, grey fine-sand, very low humus, loose, un-solidified single-grain-structure, carbonate-free, weak root zone
	jlC	0,5 – 40 (60) cm -	Very slightly gravelly, pale grey fine-sand. Loose, un-solidified single-grain-structure, carbonate-free, weak root zone sharp boundary line to IIjlC.
	IIjlC	40 (60) – 100 cm	Very slightly gravelly coal containing, weak brown, weak loamy sand, single-grain-structure, partly densified, carbonate-free, weak root zone.
Comments	Ai-Horizon very weak developed, some small coal particles in jlC, in IIjlC-Horizon distributed coal of different size.		

A.3 Calibration protocol (Amelioration with lime)

Carried out with machines

Liming ☐ Basic Fertilizing ☐ Seeding - Greening (no drilling)☐

Area: ……………………………………………………………………….. Attachment: Pictures of Samples

Size (ha / mu): ………..

11	

Numbers of calibrations to be carried out totally (1 calibration per started 5 ha):

11

Date:	1			Time: …………………………….
Spreading	1			material: Lime☐ Fertilizer☐ Seed☐

Type of spreading material in case of lime and fertilizer: Granulate☐coarsely ground☐fine ground☐lime: water content: …. %

Weather conditions: sunny☐ slightly cloudy ☐ cloudy ☐ overcast☐ slight rain☐ rain ☐

(multiple answers possible)

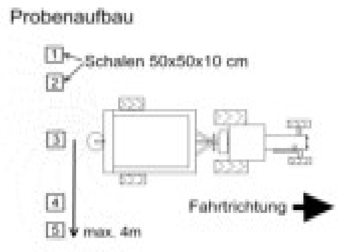
Wind: no wind☐ low wind☐ windy☐ strong wind☐ gusty☐

(multiple answers possible) Sampling (LxWxH): Pan 50x50x10 cm total size collection pan (m^2): 0.25 m^2

1	2	3	4	5
Sample No	Determined amount Collection pan g	Correspond amount / m^2 g	correspond total spreading material amount / ha	Picture of Sample-No.
1				
2				
3				
4				
5				
Average				

Name of the driver and others helping

Signature of driver: ……………………………..



Sampling instructions:

The calibration protocol has to be filled and signed by the driver.

All 5 sampling pans have to be filled during spreading while driving.

The left and right pans have to be vertical to the driver's direction, with one in the center. The pans must only be filled after a stretch of 25 – 50 m, to guarantee representativeness. After sampling, each pan shall be photographed and labeled (date; time; weight).

The results are entered in column 2 the corresponding amount for 1 m (4x) in column 3 and for 1 ha in column 4. In case of liming, the water content has to be added to the amount of pure nutrient content.

If the results differ from the requirements the spreader has to be adjusted, and a new sample has to be worked out. The pictures are part of the protocol.

A.4 Rehabilitation Protocol – planting trees

Rehabilitation Mine<name>

Date: ……………… **Year of planting:**…………..

Protocol

Examination of implementation of re-cultivation contract according to <**name** applicable law/regulation>

This examination is based on the re-cultivation plan of **<name** mining company>and tender item number: …………………………………………………

1. Open-pit area:

Project-No.:

Contractor/Company: ………………………………………………………………………………

Order Nr: 11 ……………………………..

Parties:

PCC: 1 ………………………….. Contractor: 1 ………………………………..

2 ………………………….. 2 ………………………………..

3 ………………………….. 3 ………………………………..

Planting-/forestation plan number: ………………………

Name of area: …………………………………………….. Size: ………….. ha /

Kind-of-use: Forestry ☐ Conservation ☐if conservation, type: ……….

(e.g. road-side, hedges, field-shrubs)

Agriculture ☐

2. **Planting** carried out mechanically ☐ manually ☐ seeding☐

Time (month/year): ……………………………………………………………….

3. The following fixed items of the **Planting-/Forestation-plan** were carried out according to specifications:

Tree-/Shrubs	yes	☐	no	☐
Assortment / Grading	yes	☐	no	☐
Spacing	yes	☐	no	☐
Layout	yes	☐	no	☐

If not, state deviations and reasons: ……………………………………….

4. Required **provenance** of planting/seeding material approved by delivery note

Yes☐ no☐ no proof required☐

5. Quality of delivered seeding and planting material

No visible defect . ☐

More than 5% of cultivated plants defective, faulty or damaged:

a) Planting material not visibly scarred ☐

b) Planting material partially or totally desiccated ☐

c) Shafts strongly curved (except larch, pine, oak, beech) ☐

d) Tree seedlings with shaft forks ☐

e) Main shoot with more than one terminal bud (excluding oak, beech) and/or incompletely lignified branches (except nursery-grown planting stock delivered during vegetation period and poplar clones) ☐

f) Shoot without healthy terminal bud (except beech, oak, poplar) ☐

g) Current year needles heavily damaged (only applicable to pine and Douglas fir) ☐

h) Root neck damaged (except poplar cuttings) ☐

i) Main root strongly curled (except cuttings) ☐

j) Fibrous roots missing or strongly mutilated (except cuttings) ☐

k) Planting material with serious damages caused by pests/diseases ☐

l) Planting material with visible damages caused by heating, fermentation or rot due to faulty storage in nursery ☐

m) Fungal attack ☐

6. Losses of cultivated plants: autumn, not examined yet ☐

Plantation has losses yes ☐ no ☐

If yes, estimated total losses in percentage: ……………………………….…

Losses occur:

(multiple answers permissible)

isolated patches ☐ along rows☐ on larger areas☐

isolated patches & larger areas ☐ particular tree species (in mixed plantations) ☐

If tree-specific, state species and loss-percentage: …………………………..

Planting goals of forestation-plan attainable: yes ☐ no☐

Expected growth rates attainable: yes☐ no☐

7. Plants damaged by improper on-site-storage, requiring special planting & treatment:

yes☐ no☐

If yes, type of defects and estimated volume: ……………………………..

……………………………………………………………………………………..…

8. Correct **planting depth**: yes☐ no☐

If no, type of failure(s) ……………………………………………..………

(e.g. root ends are not covered by soil, holes between roots, roots compressed)

9. **Other damages** (biotic / abiotic)

on plants yes☐ no☐

If yes, type and volume: ………………………………………………………..…

(including damages caused by improper tending, e.g. damages by cutting terminal buds)

………………………………………………………………………………………….....

10. **Status of site management:**

Management is adequate ☐ inadequate ☐

If inadequate, deviations: ……………………………………………....

(e.g. no tending, delayed tending, no watering.)

…………………………………………………………………………………………….....

11. Grass and herb seeding:

(only if work started in the year of planting)

Pos. No.: ………… according to specifications yes ☐ no ☐

Seeding yes ☐ no ☐

Species composition according to specification yes ☐ no ☐

on whole site☐on patches ☐not at all ☐

12. Forest protection / Plant protection

Protection: yes ☐ no ☐

If yes, Pos. No.: …………………… planned area ☐

Fence☐ mechanical protection of individual plants ☐
chemical protection of individual plants*☐ chemical protection of site**☐

If chemical protection: type, method and time of application: …………………………

…………………………………………………………………………………………………

Protection measures carried as specified: yes ☐ no ☐

If not, deviations: …………………………………………………………

13. **Forest protection control** on the protected site

Browsing by game: yes ☐ no ☐

If yes, estimated browsing percentage on top shoot only (e.g. game, trees species):

……………………………………………………………………..………………………..

……………………………………………………………………………………..………..

Individual mechanical plant protection:

The construction is proper worked out and fulfils its function: yes ☐ no ☐

Definitions:

☐ Defects are examined ………………………………………..

☐ Legal statement according to <**name** applicable law/regulation>. The client delivers the following legal statement to fulfil all contractual obligations: ……………

………………………………………………………………………………………..

………………………………………………………………………………………..

……………………………………………………………………………………..….

Notes:

………………………………………………………………………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………………………………

For Mining Company: for contractor:

……………………………………….. ………………………………………..

Company inspector

……………………………………….. distributing list:

Company re-cultivation officer

Notation:

Realizing the determinations:

Point…………………………………………………….…. on (date) ………………………

Point ………………………………………………….……. on(date) ………………………

Point ………………………………………………….……. on (date) ………………………

………………………….. …………… ………………………….. ……………….. Company inspector Company re-cultivation officer

A.5 Inspection protocol - Rehabilitated areas

Date:

Area details:

Mine: ………………………. Target after-use: (e-g. Agriculture)………………………..

Plan area: (planned size on map…………………) local area:

Type of recultivation:

Rehabilitation of dumps inside mine: ☐ Rehabilitation of dumps outside mine: ☐

Rehabilitated area in the surrounding: ☐ Temporary greening: ☐

Details of substrate

Soil texture: ………………..

Geological age: ……………..

Following documents / protocols have been checked by the inspection commission

	Date	Comment
Inspection protocol mining recultivation	……….	………………………………………..
Protocol of cleaned area in vicinity	……….	………………………………………..
Soil survey report	……….	………………………………………..
Protocol of amelioration	………..	………………………………………..
Forestation plan	………..	………………………………………..
First seeding (agriculture)	………..	………………………………………..
Tending protocols	………..	………………………………………..

Assessment of actual quality of the site

……

Stipulations / Instructions

……

Special site properties

……

Area inspection

Yes No Date Head of inspection commission……………………..

Transferred to mapping system of the mining company by

Surveyor

………………………………………………..

A.6 Example Soil Description according to German Soil Evaluation Method (KA 4 and KA 5)

Evaluation of soil texture "Real example"

legend

o	changed by human activities	(t)	tertiary origin
j	natural origin	(q)	quaternary origin
y	technical origin (e.g. ash)	(qt)	mixture of tertiary and quaternary origin
⇌	changing with	s	sand (ss = pure sand)
/	over (lying over)	u	silt
k	gravel contending	l	loam
x	coal contending	t	clay

Nutrient level: A = poor (A+ = poor to quite poor), Z = quite poor (Z+), M = middle, R = rich

soil texture 100 x 50m scheme

oj-(lt)xls (t) = dumped coal loam sand contending loam-clay pieces (tertiary origin)

area: 38,49 ha (from 80,34 ha = 47,9 %)

substratum: dark brown to black-brown coloured, very little gravel and coarse-sand, much fine sand, little silt and clay – bearing medium sand with varying parts of loam-clay pieces. Local you can find coal-bearing pure sand (fine sand). In the western part of the area there is a little overlapping of gravel-bearing pure sand of tertiary origin.

Soil physics	Coarse-soil:	very little gravel content
	Structure:	single-grain structure
	Compactness:	middle to high
	Usable field capacity:	middle
	Air capacity:	middle
	Water permeability:	middle

Soil chemistry	pH-value:	sour to very strong sour
	Sorption capacity:	middle to high
	Base saturation:	low base content
	C_{org} – content:	(source carbon organic) coal-bearing
	$CaCO_3$ – content:	carbonate-free
	Total sulphur content:	middle

Nutrient level: M (middle)

Lime requirement: 100 t CaO/ha (pure nutrient) related to a depth of 1 m

oj-(lt)(x)ls (t) ⇌ oj-(lt)(x)ss (t)

= coal-bearing dumped loam sand contending loam-clay pieces (tertiary origin) changing with coal-bearing dumped pure sand contending loam-clay pieces (tertiary origin)

area: 37,78 ha (from 80,34 ha = 47,0 %) on 5 partial areas

substratum: tertiary brown to black-brown coloured, very little gravel and coarse-sand, much fine sand, little coal, silt and clay – bearing medium sand changing with tertiary brown to dark brown coloured, very little gravel and coarse-sand, medium sand and very little silt and clay-bearing fine sand. Both substratum without carbonate and have varying parts of coal and loam-clay pieces.

Soil physics	Coarse-soil:	very little gravel content
	Structure:	single-grain structure
	Compactness:	middle to high
	Usable field capacity:	middle
	Air capacity:	middle to high
	Water permeability:	middle to high

Soil chemistry	pH-value:	very strong sour to strong sour

Sorption capacity:	low to middle
Base saturation:	very low to low base content
C_{org} – content:	little coal-bearing
$CaCO_3$ – content:	carbonate-free
Total sulphur content:	low to middle

Nutrient level: M (middle)

Lime requirement: 60 t CaO/ha (pure nutrient) related to a depth of 1 m

soil texture evaluated as

oj-(lt)(x)ls (t) ⇌ oj-(lt)(x)ss