Methodology for improving TMF safety

The Methodology was developed in 2015 within the project "Improving the safety of industrial tailings management facilities based on the example of Ukrainian facilities" (2013-2015), Report No. (UBA-FB) 002317/ENG,ANH2

The Methodology has been improved in 2017 within the project "Raising Knowledge among Students and Teachers on Tailings Safety and its Legislative Review in Ukraine" (2016-2017) by the Ecoplatform LLC based on the results of trainings conducted at National Mining University (Dnipro, Ukraine) and feedback of Ukrainian competent authorities. Report No. (UBA-FB) 002638/E.

The Methodology has been improved in 2018 within the project "Assistance in safety improvement of tailings management facilities (TMF) in Armenia and Georgia" by the Ukrainian expert team using the results of trainings conducted in Armenia, tailings hazard assessment, and feedback of international experts.

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On behalf of the German Environment Agency

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Umwelt Bundesamt

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Abbreviations

BAT	Best available technologies
CRS	Closure and rehabilitation strategy
DSC	Dam and screens
EIA	Environment Impact Assessment
EMP	Emergency Plan
GCR	Geological, climate, and terrain risks
INR	Facility inspection, documenting and reporting
MON	Monitoring
MSR	Minimum set of safety requirements
NGO	Non-governmental organization
STC	Substances (Tailings Capacity, Toxicity)
TDP	TMF Deposition Plan
THI	Tailings Hazard Index
TMF	Tailings Management Facility
TMFs	Tailings Management Facilities
TRI	Transportation and infrastructure
TRP	Trainings and personnel
UNECE	United Nations Economic Commission for Europe
UBA	German Environment Agency (Germ. – Umweltbundesamt)
WTM	Water management

Foreword

Background and acknowledgements

In 2013 German Environment Agency has initiated a project "Improving the safety of industrial tailings management facilities based on the example of Ukrainian facilities". The main project aim was to develop a Methodology for Comprehensive Evaluation of Tailings Management Facilities Safety (TMFs) with the TMF Checklist (hereinafter TMF Methodology) as a toolkit for competent authorities and inspecting bodies in ECE countries responsible for the safety of facilities storing hazardous mining waste. The TMF Methodology is mainly based on the document "Safety guidelines and good practices for tailings management facilities" endorsed by the Conference of the Parties to the UNECE Convention on the Transboundary Effects of Industrial Accidents at its fifth meeting (Geneva, 25–27 November 2008). This document was updated by the request of the seventh meeting (Stockholm, 14–16 November 2012) of the Conference of the Parties to the Industrial Accidents Convention.

The TMF Methodology was developed in 2015 and updated in 2017 by the Ukrainian project team that included Mr. Grygorii Shmatkov (scientific team leader), Mrs. Iryna Nikolaieva (project manager, technical expert), Mr. Dmytro Rudakov (technical expert), Mr. Yuriy Shestak (technical expert), Mrs. Kateryna Okhotnyk (technical expert) and Hanna Zadnipriana (project manager assisitant). The prime contractor of the project was International HCH & Pesticide Association (IHPA, Denmark) headed by the director Mr. John Vijgen.

The work of the Ukrainian team was technically and scientifically managed by Mr. Gerhard Winkelmann-Oei (German Environment Agency). To support the work of the Ukrainian team an international steering group was established, consisting of the following members: Mr. Wolfhart Pohl (USA), Mr. Philip Peck (Sweden), Mr. Nikolay Savov (Switzerland), Mr. Pavel Danihelka (Czech Republic), Mr. Peter Kovacs (Hungary), Mr. Zoltan Torok (Romania), Mr. Nicolae Ajtai (Romania), Mr. Timo Regina (Finland), Mr. Hovannes Nikoghosyan (Armenia), Mr. Konstatine Burjanadze (Georgia), Mrs. Irma Gurguliani (Georgia), Mr. Adam Kovacs (Austria), Mr. Oliver Kalush (Germany), Mr. Christoph Külls (Germany). The members of the steering group actively contributed to the drafting of the TMF Methodology. Also Ukrainian experts from environmental and mining-related institutions and companies have been engaged in the work within this project and suggested ideas to improve the TMF Methodology.

The relevance of the Methodology

Last two decades there is a growing concern on environmental degradation caused by unintended large-scale movement of hazardous materials as a result of failures of tailings management facilities where large amounts of mining wastes are stored. These wastes pose serious threats to humans and the environment, especially if tailings facilities are improperly designed, constructed, operated or managed. Pollution of waterways and the related damage or risk to human health, infrastructure and environmental resources has often a negative effect on relations between neighbouring countries. Such risks are posed by all TMFs, including those active, idle/inactive, neglected, temporarily or permanently closed, abandoned or orphaned.

Ukraine is a very example of inappropriate storage of mining wastes. The vast majority of more than 25 billion tons of mining wastes in the country are stored in obsolete or abandoned facilities created over 50 years ago not meeting modern safety requirements. The common practice of TMF construction was creation of dams across the ravines, gullies, and small rivers. The bottom and borders of impoundments were not covered with waterproof screens or lined, so these TMFs became a source of ground and surface water contamination.

Besides, the accidents at TMFs may frequently lead to long-term water and soil pollution, damage biota and have negative after-effects to human health. Failures may result in uncontrolled spills and releases of hazardous tailings materials. The negative impacts of such incidents on humans and the environment and severe transboundary consequences have been demonstrated by recent accidents in ECE-countries; the most known occurred at tailings in Baia Mare, Romania (2000), aluminium sludge tailings in Kolontar, Hungary (2010), at the Talvivaara Mining Company in Finland (2012).

In 1983 potash fertilizers were released in the Dniester River at Stebnikovskiy plant "Polimineral" in Western Ukraine. In 2008 due to dam failure waste products were again dumped from potash fertilizers tailings at the Kalush chemical plant into Dniester, which caused the concern of Government of the Republic of Moldova. In January 2011 the tails had dried up at the alumina refinery plant near the city of Mykolaiiv (Southern Ukraine) and stored wastes were dispersing as dry red dust. The topsoil, atmosphere, ground and surface water, settlements were affected over the area of tens of square kilometres.

Many efforts have been undertaken recently by the international expert community to improve TMF safety through strengthening the safety requirements, for instance, by putting into practice the advances in remediation technologies and techniques in mining and national practices [1, 2, 3, 4, 5, 6, 7, 8, 9]. Advances in Earth sciences in the field of geological, seismic, hydrological, and climate risks have been also taken into account for design and operation of TMFs. Nevertheless, tailings in many countries of East Europe and the former USSR urgently need taking measures to improve their safety.

Aims and scope of the Methodology

Recently the Secretariat of International Commission for the Protection of the Danube River has submitted a proposal "Environmental Safety Danube Strategy Program" to develop a checklist for safety of tailings. Based on the UNECE "Convention on the Transboundary Effects of Industrial Accidents" the UNECE has supported further implementation of "Safety Guidelines and Good Practices for Tailings Management Facilities", which was proposed by German Environmental Agency in the form of the TMF Methodology.

The main Methodology tasks to be implemented were:

- to develop a simple and easy-to-use methodology to rank the relative hazard/risk of a large number of tailings using a "Tailings Hazard Index";
- to develop the checklist for examinations of the minimum set of the TMF technical safety requirements (the TMF Checklist);
- to develop technical measures for implementing of international standards for the safe operation of TMFs (Measure Catalogue).

The resulting version of the TMF Methodology was endorsed by the Final Workshop of the project in Kyiv in 19th – 20th of May 2015 and approved by German Environment Agency in July 2015. The Methodology was updated in May 2017 and July 2018.

Both UNECE and German Environment Agency encouraged Parties and other ECE member States to disseminate the TMF Methodology for use by the appropriate authorities. Competent authorities, TMF operators, and the public are invited to apply this Methodology, which is intended to contribute to limiting the number of accidents at tailings management facilities and the severity of their consequences for human health and the environment.

Chapter 1. TMF Methodology Concept

1.1. Methodology application scope and key definitions

The Methodology is applicable to the tailings management facilities (ash storages, sludge storages, slag storages, pools for waste products accumulation including fly ash, slag, sludge and other types), which are moved hydraulically from places of their formation. Such wastes are generated at extraction and enrichment of mineral ores and coal, at large chemical industry (plants), metallurgical enterprises, coke plants, thermal power plants (coal-fired), etc.

The basic terms indicated below are used in this Methodology with the following meaning:

Abandoned TMF site is an area formerly used for mine waste storage operations (an idle/inactive site) that is neglected and whose legal owners still exist and can be located (Fig. 1).

TMF **Accident** is a dangerous man-made accident that threatens human life and health, leads to the destruction of buildings, structures, equipment and transportation facilities, disruption of the production and transportation, and affects the environment.

TMF **Closure** is a whole of TMF life process that typically culminates in tenement relinquishment (generally, after a legally binding sign-off of liability). Closure (generally) is deemed to be complete at the end of decommissioning and rehabilitation and where and all current appropriate regulatory obligations have been satisfied.

TMF **conservation** includes the complex of mining, engineering, construction, and reclamation works that ensure safe storage of wastes in the TMF for a certain period.

Primary **dam** is an embankment of soil or overburden intended for spacefilling during the first stage of the storage tank to be used for staring liquid waste (tailings, slurries).

Protective **dam** is a dam built within the danger zone to protect the area that may be affected in case of a failure of retaining structures of the storage tank.

Separating **dam** is a dam dividing the tailings pond into separate compartments.

TMF **Decommissioning** is the process that begins near, or at, the cessation of mineral production. This term refers to a transition period and activities between cessation of operations and final closure.

Dewatering is removal of water from water-saturated materials to reach the moisture content, which allows processing dewatered materials by dry excavation/drilling equipment and transportation by mechanical transport.

Drainage system includes the complex of hydraulic structures, equipment and facilities designed for controllable diversion of seepage water through the dam.

Emergency reservoir/tank is a periodically emptied reservoir intended for receiving slurry during a short-term failure of the main hydraulic transportation system or an emergency at the main reservoir/storage.

Emergency situation (Emergency) is a situation formed in a certain territory as a result of a TMF accident, which may lead or led to human casualties, damage to human health or the environment, significant economic losses, and disruption of life activity.

Factor of Safety (FoS) is the ratio of the shear strength (or, alternatively, an equivalent measure of shear resistance or capacity) to the shear stress (or other equivalent measure) required for dam slope equilibrium. If FoS is less than 1.0, the slope is unstable.

Harm is any damage to people, property, or the biophysical, social, or cultural environment.

Hazard is a source of potential harm or a situation with a potential for harm, thus a potential cause of harm. Hazard is a property or situation that, in particular circumstances, could lead to harm.

Hazard class of waste is a characteristic of waste quantifying its potential hazard to the environment and humans due to toxicity.

Hydraulic protection system incudes the complex of hydraulic structures (ditches, channels, ponds, etc.) intended for capturing and diversion of surface runoff from the catchment area of the tailings pond.

Hydraulic transportation is the technological process of moving materials by water flow. Depending on how slurry is transported through the pipeline, hydraulic transportation may be driven by gravity only, pressure and gravity, and pressure only.

Hydrotechnical structures (HTS) are dikes, the dams protecting storage tanks and reservoirs, low-permeable screens, spillways, water drainage and water discharge facilities, channels, pumping stations for delivery of slurry and circulating water, and other facilities intended for water storage and prevention from harmful effects of liquid waste.

Impoundment bed is the surface of the bottom, natural slopes and upper slopes of the enclosing structures of the TMF below the design mark of their crest.

Injection/filling method is the method to release tailings material through the distributing pipelines to different sections of the tailings pond.

In-situ observations are observations conducted at the TMF to control its parameters; in-situ observations include visual inspection and instrumental measurements.

Lagoon is the area of surface sediments above the water level limited by the dam slope and the water edge in the settling pond.

Level of filling is the average elevation of the surface of tailings materials within the tailings pond.

Liquid waste storage is a reservoir intended for storing industrial wastes delivered by hydraulic transportation, which includes a complex of technologically interconnected structures, equipped and operated in accordance with the design. Depending on waste type and the intended purpose liquid waste storages, include tailings, slurry (slime) storages, industrial wastewater storages, sedimentation tanks, evaporation ponds, fly-ash storages, piles, sludge collectors.

Low-permeable screen is a layer of low permeable materials installed by the placement of appropriate materials (low-permeable clays, sludge etc.) in the impoundment bed.

Maximum water level is the maximum permissible water level at the design mark of the crest of enclosing structures. For stage-by-stage construction of TMFs maximum water level is defined for each stage or the layer of filling the tailings pond.

Monitoring of TMF safety is a set of continuous observations of the TMF state and its environmental impact.

Neglected TMF site is an idle or inactive site that has **not** been closed and has no clear and **obvious** owner but that **may** still be held under some form of title and where all current appropriate regulatory obligations have **not** been satisfied (Fig. 1). **Orphaned** TMF site is abandoned TMF operations or facilities for which the responsible party no longer exists or cannot be located (Fig. 1).

Progressive Rehabilitation is a process referring to the ongoing rehabilitation of TMF sites and mineral related facilities **during the operational life** of a facility. Progressive rehabilitation may include works such as re-vegetation of areas disturbed during project development and operations, re-vegetation of abandoned or filled mine waste areas including tailings impoundment areas; removal and/or disposal of any obsolete structures and materials as per a final rehabilitation and closure plan; backfilling of approved underground or surface excavations using mill tailings to reduce tailings im-

poundment areas; methods to reduce or eliminate soil erosion and stabilization of the site which will facilitate re-vegetation and reclamation; placement of waste rock in the underground workings or open pits, or by covering the waste rock with till or topsoil and then re-vegetating in an acceptable manner, and so forth.

Recycled water supply system is the complex of equipment and facilities for supply of recycled process water within the TMF area.

Rehabilitation (Reclamation) is the return of the disturbed land to a stable, productive and/or self-sustaining condition, taking into account beneficial uses of the site and surrounding land.

Risk is a possibility of a defined hazard or damage, and the magnitude of the consequences of the occurrence.

Risk assessment includes risk estimation and risk evaluation.

Risk estimation is concerned with the outcome or consequences of an event/action taking account of the probability of occurrence,

Risk management is the process of implementing decisions about accepting or altering risks.

Safety level is the index quantifying the probability that harm can become actual. Safety level can be defined as a relative level of risk reduction provided by implementation of technical or organizational safety measures. Safety level serves as the criterion to check the effectiveness of safety measures at the TMF site.

Safety measure is a measure taken to improve inconsistencies with safety requirements revealed by the inspection of the TMF site.

Safety of the TMF is the state of the tailings management facilities, which allows protecting the life, health and legitimate interests of people, the environment, the safe functioning of infrastructure and economic entities.

Settling pond is the pond within the impoundment intended for clarification, accumulation and withdrawal of circulating water.

Sludge is disperse liquid waste generated in technological processes of chemical, metallurgical and other industries.

Slurry is a turbulized mixture of solid particles of tailings materials with water.

Slurry pipeline is the pipeline, channel or tray for slurry transportation. Depending on the intended use there may be main or distribution slurry pipelines.

Coastal **spillway** is a channel-type structure installed in the coastal abutment of the tailings pond or the storage tank to discharge water from a settling pond.

Discharge **spillway** is a structure designed to discharge water from a settling pond.

Starter dam serves as the starting point for embankment construction. The starter dam design specifies the internal and external geometry of the structure, and should include specifications for drainage, seepage control, and in some cases liner systems required to maintain embankment stability and control releases to the environment.

Tailings materials are the fine-grained waste material remaining after the metals and minerals recoverable with the technical processes applied have been extracted. The material is rejected at the “tail end” of the process with a particle size normally ranging from 10 µm to 1.0 mm.

A **Tailings dam (bund wall)** is a tailings embankment or a tailings disposal dam. The term “tailings dam” encompasses embankments, dam walls or other impounding structures, designed to enable the

tailings to settle and to retain tailings and process water, which are constructed in a controlled manner.

A **Tailings Impoundment** is the storage space/volume created by the tailings dam or dams where tailings are deposited and stored. The boundaries of the impoundment are given by the tailings dams and/or natural boundaries.

Tailings Management Facility is intended to encompass the whole set of structures required for the handling of tailings including the tailings storage facility, tailings dam(s), tailings impoundment, clarification ponds, delivery pipelines, etc.

A **Tailings Storage Facility** is a facility used to contain tailings. This can include a tailings dam (impoundment and pond), decant structures and spillways. A tailings storage facility can also be open pits, dry stacking, lakes or underground storages.

Temporary Closure (An **Idle/Inactive** TMF site under **Care and Maintenance**) is the phase following temporary cessation of operations when infrastructure remains intact and the site continues to be managed. The site is still held under some form of title and all current appropriate regulatory obligations for closure have **not** been satisfied. When being maintained in some way with a view to future resumption of operations, such sites are frequently referred to as being under care and maintenance (Fig. 1).

TMF capacity is the amount of waste (tailings materials, sludge) that can be stored in the tailings pond/storage according to the technology accepted in the TMF design. (Another definition: **TMF capacity** is the total volume of the impoundment within the design elevation of the enclosing dam crest).

TMF life cycle is a regular sequential change in the stages of TMF existence; TMF life cycle includes the stages of design, construction, operation, closure and rehabilitation.

TMF operator (TMF operating company) is a state, private, or municipal company or other entity/organization legally responsible for the TMF.

TMF owner is the state or private or any other legal form entity, which has the rights to own, use, and dispose of the TMF. The owner of the tailings dump is in most cases the TMF operator (TMF operating organization).

TMF total area is the area of the TMF site within the boundaries of the land lease for storage of tailings materials.

TMF used area is the area limited by the horizontal projection of the tailings pond contours within the area filled in tailings materials.

TMF used capacity is the amount of waste (tailings materials, sludge) that are actually stored in the tailings pond/storage.

Transboundary emergency is an emergency with the damaging factors going beyond the state borders, or an emergency that occurred abroad and affects the territory of the state.

Inundation **zone** is the zone within which flow formed after dam failure moves.

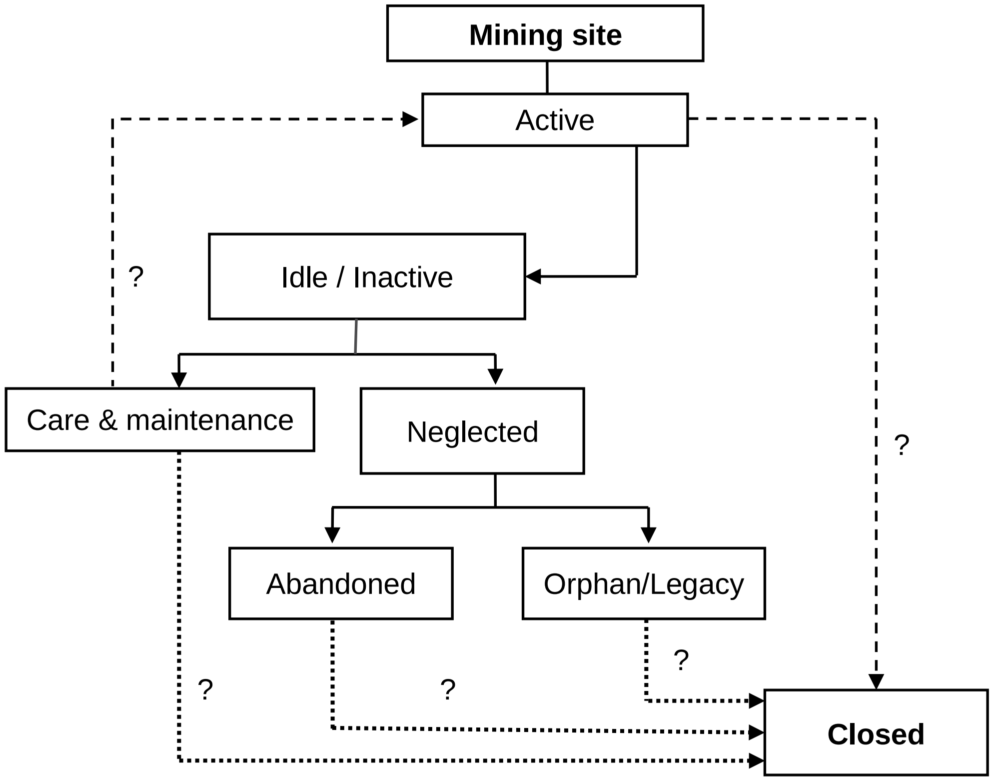
Dangerous **zone** is the zone adjacent to the downstream area of retaining structures; flooding of this zone may lead to catastrophic consequences.

Secured **zone** is an area around the TMF and along the pipelines for slurry and water delivery, within which working, staying people and mechanisms not related to TMF operation is prohibited.

Sanitary-protection **zone** is the area between the borders of the TMF site including the storages of materials and reagents and residential areas.

Definitions above are based on the terminology used in [5, 8, 9, 10].

Figure 1: TMF status diagram [8]



1.2 TMF Methodology essence

The control of TMFs safety requires regular inspections of these objects to be performed according to national regulations taking into proper account international safety requirements as well as the best available technologies (BAT) and engineering solutions in sustainable mining and environment restoration.

The TMF Methodology includes the evaluation of the tailings potential hazard for the large amount of the TMFs on the national level; the overall and detailed evaluation of the TMF safety level, prescription of protective and preventive measures based on BAT, putting them into common practice.

The developed TMF Checklist is based on the test question method, which implies answering the questions specially selected to identify the main problems of the studied case and come to the most powerful solutions.

The advantages of the developed TMF Methodology are that

- all Methodology users (competent authorities, inspectors and operators) work comply with the same inspection procedure
- TMF operators can detect non-compliances with minimum set of the safety requirements at the TMF prior to check and start getting them fixed in advance
- all Methodology users work with the same Measure Catalogue that is accumulating best available technologies in sustainable mining.

1.3 TMF Methodology Structure

The TMF **Methodology** includes the following elements:

1. The Method of evaluation of Tailings Hazard Index (THI Method).
2. The TMF Checklist including

   - The Questionnaire (three groups of questions).
   - The Evaluation Matrix for the TMF safety level.
   - The Measure Catalogue for taking actions to improve TMF safety.

The Method for evaluation of tailings potential hazard is intended for prompt preliminary evaluation of Tailings Hazard Index first of all for the large amount of the TMFs on the national level. Applied to Ukrainian TMFs the Method allowed creating the national catalogue of hazardous TMFs and ranking all facilities identified throughout the country according to their hazard index. The THI Method is available in Excel format, which facilitate its practical use due to automatic calculation of the Tailings Hazard Index (please refer to the Excel file "Template_THI method.xls" that can be obtained by request from German Environment Agency, contact information for request: Mr. Gerhard Winkelmann-Oei, email: gerhard.winkelmann-oei@uba.de).

The TMF Checklist is based on the technical explanations to the safe operation of TMF [5] and includes all references to the newest standards and guidelines as well as an assessment of recent disasters. The questions of the Questionnaire are formulated in such way to encompass the minimum set of the requirements critical for TMF safety, which allows evaluating the TMF conditions. Questions in all groups of the Checklist are sorted by the TMF life-cycle and each subsection does contain relevant questions applied to the specific stage.

The developed Evaluation Matrix of TMF safety level gives the assessment of TMF being checked in compliance with applicable safety requirements formulated in the Questionnaire. The Evaluation Matrix unifies the answers to the questions; it includes both overall and categorial evaluation using specific categories, which allows thorough checking all TMF elements. Besides, the Matrix enables evaluating uncertainties caused by the lack of data on the inspected TMF.

The application of the TMF Checklist is supported by a Measure Catalogue with short-, medium- and long-term safety measures. The short- and medium- term measures should be based mostly on economic aspects, the long-term measures should meet high international safety standards.

Developed TMF Checklist is also available in Excel format to facilitate its practical use due to automatic calculation of the safety level and easy way for search and identification of the appropriate safety measures. The file can be obtained by request from German Environment Agency, contact information for request: Mr. Gerhard Winkelmann-Oei, email: gerhard.winkelmann-oei@uba.de.

Detailed instructions how to apply the TMF Methodology and recommendations to users are given below in Sections 2 – 5.

1.4 Benefits of TMF Methodology application

The TMF Methodology was conceived as a toolkit to improve public safety in the areas (could be potentially) affected by tailings. The TMF Methodology may bring many organizational and managerial benefits listed below.

- The approval of the Method of evaluation of Tailings Hazard Index on the governmental level will enable primary check of all TMF and creating the country's catalogue of TMFs. This catalogue has to rank all checked TMF according to their hazard and safety conditions, and then prioritize the further safety measures.
- The TMF Checklist imposes unified strict qualification requirements both to TMF operators and state inspectors. Thus, systematic application of TMF Checklist will enforce both TMF operators and state inspectors enhance their skills and qualification permanently.
- The TMF Checklist specifies the requirements to the operator how to aware the local communities in case of emergencies and accidents. Discussions with local communities in the form of public hearings, necessity to consult with local authorities and receive their approval of the project design document of a TMF will be mandatory.
- The TMF Checklist unifies the procedure to evaluate the safety of various TMFs, which complies with EU policy in harmonization of legislation.
- The TMF Checklist requires obligatory development of Closure and Rehabilitation plans to all TMF, both operated and designed; the availability of these plans have to be the common practice.
- Regular trainings for the TMF personnel, which are obligatory required in TMF Checklist, will enhance staff preparedness to emergencies and accidents.
- Systematic application of the Checklist to various TMFs in different countries will contribute to better understanding the risks posed by TMFs and lowering vulnerability of tailings in terms of natural and man-made risks.
- The Method of evaluation of Tailings Hazard Index may be transforming into a widening database/GIS very helpful to competent authorities responsible for environment rehabilitation of post-mining sites.

Chapter 2. Method of Evaluation of the "Tailings Hazard Index"

The Tailings Hazard Index method (THI method) is intended for the use by state competent authorities in order to create an overview of potential hazards/risks posed by TMF or a large number of TMFs as hazardous facilities by analysis of a few critical parameters. The THI evaluation can be performed based on the documentation available within a short time period. The evaluation results can also be used for making decisions by state competent authorities responsible for environmental safety. In the first instance, the THI has to be applied to a large number of TMFs on the national level.

The THI method is used for

- creation and/or update of the country's Catalogue of TMFs;
- ranking of all country's TMFs under the index of their potential hazard/risk.
- identification of the most dangerous TMFs (the TMFs of highest concern) in the country;
- optimization of usage of limited financial and institutional resources to improve safety at TMFs.

The Tailings Hazard Index (THI) is the index that demonstrates the measure of specific potential hazards/risks posed by tailings facilities to the environment, infrastructure, and humans. The THI is calculated by summing up the major TMF parameters that significantly effect on the level of its safety. These are:

- volume of tailings,
- toxicity of substances in tailings,
- TMF management status,
- natural conditions (geological, seismological, and hydrological conditions) specific to the TMF site,
- and dam safety.

Tailings Hazard/risk Index can be calculated in two ways depending on the availability of data on TMFs:

1. Basic THI is simple calculation approach by using the data on two major parameters, which are volume and toxicity of tailings material;
2. Extended THI is detailed approach by using the data on two major parameters of Basic THI and additionally three other parameters clarifying TMF status, natural conditions and dam safety.

The Basic THI is calculated stepwise by the formula

$$THI_{Basic} = THI_{Cap} + THI_{Tox} \quad (2.1)$$

where THI_{Cap} is the measure of hazard/risk caused by the volume of tailings stored in TMF (TMF capacity);

THI_{Tox} is the measure of hazard/risk caused by toxicity of substances contained in tailings.

The Extended THI is calculated stepwise by the formula

$$THI_{Extended} = THI_{Cap} + THI_{Tox} + THI_{Manag} + THI_{Site} + THI_{Dam} \quad (2.2)$$

where

THI_{Manag} is the measure of hazard/risk related to improper management of facilities;

THI_{Site} is the measure of hazard/risk related to specific geological and hydrological conditions at the TMF site;

THI_{Dam}* is the measure of dam failure hazard/risk related to structural and component items of the dam, its integrity and functionality.

* - To properly quantify THI_{Dam} the critical parameter for dam slope stability Factor of Safety (FoS) is needed; however, FoS, may be unavailable for a user. Thus, the THI Method proposes the other alternative parameters, which are much easier to obtain and usually available. In this way a user can be more flexible and apply the appropriate criteria regarding to data availability.

The calculation procedure for the THI_{Basic} includes two steps (1st and 2nd steps below), the procedure for the $THI_{Extended}$ does five steps (steps 1st through 5th). In case if values of some parameters are unavailable or impossible to identify the maximum values have to be used. Thus, the hazard/risk related to an unavailable TMF parameter (for example, toxicity) is expected to be higher if relevant information is absent.

1st Step: Capacity. The data of the parameter "TMF capacity" is the volume of stored tailings materials in the facility (m^3). The index hazard/risk of the parameter is assumed to increase with the growing volume by logarithmic relation with the base of 10. Thus, increasing the volume of tailings materials by 10 times (one order) will increase the value of the hazard index by 1.

The hazard index "TMF capacity" is calculated by the formula

$$THI_{Cap} = Log_{10}\,[V_t] \qquad (2.3)$$

where V_t is the volume of tailings materials in the TMF (or TMF capacity), m^3.

Examples.

For a large TMF with V_t= 10 Mio m^3 we obtain THI_{Cap} = Log_{10}[10 000 000] =7.

For a small TMF with V_t= 0,01 Mio m^3 we obtain THI_{Cap} = Log_{10}[10 000] =4.

2nd Step: Toxicity. The index hazard/risk of the parameter "Toxicity" is evaluated based on the data of the Hazard Class of tailings materials according to the national classification. The compatibility of two widely used toxicity classifications (German WGK classification and Hazard Class classification, the latter is similar to those used in the most of former USSR countries) is shown in Table 1. According to Table 1 the notations “WHC 3” or “HC 1” relates to maximum toxicity of substances, the notations “WHC 0” or “HC 4” relates to minimum toxicity of substances.

Table 1: Evaluation of THI_{Tox}

Data for calculation of the THI_{Tox}		Value of THI_{Tox}
Classification		
Water Hazard Class, WHC[1]	Hazard Class, HC[2]	
“0”	“4”	0
“1”	“3”	1
“2”	“2”	2
“3”	“1”	3

[1] WHC = Water Hazard Class, WGK = Wassergefährdungsklasse, German classification [11];

[2] HC = Hazard Class, classification used in the former USSR [12];

3rd Step: TMF Management. The data of the parameter "TMF management" is the TMF status that should be identified from proposed two options in Table 2. The TMF accident statistics [13, 14, 15] show that closed and rehabilitated TMFs are safer in terms of accident frequency. Less than 15% of all accidents occurred at inactive TMFs, some of them are abandoned. For this reason the index of hazard/risk related to management of TMF is assumed to be higher if the facilities are active, abandoned or orphaned. On the contrary, closed and rehabilitated facilities are assumed to be of lower hazard/risk.The value of THI_{Manag} is determined according to Table 2. The differences between "abandoned" and "orphaned" TMFs are explained in Section "Terminology".

Table 2: Evaluation of THI_{Manag}

Data for calculation of the THI_{Manag}	**Value of THI_{Manag}**
1) TMF is closed or rehabilitated	0
2) TMF is active or abandoned/orphaned	1

4th Step: Site. The measure of TMF site-specific hazard/risk includes the contributions of seismic and flood hazards/risks, which are the most critical for TMF safety among natural impacts.

$$THI_{Site} = THI_{Seismicity} + THI_{Flood} \quad (2.4)$$

The value of $THI_{Seismicity}$ is calculated based on the data on reference peak ground acceleration (Reference PGA) a_{gR} with the returning period T_{Ret}, years [16]..The parameter Reference PGA allow harmonize different national classifications [17] and free available at [18]. The seismic hazard/risk is defined as "Low" if "Reference PGA" is ≤ 0.1, and "Moderate or High" if "Reference PGA" is >0.1.

The $THI_{Seismicity}$ is evaluated according to Table 3.

Table 3: Evaluation of $THI_{Seismicity}$

Data for calculation of the $THI_{Seismicity}$	**Value of $THI_{Seismicity}$**
Reference PGA a_{gR} with the returning period T_{Ret}	
≤ 0.1	0
> 0.1	1

Note

The returning period T_{Ret} used for zoning seismic hazard equals 475 years..

The value of THI_{Flood} is calculated using statistical data on frequency of floods and, specifically, the parameter HQ_{500} that quantifies flood event frequency with a five-hundred-year return period (floods with a probability of 1 in 500). The flood-induced hazard/risk at the TMF location area is determined according to Table 4. The values and levels of HQ_{500} can be obtained from open sources, for example [19]; these maps have to be updated regularly regarding to climate changes.

Table 4: Evaluation of THI_{Flood}

Data for calculation of the THI_{Flood}	**Value of THI_{Flood}**
TMF location	
In the area of HQ_{500}	1
Beyond area of HQ_{500}	0

5th Step: Dam. The measure of dam failure hazard/risk (THI_{Dam}) can be calculated in two different ways.

1. *Preferred way.* If Factor of Safety (FoS) [20, 21, 22] is available for all facilities THI_{Dam} is calculated using the parameters of dam slope stability (FoS) and TMF age by the formula

$$THI_{Dam} = THI_{FoS} + THI_{Age} \quad (2.5)$$

where THI_{FoS} is the measure of hazard/risk due to slope instability evaluated according to Table 5; FoS has to be calculated already at the TMF design stage.

THI_{Age} is the measure of hazard/risk caused by the age of the dam.

2. *Alternative way.* If Factor of Safety is unavailable THI_{Dam} is calculated using the data on dam material, geometry and TMF age by the formula

$$THI_{Dam} = THI_{DamMaterial} + THI_{DamWidth} + THI_{Age} \quad (2.6)$$

where $THI_{DamMaterial}$ is the measure of hazard/risk related to dam embankment material;

$THI_{DamWidth}$ is measure of hazard/risk related to dam width.

Table 5: Evaluation of THI_{FoS} (preferable parameter)

Data for calculation of the THI_{FoS}	Value of THI_{FoS}
FoS range	
FoS > 1,5	0
1,2 < FoS ≤ 1,5	1
FoS ≤ 1,2	2

The dam failure hazard/risk is assumed to increase for aged facilities, which is evaluated according to Table 6.

Table 6: Evaluation of THI_{Age}

Data for calculation of the THI_{Age}	Value of THI_{Age}
TMF Age	
≤30 years	0
>30 years	1

For the alternative way (Eq. 2.6) the hazards/risks related to improper dam material $THI_{DamMaterial}$ and narrow/insufficient dam width $THI_{DamWidth}$ have to be evaluated by Tables 7 and 8.

The embankment constructed of a hard/blast rock is assumed to be more stable than the embankment of non-hard rocks or soils (earthen dams). In case if this material is unknown it can be identified by tensile strength at uniaxial compression σ_{DC}. For hard rocks σ_{DC} > 5 MPa, for non-hard rocks and soils $\sigma_{DC} \leq 5$ MPa.

Table 7: Evaluation of $THI_{DamMaterial}$ (alternative parameter)

Data for calculation of the $THI_{DamMaterial}$	**Value of $THI_{DamMaterial}$**
Embankment material	
Hard rocks	0
Non-hard rocks and soils	1

The dam is assumed more stable if the width of dam crest (and obviously, the dam basement) is sufficiently large to retain stored tails in the impoundment.

Table 8: Evaluation of $THI_{DamWidth}$ (alternative parameter)

Data for calculation of the $THI_{DamWidth}$	**Value of $THI_{DamWidth}$**
Dam crest width	
> 10 m	0
≤ 10 m	1

The capacity of the largest TMF in Europe ("Zelazny Most", Poland) is evaluated at roughly 500 millions m^3 [23]; "Reference Document on BAT… " [4] gives an example of the largest TMF capacity that contains 330 millions m^3 of tailings materials. Assuming the maximum capacity of a TMF is 1 billion m^3 and using Eq. A 2.3 and Table 1 yield 12 as the maximum value of the THI_{Basic}. Summing up this value and the maximum values of THI_{Manag}, THI_{Site}, and THI_{Dam} yields the maximum value of the $THI_{Extended}$ equal to 18.

The TMF data in different countries may be incomplete or uncertain. In this case, it should select the worst option in terms of hazard for the appropriate THI. For example, a TMF contains the waste of non-ferrous metal extraction but the exact composition of tailings materials is unknown. The value toxicity of materials should be evaluated at highest possible hazard, i.e. THI_{Tox}=3 (See Table 1).

The THI method can be used to create a country/region TMFs database and rank the TMFs according to their THI values. THI evaluation has to be followed by more detailed evaluation of the most hazardous individual TMFs using the TMF Checklist. The procedure of TMF Checklist application is described in Section 3.4 of the Methodology.

Chapter 3. TMF Checklist

Chapter 3.1 describes the hierarchy of the TMF Checklist and provides the rationale for the grouping of its questions, defines the purposes and intended users of all question groups. Section 3.2 provides detailed information on evaluation of the TMF safety level, using different approaches demonstrated with examples. Section 3.3 describes the structure of Measure Catalogue that lists actions to be prescribed in order to increase the TMF safety level. The order of Checklist application is described in Appendix 3.

The Excel file developed for Checklist application provides an automatic calculation of the relative TMF safety level using numerical analysis of the answers to the questions of Groups A, B and C. In addition, the Excel file also contains a Measure Catalogue, which allows automatic transition to recommended action(s) by choosing appropriate hyperlink(s) provided for each Checklist question. Thus, it is not required that Checklist users to remember or learn the formulae used for calculating the TMF safety level and all actions prescribed by Measure Catalogue. Users need only to correctly fill answers to Checklist questions and select one or more appropriate measures from the proposed list.

The template of TMF Checklist for the practical application developed in Excel format can be obtained by request from German Environment Agency, contact information for request: Mr. Gerhard Winkelmann-Oei, email: gerhard.winkelmann-oei@uba.de.

3.1 TMF Checklist Structure

The TMF Checklist (Appendix 2) includes three groups of questions called as follows:

- "Basic Check" (Group A);
- "Detailed Check" (Group B); and
- "Check of Inactive Sites" (Group C).

Each group includes two subgroups; the first subgroup is intended for visual inspection, the second subgroup is elaborated to work with documentation. Visual inspection is mandatory for all groups. Short descriptions of TMF Checklist groups see in Table 9 and Fig. 2.

Table 9: TMF Checklist question groups

Question group (number of questions)	Purpose	Data source	User*
Group A "Basic Check" (61) Preliminary and prompt evaluation of the safety level of TMFs aimed to prioritize the following detailed check			
Subgroup A1 "Basic Visual Inspection» (26)	Preliminary and prompt visual evaluation of the TMF safety level	Visual inspection, interview with TMF staff	State competent authorities
Subgroup A2 "Basic Document Check" (35)	Preliminary and prompt documentary evaluation of the TMF safety level	Available operator's documentation	State competent authorities
Group B "Detailed Check" (304) Comprehensive and de-tailed evaluation of the TMF safety level aimed to identify the need for tak-ing measures			
Subgroup B1 "Detailed Visual Inspection" (37)	Detailed visual evaluation of the TMF safety level	Visual inspection, interview with TMF staff	State inspectors and TMF operators
Subgroup B2 "Detailed Document Check" (267)	Detailed documentary evaluation of the TMF safety level	Available operator's documentation and additional studies and tests clarifying all TMF parameters, with involvement of external experts	State inspectors and TMF operators
Group C "Check of Inactive Sites" (61) Evaluation of the safety level of an inactive TMF aimed to identify the need for taking measures			
Subgroup C1 "Visual Inspection of Inactive Sites" (37)	Visual evaluation of the safety level of an inactive TMF	Visual inspection, interview with TMF staff	State inspectors and TMF operators
Subgroup C2 "Document Check of Inactive Sites" (24)	Documentary evaluation of the safety level of an inactive TMF	Available operator's documentation and additional studies and tests clarifying all TMF parameters, with involvement of external experts	State inspectors and TMF operators

* State competent authorities and TMF operators can involve independent auditors into the process of checking and evaluating the safety level of TMF.

The **"Basic Check"** group **(Group A)** is intended for use by state competent authorities. The "Basic Check" group of questions includes the subgroups "Basic Visual Inspection" (A1) and "Basic Document Check" (A2). The evaluation can be performed based on the analysis of available operator's documentation and site visit results within a short period.

The tasks of the "Basic Check" group (**Group A**) comprise:

- General assessment of the safety level of a large number of TMFs;
- Determination of the need for more detailed evaluation to be performed using "Detailed Check" group (Group B).

The **"Basic Visual Inspection"** subgroup **(Subgroup A1)** is intended for use during the visit to the TMF evaluated; it includes the questions that can be answered or clarified on the TMF site only. The subgroup A2 can be used separately in case of the absence of TMF documentation.

The "Basic Document Check" subgroup **(Subgroup A2)** includes the questions related to documentation selected to preliminarily and promptly evaluation how applicable safety requirements are adhered to among the majority of country's TMFs. Detailed description of the evaluation method used in subgroup A2 is given in Section 3.2.

The applying of subgroups A1 and A2 together is preferably for TMF Checklist users for complete and reliable evaluation of the TMF safety level. Cancelling of visual inspection should be justified by the Checklist user and is allowed only if the Checklist user does not have sufficient time and resources for visiting the TMF site.

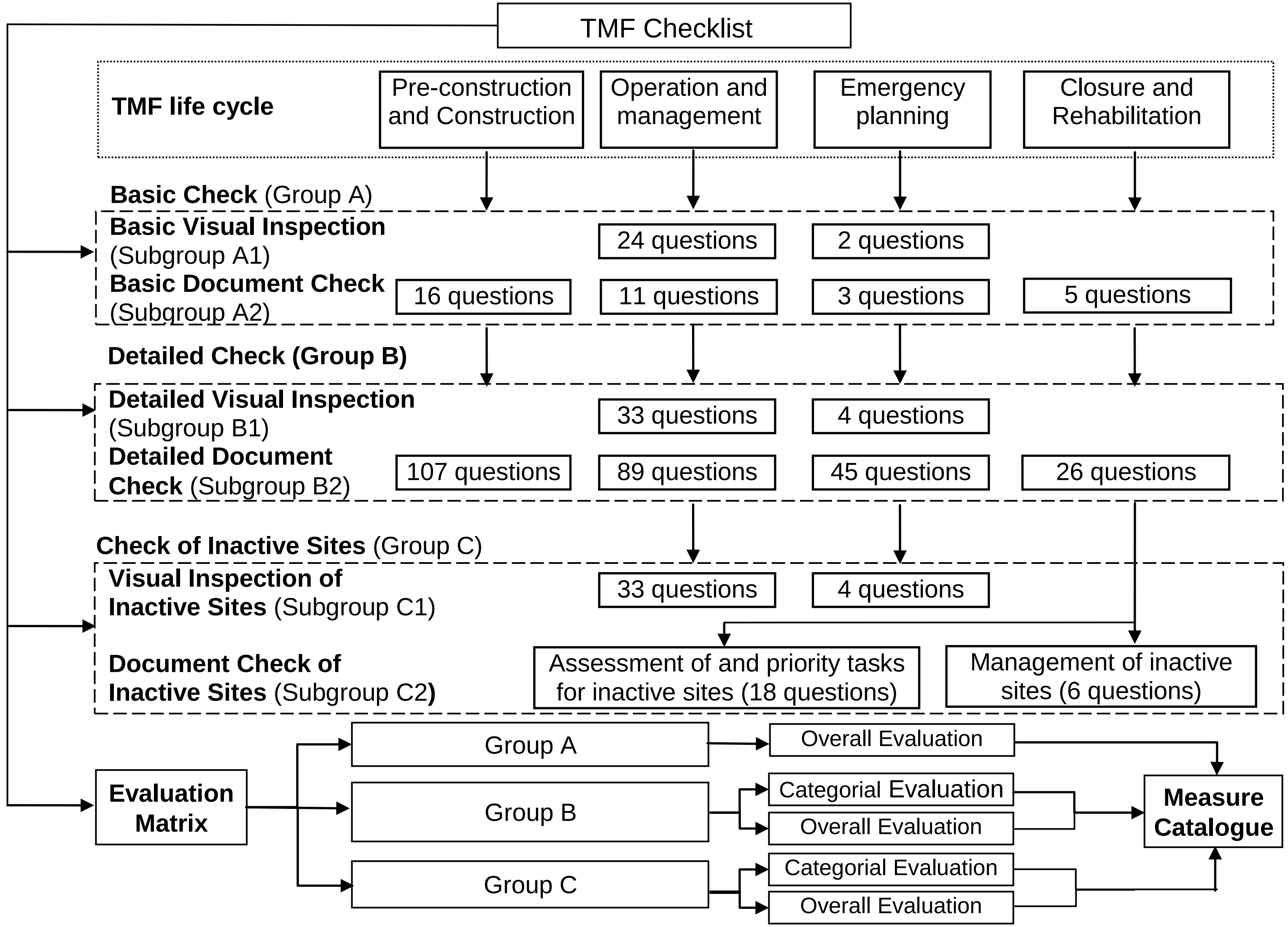
The **"Detailed Check"** group **(Group B)** is intended for use by state inspectors and TMF operators in order to evaluate the safety level of individual TMF. The "Detailed Check" group includes the subgroups **"Detailed Visual Inspection" (Subgroup B1)** and **"Detailed Document Check" (Subgroup B2)**.

Evaluation can be performed based on the analysis of available design information and operator records, reinforced with additional studies and tests clarifying all TMF parameters performed by external experts if required and using information received during site visit to the TMF company and interviewing TMF staff.

The tasks of the "Detailed Check" group comprise:

- assessment of all TMF systems and technical components;
- assessment of all risks/hazards, impacts and potential impacts, linked with TMF construction, operation, closure, and rehabilitation;
- and determination of the needs and priorities for taking short-, medium, and long-term measures aiming to improve the TMF safety level.

Figure 2: TMF Checklist structure



The safety evaluation within the "Detailed Check" group requires engagement of appropriate external bodies, with proven professional technical expertise, to assess and to test technical implementation of the executed measures. A Measure Catalogue is attached to "Detailed Check" group.

Thorough and comprehensive analysis of TMF safety is made through the assessment of the answers to the questions of Group B using specific categories described in Section 3.2.3 of the Methodology. The "Detailed Check" Group is intended for use after the site visit and implies paperwork and work on computer by filling the TMF Checklist in MS Excel file. The user fills in the answer cells of Group B and adds the necessary proofs and documentation. Based on this information submitted, the authorities can make the counter check if required.

The Group B should be used by experienced inspectors and personnel; it can be used for advanced trainings. It is recommended to use the Group B, primarily, for unsafe TMFs, while changing regulatory requirements, implementing technical process or construction upgrading, or when assessing after-effects of accidents occurred at similar facilities.

The group **"Check of Inactive Sites"** (**Group C**) is intended for evaluation of non-active TMFs including also those abandoned and orphaned (See Terminology). Its tasks comprise:

- assessment of inactive sites and inspection priorities;
- improvement of management at inactive sites.

The Group C includes the subgroups **"Visual Inspection of Inactive Sites" (Subgroup C1)** and **"Document Check of Inactive Sites" (Subgroup C2)**. Visual inspection of inactive TMF sites is mandatory.

A tabular approach for formatting the TMF Checklist has been applied in spreadsheets (Excel format) with colour highlighting of column headings and different questions. This is intended to facilitate easier processing of the data and the evaluation procedure[2]. The Checklist user should specify the grounds for accepting the selected answer in the column "Data sources"; this has to be performed in the form of (a) provision of requisite documents and/or, (b) photographs, as evidences supporting the answer/response provided.

3.2 TMF Safety Evaluation

This section presents a detailed description of all calculation procedures applied in the Checklist for evaluating the TMF safety level. The Checklist user is provided by a Checklist template in MS Excel with all necessary formulae embedded that automatically calculate the TMF safety level in compliance with the procedures outlined below. The file can be obtained by request from German Environment Agency, contact information for request: Mr. Gerhard Winkelmann-Oei, email: gerhard.winkelmann-oei@uba.de. For more information how to fill the TMF Checklist using the template in Excel format see Appendix 3.

3.2.1 General approach

Evaluation of the TMF safety level within the Checklist is performed with the Evaluation Matrix (EM), which is the matrix of numerical values of answers to the Checklist questions. The matrix elements are calculated by special procedures depending on the scope of the check. Thus, the Checklist EM includes different evaluation matrices for the Groups A, B, and C.

The safety level of an individual TMF is evaluated by the following Evaluation Matrices for three groups of the TMF Checklist:

- Evaluation Matrix for Group A as **Overall Basic Evaluation of the TMF safety level**

2 All tables contain the column "Reference to Safety Guidelines…" specifying the page number and relevant clauses in the document "Safety guidelines…" [12].

- Evaluation Matrix for Groups B and C as **Overall Detailed Evaluation of the TMF safety level**
- Evaluation Matrix for Groups B and C as **Categorial Evaluation of the TMF safety level**

The overall evaluation of the TMF safety level summarizes the numerical contributions of all answers to Checklist questions. The overall safety level calculated by Group A ranks the priority of further detailed check of the TMFs. The overall safety level calculated by Group B and C identifies the TMF state and quantifies the priority of recommended interventions and remedial actions (Section 3.2.2).

The categorial evaluation is additional to the overall evaluation for Groups B and C, and demonstrates the TMF safety in different aspects and details of TMF performance and conditions (Section 3.2.3).

All answers to Checklist questions of Groups A, B and C are unified. There are four alternative options.

1. “Yes” is applied if a Checklist user has enough data or information to give the positive answer.
2. “No” is applied if a Checklist user has enough data or information to give the negative answer or does not have any information to answer the question.
3. “Mostly yes” is applied if a Checklist user does not have enough data or information to give the definitive answer (“yes” or “no”) but the user has more arguments to accept the positive answer “yes” rather than “no”.
4. “Mostly no” is applied if a Checklist user does not have enough data or information to give the definitive answer (“yes” or “no”) but the user has more arguments to accept the negative answer “no” rather than “yes”.

Each answer to questions of the TMF Checklist is quantified (Table 10). Each question in Groups A, B, and C is formulated in such a way that the positive answer “yes” is interpreted as the maximum level of TMF safety per the evaluated factor; the negative answer “no” is considered as the minimum level of TMF safety per the evaluated factor. The ambiguous answers “mostly yes” and “mostly no” allow the Checklist user to be flexible in evaluations taking into account availability and credibility of data sources.

The overall evaluation of the TMF safety level is quantified by two ranks “Meeting Safety Requirements” (MSR) and “Credibility”.

“MSR” rank within the TMF Checklist is the index quantifying how many parameters of components and characteristics of the inspected TMF meet the minimum set of requirements of environmental and industrial safety.

“Credibility” rank within the TMF Checklist is the index quantifying the sufficiency and consistency of data used for calculating the “MSR” rank.

Table 10: The values of answers to Checklist questions of Groups A, B, and C

Answer	Yes	Mostly yes	Mostly no	No
Value	3	2	1	0

3.2.2 Overall evaluation

The overall evaluation of the TMF safety level is applicable to the Groups A, B, and C of the TMF Checklist.

“MSR” rank is calculated by summing up the values of quantitative answers (Table 10).

$$MSR = 100\% \cdot \frac{1}{3N} \sum_{i=1}^{N} r_i \qquad (2.7)$$

where r_i is a quantitative value of an i-th answer;

N is the total number of questions in the evaluated Checklist group.

The maximum sum of all answer values equals $3N$.

"Credibility" rank is calculated by summing up the values of definitive answers ("yes" or "no") divided by the total number of answers

$$Credibility = 100\% \frac{1}{N}\sum_{i=1}^{N} S_i \tag{2.8}$$

where s_i = 1, if answer is "yes" or "no"

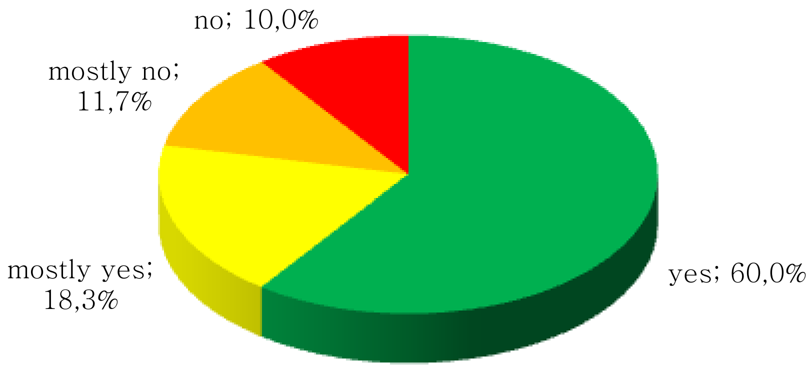
s_i = 0, if answer is "mostly yes" or "mostly no"

N is the total number of questions of the evaluated Checklist group.

Answering negatively ("no") to all questions makes this rank value equal to 0%. If an ambiguous answer "mostly yes" or "mostly no" is given to some (but not all) questions, then the value of the "Credibility" rank will be greater than 0% and less than 100%.

The total result of all answers to Checklist questions is also visualized by the circle chart that shows the shares of specific answers (Fig. 3). This provides for clearer demonstration of the share of definitive answers ("yes" and "no") and ambiguous answers ("mostly yes" and "mostly no"); besides, this helps to better understand the state (conditions) of the inspected TMF.

Figure 3: Percentage shares of the answers given at the evaluation of the TMF safety level (an example to Group A)



The more definitive answers are received, the higher the "Credibility" rank becomes; thus, ambiguous answers to Checklist questions decrease this rank value. Answering either only positively or only negatively to all Checklist questions makes the value of the rank "Credibility" equal to 100%, although the "MSR" rank value will be different for that cases (100% and 0%, respectively). If all answers are ambiguous ("mostly yes" or "mostly no") the value of the "Credibility" rank will be 0%. In fact, the "Credibility" value less than 100% means that there are no reliable data for answering to some Checklist questions.

The overall evaluation quantifies the TMF safety level taking into account the reliability of the answers by coupling the ranks "MSR" and "Credibility". For clarity, the graphical representation of evaluation results includes two axes; they are called "MSR" and "Credibility". The overall evaluation result can be graphically represented as a point in the two-dimensional chart in the range from 0 to 100% on both axes.

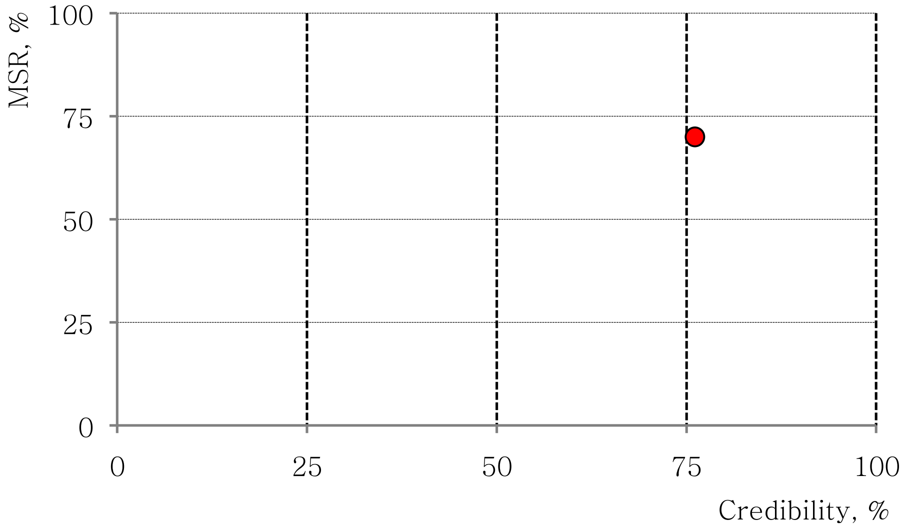
Answering positively ("yes") to all questions of any Checklist Group makes the values of its "MSR" and "Credibility" ranks equal to 100%.

Example. The Group A of the TMF Checklist includes 61 questions in two subgroups. Let us suggest, that number of applicable questions N = 60, 36 questions are answered "yes", 10 questions are answered "mostly yes", 8 questions are answered "mostly no", and 6 questions are answered "no" as a result of evaluating the TMF. Then the values of "MSR" and "Credibility" ranks will be

$$MSR = 100\% \cdot \frac{1}{3 \cdot 60}(36 \cdot 3 + 10 \cdot 2 + 8 \cdot 1 + 6 \cdot 0) = 100\%\frac{136}{180} = 76\%$$

$$Credibility = 100\% \cdot \frac{1}{60}(60 - 18) = 100\%\frac{42}{60} = 70\%$$

Figure 4: Graphical interpretation of the evaluated TMF safety level



The overall result is shown by the marker (an example to Group A)

3.2.3 The categorial evaluation

The categorial evaluation of the TMF safety level is additional to the overall evaluation and applicable to the Groups B and C of the TMF Checklist.

Evaluation of the TMF safety level using the questions of the Group "Detailed Check" is based on independent evaluation of the question subsets of this Group called by categories. These categories listed in Table 11 cover all major aspects of TMF performance and site conditions. Each question can relate to only one of 12 categories; thus, the total number of questions of all categories equals the total number of questions in the Group B. The Croup C includes the questions belonging to 11 categories.

Categorial evaluation of the TMF safety level is performed by calculation of the "MSR" rank for all categories of Group B or C separately.

The absolute value of the "MSR" rank for *i*-th category (*i*=1, ..., 12) S_i is calculated by summing up the values of the answers given to the evaluated category questions.

$$S_i = \sum_{j=1}^{N_i} r_j \qquad (2.9)$$

where r_j is a quantitative value of an *j*-th answer defined according to Table 10,

N_i is the total number of questions of the *i*-th category.

The value of the rank “MSR” in per cents for each category is calculated as follows

$$MSR_i = 100\% \cdot \frac{S_i}{3N_i} \tag{2.10}$$

where MSR_i is the “MSR” rank value in per cents for i-th category;

N_i is the total number of questions of the i-th category.

The maximum sum of all answer values equals to $3N_i$.

Table 11: Categories of TMF performance and conditions (Groups B and C)

No	Category	Abbreviation	Number of questions	
			Group B	Group C
I	Geological, climate, and terrain risks	GCR	19	1
II	TMF Deposition Plan	TDP	16	5
III	Substances (Tailings Capacity, Toxicity)	STC	23	3
IV	Dam and screens	DSC	32	8
V	Transportation and infrastructure	TRI	9	0
VI	Water management	WTM	28	9
VII	Environment Impact Assessment	EIA	21	8
VIII	Emergency Plan	EMP	49	8
IX	Monitoring	MON	33	11
X	Training and personnel	TRP	18	1
XI	Inspection and reporting	INR	29	6
XII	Closure and rehabilitation strategy	CRS	27	1
Total			**304**	**61**

The values of the “MSR” rank are used for creating a polar diagram (spider diagram) automatically plotted in the Excel file. The diagram enables revealing the most problematic issues and aspects of TMF performance that need urgent improvement or rectification. The “MSR” rank for the whole TMF is calculated as the arithmetical mean value of “MSR” ranks per all 12 categories.

The rank “Credibility” in the Groups B and C is calculated by Eq. A 2.8 in a similar manner as for the Group A, taking into account the difference of the number of questions for the groups. The principle of independent evaluation of different categories is the significant advantage of the evaluation procedure. In case of Checklist modification by adding new questions to or removing some questions from any category will not change the evaluation results for other categories.

To prioritize the measures for improvement of the safety level of the checked TMF the categories listed in Table 11 are subdivided onto “critical” and “non-critical” ones (Table 12).

Critical (Highly important) safety categories are the categories of TMF safety that cover, primarily, the technical aspects of TMF operation and are vitally important for maintaining tailings facilities in safe condition. Detection of non-compliances with safety requirements in these categories will require mandatorily taking certain technical measures on-site prescribed by the Measure Catalogue.

Non-critical (Important) safety categories cover the issues related mostly to documentation, personnel, and paperwork. Detecting non-compliances with safety requirements in these categories will not require taking technical measures on-site; only paperwork or expert assessments will be required.

Table 12: Priority of TMF categories for TMF safety

No	Category	Priority for TMF safety
I	Geological, climate, and terrain risks	Non-critical
II	TMF Deposition Plan	Non-critical
III	Substances (Tailings Capacity, Toxicity)	Critical
IV	Dam and screens	Critical
V	Transportation and infrastructure	Critical
VI	Water management	Critical
VII	Environment Impact Assessment	Critical
VIII	Emergency Plan	Critical
IX	Monitoring	Critical
X	Training and personnel	Critical
XI	Inspection and reporting	Non-critical
XII	Closure and rehabilitation strategy	Non-critical

The conclusion on the TMF safety level is drawn using Table 13. This scale prioritizes not only the TMF Checklist categories but also relevant safety measures to be taken for improving TMF safety (See Section 3.3). This scale enforces the user to start improving the TMF safety level from technical measures related to critical categories instead of doing paperwork. Besides, this scale allows identifying the progress in TMF safety as a result of measures taken till 100% of minimum set of requirements will be met.

Table 13: Identification of TMF safety level after evaluation by Group B and C

TMF safety level	Criteria
Acceptable	100% of minimum set of safety requirements are met (MSR = 100%)
Unacceptable	Less than 100% of minimum set of safety requirements are met (MSR < 100%)
Accidental condition	At least five critical questions* related to visual inspection are anwered “no” or the TMF operator deliberately prevents from inspection of the TMF or its parts

* Critical questions are the questions of Subgroup B2 “Detailed visual inspection” that directly relate to operational TMF safety (drainage facilities, dam safety, neutralization of hazardous substances, monitoring); they include the questions nr. 6, 7, 8, 9, 10, 11, 15, 16, 18, 19, 21, 22, 23, 24, 26, 28, 35.

In case if TMF safety level is evaluated as “Unacceptable” the inspector(s) has (have) to develop an Investment program for improving TMF safety based on the approproate measures lested in Measure Catalogue and send it together with the report to the competent authorities and the TMF operator.

In case if TMF safety level is evaluated as “Accidental condition” the inspector(s) has (have) to submit the report to the competent authrities with the request to urgently made a dicision about TMF operation including its cessation and immediate measures from Emergency plan and Measure Catalogue regarding the national legislation in this field.

The example of the safety level evaluation for a hypothetic active TMF using the Group B (Detailed Check) is shown in Table 14 and Figure 5.

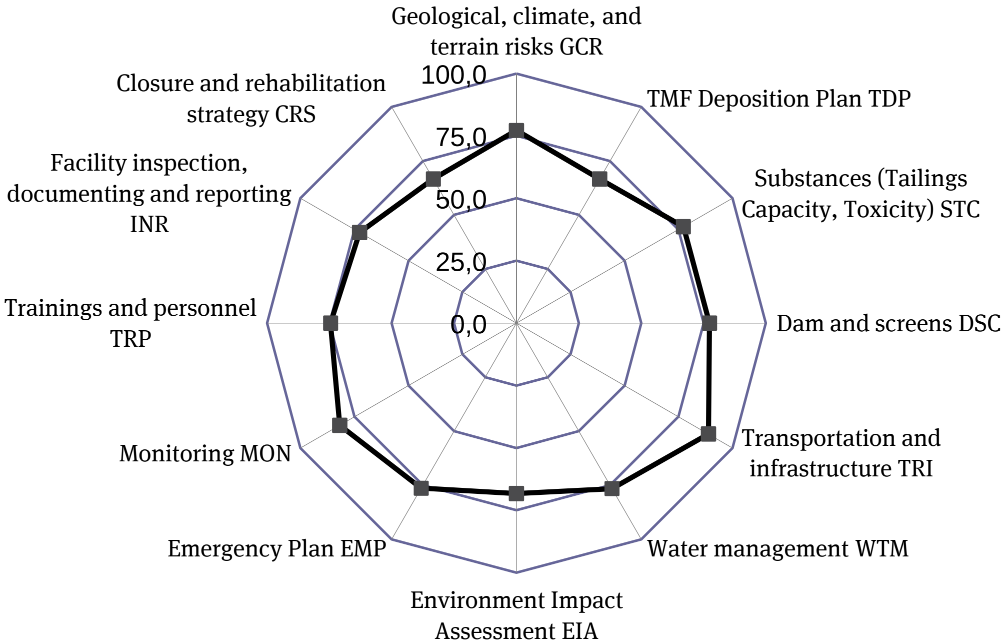
Table 14: Example of categorial evaluation of the TMF safety level by Group B

Category	Total number of questions	Maximum value*, score	Evaluation result, score	Evaluation result, %
Geological, climate, and terrain risks	19	57	44	77.2
TMF Deposition Plan	16	45	30	66.7
Substances (Tailings Capacity, Toxicity)	23	66	51	77.3
Dam and screens	32	93	72	77.4
Transportation and infrastructure	9	27	24	88.9
Water management	28	81	62	76.5
Environment Impact Assessment	21	63	43	68.3
Emergency Plan	49	144	110	76.4
Monitoring	33	99	81	81.8
Training and personnel	18	51	41	80.4
Inspection and reporting	29	84	61	72.6
Closure and rehabilitation strategy	27	72	51	70.8

*Maximum value was calculated taking into account the number of applicable questions

For the given example, the "MSR" rank for all categories equals 75.7%; and the "Credibility" rank equals 74.5%, which means that this TMF needs an improvement of the safety level. The user's attention and priority measures should be focused on the lowest percentage categories.

Figure 5: Spider diagram to the example of categorial evaluation. The values of all categories are in percents



The MSR rank for critical categories MSR_{crit} = 78.4%, the MSR rank for non-critical categories $MSR_{non-crit}$ = 71.8%. According to the criteria in Table 13 this TMF safety level is identified as “Unacceptable”.

3.3 Measure Catalogue

The Measure Catalogue (see Appendix 3) includes the list of actions to be taken in the case that partial or full non-compliances of TMF conditions to actual safety requirements or regulations have been established. Experts should determine the appropriate action(s) for each problem detected at the TMF.

The Measure Catalogue is based on the world experience in sustainable mining and environmental rehabilitation, modern and advanced safety standards [11]. The list of measures has to be updated permanently regarding the advances and recent successful applications.

The measures cover all phases of TMF life-cycle and are grouped in such a way to solve specific problems (non-compliances) detected during TMF evaluation; the measures are specified according to their priorities that depends on time limits recommended and the question category (Table 11).

“Detected problem” is clearly and briefly formulated non-compliance between applicable safety requirements and the actual state of TMF components or TMF performance. Each question of the Group B or C refers to a certain problem in the Measure Catalogue, to which some solutions are proposed; this way facilitates selection of appropriate measures by Checklist users.

“Measures prescribed” are one or more actions aimed to improve the TMF safety level. There can be several measures proposed to solve or mitigate the same problem. The user task is to select those most appropriate for the specific case taking into account TMF and site specific features.

Each measure is specified by a number of the problem detected and added by a capital letter in the measure list, such as 3A, 21D, etc. For instance, to cope with the problem No 4 “Natural and man-made risks were not taken into account in accident scenarios” four kind of measures can be proposed that are numbered as follows.

4A “Perform the study for each possible accident scenarios and their after-effects”;

4B “Assess possible local, geological, and climate risks related to the TMF”;

4C “Assess possible man-made risks related to the TMF”;

4D “Assess the impact of the TMF on the environment and health of population”.

“Priority” is dependent on the urgency and costs of prescribed action(s) and can be defined as short-, mid-, and long-term. These measures are classified in Table 15.

The Checklist user should also distinguish short-term measures and Emergency plan actions; the latter are defined separately and should be agreed with local departments of the state emergency service.

Table 15: General classification of measures

Duration	Aim and standards applicable	Resources	Recommended terms*
Short-term measures	Urgently reconcile inconsistencies with safety requirements at the TMF according to national** technical standards	Available resources of the TMF operator sufficient to provide low-cost measures or actions	To be completed no later than 3 months after prescription
Mid-term measures	Reconcile the inconsistencies with safety requirements that need some months for geotechnical or technological implementation according to national / international technical standards	Available resources of the TMF operator and external sources; the measures have to be justified by "cost-effectiveness" criteria	To be completed no later than 1 year after prescription
Long-term measures	Technical transformation of the inspected TMF to meet the safety requirements or recommendations regarding the implementation of modern international standards for industrial and environmental safety	Available resources of the TMF operator and external sources including governmental sources; the measures have to be justified by "cost-effectiveness" criteria	To be completed no later than 5 years after prescription

* This limitation can be changed in case of emergencies, accidents and for other important reasons.

** International standards are applied if no national standards to a specific issue are available.

Long-term measures are mostly applicable to Closure and Rehabilitation stages of the TMF life-cycle.

Information how to use Checklist provided in the Appendix 3.

Chapter 4. Evaluation procedure and Reporting

The procedure of the TMF safety level evaluation using the TMF Checklist is mainly based on standard inspection procedures prescribed in the International Standard ISO 19011:2011 – Guidelines for auditing management systems [7]. This section briefly describes the TMF evaluation workflow and describes the minimal set of working steps to be completed. Regarding to the site specifics the procedure could be modified/supplemented if necessary.

TMF safety level evaluation involves the following working steps:

1. Elaboration of the TMF Evaluation Program
2. Familiarization with the TMF
3. Visiting the TMF site
4. Reporting on evaluation results

4.1 TMF Evaluation Program

Primarily, the TMF Checklist user should develop a "Program of the TMF evaluation". The Program should cover all working steps resulting in the evaluation of the TMF safety level.

Table 16: Template "Program of the TMF evaluation"

"Program of the TMF evaluation" using the TMF Checklist		
Name of the evaluation site/object:		
Site location (address and GIS coordinates):		
User Name (inspector / auditor):		
Period of evaluation: dd-mm-yyyy – dd-mm-yyyy		
No	**Stage of the TMF evaluation procedure**	**Terms (depend on the evaluated object)**
1	Preparation of the "Request for general information about evaluation object (company and TMF)" (refer to the Template in the Section 4.2 below)	1 day
2	Elaboration and sending the "Site-visit Plan" (see the template in the Section 4.3)	5 days
3	Site-visit to the object	1-2 days
4	TMF evaluation using the TMF Checklist (MS Excel file) including the study of the documents and information received during previous stages	10-20 days
5.	Sending the additional request for TMF documents (if needed)	1-2 days
6.	Preparation of a report in MS Word (see the template in the Section 4.4 below)	5 days
		Date of Program preparation: dd-mm-yyyy

4.2 Familiarization with the TMF

Prior to start applying the TMF Checklist the user has to be familiar with the company and the TMF being evaluated. For this reason it is necessary to make a list of general information required for TMF safety level evaluation. The list should be sent to the TMF operator as a request to obtain general information as **a brief summary** of the TMF being evaluated. The list should include the type of information on the categories indicated in the Table 17.

Table 17: Template "Request for general information about the evaluation object (company and TMF)"

No	Requested information (categories)	Information provided by the TMF operator (charts, maps should be provided separately as annexes)
1	Technical information and design documentation: flowcharts, description of the production process used at the enterprise, specification of input raw materials, chemical and physical composition of tails, etc.	
2	Geographical site information: climate conditions, including weather extremes, wind speed, precipitation, and floods	
3	TMF Deposition Plan: maps, schemes, cadastral borders, adjacent infrastructures	
4	Geological and hydrogeological conditions: seismic activity, landslides, faults, karst areas, soil properties, groundwater regime, etc.	
5	Ecological environment: flora, fauna, water and land ecosystems	
6	Social environment: location, condition and size of communities and settlements; land use, access to the TMF territory	
7	Risks to: surface water bodies, groundwater, air, soils, and biota	
8	Stored material: hazardous substances and materials stored in the TMF	
9	TMF history: construction and operation periods, contractor(s), accidents occurred.	
10	TMF management: bodies/persons responsible for TMF operation/maintenance	

If any part of this information is not provided without written justification of TMF operator managers, the inspector should assume the worst case scenario and evaluate the TMF safety level as „Accidental conditions" (Table 17) due to lack of necessary data. The inspector has to submit the appropriate report to the competent authorities drawing their attention to the following likely situations

1) the TMF site has been preliminary evaluated to have accident hazard, therefore a detailed investigation is urgently needed;
2) the recommended detailed investigations cannot be performed because of the operator's resistance and refuse to cooperate,
3) the real danger of an accident event with possible dramatic consequences due to potentially missing safety measures exists.

The inspection report has to be considered urgently and followed by taking immediate actions as described in Subsection 3.2.3.

4.3 Visiting the TMF site

Visiting the company for evaluation of TMF safety should be carried out according to a "Site-visit Plan" that includes working steps using the TMF Checklist Methodology.

Preparatory works for the visit to the TMF site include the following steps.

- Studying the "Brief summary of TMF company" provided by the TMF operator;
- Elaboration of the "Site-visit Plan" including the "Work plan on the site" and a preliminary list of documents requested for evaluation; and

- Sending the "Site-visit Plan" to company managers.

Using drones with high-resolution cameras, photo shooting, and appropriate remote control equipment is strongly recommended for visual inspection of hard-to-reach parts of the TMF critical to its safety. The recorded video and pictures should be interpreted later on and used as evidences in evaluation of visual inspection results.

The template of "Site-visit Plan" is given below.

______________________________Begin of the Template of "Site-visit Plan"____________________________

Site-visit Plan

Name of the site(s) / object(s):

Site location (the address and GIS coordinates):

Date of the Site-visit: from dd-mm-yyyy to dd-mm-yyyy.

Objective(s) for the Site-visit:

Name of inspecting Party:		
No	**Name of inspector/auditor**	**Position**
1		

Name of the host Party:			
No	**Position**	**Name**	**Phone, e-mail**
1	Representative of senior management		
2	Representative of Metrological Service (Chief Metrology)		
3	Representative of technological service		
4	Representative of power services (chief power engineer)		
5	Representative of the environmental services (incl. waste management department)		
6	Representative of a management staff responsible for staff training		

Work plan on the site

Time	**Activities**
Date: dd-mm-yyyy	
time - time	Arrival of inspectors / auditors at the site
time - time	Introductory meeting. Presentation of the objective and tasks. Organizational issues. Agenda of the introductory meeting is attached
time - time	Obtaining documentation, working with documents, selection of documents for the further detailed study (copying and photographing)
time - time	Lunch break
time - time	Visual inspection (Walkover survey) of the TMF (copying and photographing documents and facilities on the site)

time - time	Summary and closing remarks
Date: dd-mm-yyyy	
time - time	Visual inspection (Walkover survey) of the TMF (copying and photographing documents, and facilities on the site)
time - time	Lunch break
time - time	Obtaining of additional documentation, if necessary. Discussion of the site-visit results
time - time	Departure the group of inspectors / auditors

Topics to be discussed

1. Introduction of the Group of inspectors / auditors.
2. Presentation of the inspection process:

- the objective and tasks;
- evaluation criteria; methods;
- the audit scope;
- the format of expected results and conclusions.

1. Introduction of the responsible persons of the host party.
2. Brief summary of the company/TMF.
3. Interviewing representatives of different company departments and services.
4. List of major issues to be discussed: …

Provisional list of documents required for evaluation

Title of the documents (below are examples)	Comments
Project Design Document (PDD)	
Environmental impact assessment (EIA)	
Reporting on monitoring the ecological aspects	
Certificates of qualification and staff trainings	
Management documents	

Name of the team leader of the inspecting group_____signature______date___

________________________________End of the Template of "Site-visit Plan"______________________________

If the inspection is actively prohibited by the operator through the prevention from interviewing the TMF personnel, groundless denial of access to inspect any of TMF parts, especially those critical for safety, prohibition against using remote checking like drones (if this allowed by actual national regulations), the inspector has to suspect a serious problem which could result in a dramatic failure or catastrophe. In this case the inspector should assume the worst case scenario and evaluate the TMF safety level as „Accidental conditions" (Table 17) due to lack of necessary data. The inspector has to submit the appropriate report to the competent authorities drawing their attention to the situations described above (see Subsection 4.2). The inspection report has to be considered urgently and followed by taking immediate actions as described in Subsection 3.2.3.

4.4 Reporting on evaluation results

Based on evaluation results obtained after filling the TMF Checklist in MS Excel file (see Annex 3), the user should report on the works performed using the template in the MS Word file.

Content of the "Report on Evaluation of the TMF safety level"

Recommendations to fill each section of the Report are described in details in Table 18.

Table 18: Recommendations to generate the "Report on Evaluation of the TMF safety level"

Section of the Report	Recommendations
Introduction	This section should include the description of the objective and tasks of evaluation to be performed. See below a brief example for filling this section. The evaluation objective is to improve the TMF safety level through the examination of minimum set of the TMF technical safety requirements (applying the TMF Checklist) and developing recommended technical measures for implementing of international standards for the safe operation of TMFs (using the Measure Catalogue). The main evaluation tasks to be implemented were: ► to detect non-compliances with minimum set of the safety requirements at the TMF applying the TMF Checklist; ► to identify the troublesome spots/areas of the evaluation object; ► to select appropriate technical measures for implementing of international standards for the safe operation of TMFs from Measure Catalogue
Evaluation procedure	This section should list all user actions and preparatory works consistently outlined within the framework of the evaluation procedure as the following mandatory steps: Elaboration of the TMF Evaluation Program. Familiarization with the TMF: elaboration and sending out the list of general information required for TMF safety level evaluation; receiving the "Brief summary of TMF company". Visiting the TMF site. Preparatory works for the visit to the TMF site include the following steps: ► studying the "Brief summary of TMF company" provided by the TMF operator; ► elaboration of the "Site-visit Plan" including the "Work plan on the site" and a preliminary list of documents requested for evaluation; and ► sending the "Site-visit Plan" to company managers. ► The site-visit includes the following sequence of activities: ► introductory meeting; ► interviewing the staff; ► receiving, reviewing and studying of documents; ► visual inspection of the TMF (photographing); ► taking notes on the information received after inspection; ► holding a concluding meeting. 4. Reporting on evaluation results: ► work on the TMF Checklist: filling the Checklist in the MS Excel file (Groups A or B or C) on the base of the documents and information of the company (inter-viewing, photos), selection of the measures for improving the TMF safety level; ► generating the final report in MS Word
1. TMF Evaluation Program	This section should include the "Program of the TMF evaluation" that was developed and sent to the TMF company
2. Familiarization with the TMF	This section should contain 10 categories listed in the "Request for general information about the evaluation object (company and TMF)" (see Section 4.2). The brief example of introductory text is indicated below. Prior to the start of the TMF Checklist applying user has familiarized with the evaluation object (company and TMF). For these purposes a list of general information required for TMF safety level evaluation was developed. The list was sent to the TMF operator as a request to obtain required information as a brief summary of the TMF company being

Section of the Report	Recommendations
	evaluated. In response to this request the "Brief summary of TMF company" has been received on dd-mm-yyyy, which is outlined below
3. Visiting the TMF site	See the brief example of filling this section below. The inspector has developed and sent "Site visit plan" to the company on dd-mm-yyyy. The Site visit took place on dd-mm-yyyy according to "Site visit plan", holding to the proposed time schedule and sequence of activities, namely: ► introductory meeting; ► interviewing the staff; ► receiving, reviewing and studying of documents; ► visual inspection of the TMF (photographing); ► taking notes on the information received after inspection; ► holding a concluding meeting. All planned preparatory works under the "Program of the TMF evaluation" have been accomplished; by that result the inspector proceeded to the stage "TMF Checklist application"
4. Evaluation results and recommended measures	Evaluation can be reported like a brief example below. Upon receiving all necessary information (site documents, staff interviews, and photographs), after the site visit the inspector proceeded to the office work to evaluate the TMF safety level using the TMF Checklist. The inspector has applied the following sequence for evaluation: Filling the TMF Checklist in the MS Excel file (Groups A or B or C) on the base of documents and TMF company information (interviewing, photos) in order to evaluate the TMF safety level and select the measures to improve TMF safety level. Upon filling the TMF Checklist in MS Excel the inspector has generated this Report on the work performed and the results obtained, drawn the conclusions and outlined plans for further actions to improve the safety at the TMF site. The results of TMF Checklist application obtained in MS Excel should be reported in the following way: Evaluation results: Copy the page from the Excel file with the evaluated TMF safety level and paste a chart in the section; Recommended actions: Copy each TMF Checklist question answered not positively (answers "no", "mostly no", or "mostly yes"), and recommend the relevant measure(s). Therefore, this section will summarize the result of TMF safety level evaluation, describe troublesome spots/areas and recommend measures to eliminate the problems detected
Conclusions	Section "Conclusions" should describe: ► the troublesome spots/areas detected as a result of evaluation; ► all the decisions on further actions required to implement the recommended measures (timing, resources, efforts); ► the procedure for controlling over the actions/measures to be implemented (responsible persons, timing)
References	Two lists of documents have to be cited: 1. Regulatory documents including international and national documents as the criteria for the user evaluating the object. 2. Company documents used for evaluation of the TMF safety level

Chapter 5. Recommendations to users

This Chapter provides the users by three types of recommendations that can facilitate effective use of the TMF Checklist. The recommendations are briefly described in Table 19 and more detailed in Sections 5.1 – 5.3.

Table 19: Recommendations to users of the TMF Checklist

No	Scope	Contents	Application	Users
1	Education and training of inspectors	Rules and recommendations on training the inspectors checking TMF	Education of personnel responsible for inspecting TMF sites	State competent authorities
2	Facility inspections	Rules and recommendations on the verification of TMF condition during all phases of life-cycle	Check and verification of TMF conditions and safety	State competent authorities
3	Performance of TMF on-site monitoring	Basic parameters of geotechnical and environmental monitoring at the TMF site	Internal routine check of the TMF site	TMF operators

The document “Safety Guidelines and good practices for tailings management facilities” is the data source for the recommendations No 1 and No 2. The TMF operator’s records of monitoring parameters under normal operation have to be processed according to the recommendations No 3. These recommendations can be added in each country depending on the existing national regulatory base.

5.1 Recommendations to education and training of inspectors

These recommendations based on “Safety guidelines and good practices for TMF” are intended for the use by state competent authorities in order to maintain high qualification of the personnel (e.g. state inspectors) responsible for checking TMF as hazardous sites.

TMF inspectors should be trained in:

a) New technologies in TMF management;
b) Standards and procedures of TMF safety and design;
c) Corporate (environment and safety) management methods and tools, and corporate auditing;
d) Monitoring and auditing standards for operations;
e) Risk assessment and risk communication;
f) Communication with operator personnel and the local community.

The training resources should be evaluated and augmented as necessary to provide the complete range of subjects and skills required for life-cycle TMF inspection.

5.2 Recommendations to facility inspections

These recommendations based on “Safety guidelines and good practices for TMF” [12] are intended for use by state competent authorities as guidelines on how to take all necessary steps to verify TMF safety.

Facility inspections should be performed by the competent authorities at all phases of the life cycle of the TMF, and should ensure that TMF operators are taking all the necessary steps to manage the safety

of a TMF throughout its lifecycle without posing excessive risk to the environment or human health. The inspectors should verify in particular if the TMF is managed in accordance with the applicable legal and regulatory standards, as well as with the approved operation manual and waste management plan, as follows:

a) During the pre-construction and construction phase: verification of the location for the waste facility; verification of assumed factors affecting design in the field; construction of the tailings dam;
b) During the operation phase: verification that the physical stability of the waste facility is ensured and that pollution or contamination of soil, air, surface water or groundwater are prevented; verification of regular monitoring of effluent and emission measurements; verification that failures or non-compliance issues were properly reported and proper corrective action was taken;
c) During closure and after closure: verification that the physical stability of the waste facility is ensured; verification of the rehabilitation process, including its proper documentation.

If the management of the TMF does not follow the operation manual and/or waste management plan, the inspection authority should urge the operator to introduce corrective actions within a specified period, and if this is not performed, to revoke the operation permit.

5.3 Recommendations to TMF on-site monitoring

These recommendations (Table 20) are based on Reference document [11]. They are intended for use by the TMF operator to regularly and properly monitor the TMF site under normal operation. Monitoring results have to be regularly delivered to state competent authorities. These recommendations should be used to control the TMF operational state throughout internal routine check of TMF monitoring parameters. In case of unacceptable deviations of monitoring parameters from normal (acceptable) ranges one should determine the need for taking appropriate actions prescribed by the emergency plan; and determine the need for more detailed evaluation using “Detailed Check” group and the need for taking appropriate measures.

The following aspects are critical for TMF on-site monitoring [15, 16]:

1. Constant operational control of the decant facility.
2. Maintenance of internal beach width.
3. Maintenance of storm freeboard.
4. Control of beach slopes.
5. Measurement of seepage discharge and turbidity.
6. Measurement of the internal phreatic surface within the dam wall.
7. Pore pressure measurement.
8. Recording of movements in the dam wall.
9. Recording of seismic events.
10. Recording of delivered tailings particle size distribution.
11. Ensuring that the deposition process achieves adequate particle size segregation on the beaches.
12. Regular monitoring of the behaviour of walls and beaches and physical properties of the deposited tailings, and the deposition procedures.
13. Management and maintenance of tailings delivery systems.
14. Regular updating of monitoring response plans.
15. Management of all data.

These factors should also be addressed in the post closure phase of the dam.

Good surveillance includes the careful keeping of surveillance records + interpretation of these by experienced persons.

Table 20: Recommended frequency of measurements at monitoring of the TMF site

No	Parameters	Recommended frequency
1	Dam-controllable parameters (height, length, evidence of cracks or erosion, crest displacement)	Weekly
2	Lagoon-controllable parameters (filling depth, beach width)	Weekly
3	Controllable seepage parameters (flow line, dam washout and water pressure in pores of protective shields and dam)	Monthly
4	The composition, physical and mechanical properties of tailings materials	Yearly
5	Groundwater level and composition at the TMF site	Monthly
6	Surface water composition in the water bodies located within the TMF	Quarterly
7	Composition and amount of drain water	Monthly
8	Operating conditions of drainage facilities	Monthly
9	Wastewater amount and composition	Monthly
10	Operating conditions of the pipeline and pumps	Monthly
11	Controllable physical and mechanical parameters for soils having formed the dam	Yearly
12	Controllable physical and mechanical properties for soils underlying the TMF	Yearly
13	Controllable physical and mechanical properties for the soils adjoining to the TMF area	Yearly
14	Operating condition of the protective surface cover	Yearly
15	Landslides and soil subsidence	Yearly
16	Seismic activity	Events, regarding to site seismicity

There must be a clear path for reporting of deviances and a mechanism for motivating and implementing remedial actions where necessary.

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Appendix 1. Tailings Hazard Index Method

1. The essence of the THI Method

The Tailings Hazard Index method (THI method) is intended for the use by state competent authorities in order to create an overview of potential hazards/risks posed by TMF or a large number of TMFs as hazardous facilities by analysis of a few critical parameters. The evaluation results can also be used for making decisions by state competent authorities responsible for environmental safety.

The Tailings Hazard Index (THI) is the index that demonstrates the measure of specific potential hazards/risks posed by tailings facilities to the environment, infrastructure, and humans. The THI is calculated by summing up the major TMF parameters that significantly effect on the level of its safety. These are:

- volume of tailings,
- toxicity of substances in tailings,
- TMF management status,
- natural conditions (geological, seismological, and hydrological conditions) specific to the TMF site,
- and dam safety.

Tailings Hazard Index can be calculated in two ways depending on the availability of data on TMFs:

1. Basic THI is simple calculation approach by using the data on two major parameters, which are volume and toxicity of tailings material;
2. Extended THI is detailed approach by using the data on two major parameters of Basic THI and additionally three other parameters clarifying TMF status, natural conditions and dam safety.

The Basic THI (THI_{Basic}) is calculated stepwise as the sum of two parameters which are THI_{Cap} and THI_{Tox}. The first parameter THI_{Cap} is the measure of hazard/risk caused by the volume of tailings stored in TMF (TMF capacity), the second parameter THI_{Tox} is the measure of hazard/risk caused by toxicity of substances contained in tailings materials.

The Extended THI ($THI_{Extended}$) is calculated stepwise as the sum of five parameters which are THI_{Cap}, THI_{Tox}, THI_{Manag}, THI_{Site}, and THI_{Dam}.

The first and second parameters are those used for calculation of THI_{Basic}, the third parameter THI_{Manag} is the measure of hazard/risk related to improper management of facilities; the fourth parameter THI_{Site} is the measure of hazard/risk related to specific geological and hydrological conditions at the TMF site; THI_{Dam} is the measure of dam failure hazard/risk related to structural and component items of the dam, its integrity and functionality.

The calculation procedure for the THI_{Basic} includes two steps (1st and 2nd steps below), the procedure for the $THI_{Extended}$ does five steps (steps 1st through 5th). In case if values of some parameters are unavailable or impossible to identify the maximum values have to be used. Thus, the hazard/risk related to an unavailable TMF parameter (for example, toxicity) is expected to be higher if relevant information is absent.

1st Step: Capacity. The hazard index "TMF capacity" (THI_{Cap}) is calculated as the logarithm of the volume of tailings materials in the TMF (or TMF capacity), m^3 to the base 10. The capacities of the largest TMFs in Europe are reported at 330 or 500 million m^3. Then, assuming the minimum capacity of a TMF is 1 thousand m^3 yields the range for THI_{Cap} values from 3 to 8,7.

2nd Step: Toxicity. The index hazard/risk of the parameter "Toxicity" (THI_{Tox}) is evaluated based on the data of the Hazard Class of tailings materials according to the national classifications. Two widely used

toxicity classifications (German and Ukrainian, the latter is applicable in the most of former USSR countries) group all substances on four classes of water hazard (hazard). Thus, the values of THI_{Tox} are integer numbers ranging from "0" for substances of minimum toxicity to "3" for substances of maximum toxicity.

3rd Step: TMF Management. The index of hazard/risk related to management of TMF (THI_{Manag}) is assumed to be higher if the facilities are active or abandoned or orphaned. The parameter THI_{Manag} is assigned "0" if a TMF is closed and rehabilitated; THI_{Manag} is assigned "1" if a TMF is active, abandoned or orphaned.

4th Step: Site. The measure of TMF site-specific hazard/risk (THI_{Site}) sums the contributions of seismic hazards/risk ($THI_{Seismicity}$) and flood hazards/risk (THI_{Flood}), which are the most critical for TMF safety among natural impacts.

The value of $THI_{Seismicity}$ is calculated based on the data on reference peak ground acceleration (Reference PGA) a_{gR} with the returning period T_{Ret}, years. The parameter T_{Ret} is established by national requirements, and in case they are absent T_{Ret} should be defined by international ones. The seismic hazard/risk is defined as "Low" if "Reference PGA" is less or equal 0.1, and "Moderate or High" if "Reference PGA" is greater than 0.1.

The value of THI_{Flood} is calculated using statistical data on frequency of floods and, specifically, the parameter HQ_{500} that quantifies flood event frequency with a five-hundred-year return period (floods with a probability of 1 in 500). The index of flood-induced hazard/risk at the TMF location area is assigned "1" if a TMF located in the area of HQ_{500} and "0" otherwise.

5th Step: Dam. The measure of dam failure hazard/risk (THI_{Dam}) can be calculated in two ways.

1. *Preferred way.* If Factor of Safety (FoS) is available for all tailings the parameter THI_{Dam} is calculated as the sum of the hazard/risk indices related to slope instability (THI_{FoS}) and TMF age (THI_{Age})

The parameter FoS has to be calculated at the TMF design stage.

2. *Alternative way.* If Factor of Safety is unavailable the parameter THI_{Dam} is calculated as the sum of the hazard/risk indices related to dam material (THI_{Dam}), geometry (THI_{Width}), and TMF age (THI_{Age})

The parameter THI_{FoS} is assigned "0" for stable dam slopes with FoS>1,5; THI_{FoS} is assigned "1" for conditionally stable dam slopes with 1,2<FoS≤1,5, and "2" for unstable slopes with FoS≤1,2.

The dam failure hazard/risk is assumed to increase for aged tailings. Then, the parameter THI_{Age} is assigned "1" in case if a TMF is older than 30 years, and "0" otherwise.

The embankment constructed of a hard/blast rock is assumed to be more stable than the embankment of non-hard rocks or soils (earthen dams). In case if this material is unknown it can be identified by tensile strength at uniaxial compression σ_{DC}. For hard rocks σ_{DC} > 5 MPa, for non-hard rocks and soils $\sigma_{DC} \leq$ 5 MPa. The parameter $THI_{DamMaterial}$ is assigned "1" for non-hard rocks or soils and "0" for hard rocks.

The dam is assumed more stable if the width of dam crest (and obviously, the dam basement) is sufficiently large to retain stored tails in the impoundment. Thus, the parameter $THI_{DamWidth}$ is assigned "1" for narrow dams with crest width less than 10 m and "0" if crest width exceeds 10 m.

Summing up the maximum values of THI_{Cap}, THI_{Tox}, THI_{Manag}, THI_{Site}, and THI_{Dam} yields the maximum value of the THI_{Basic} equal to 12 and $THI_{Extended}$ equal to 18.

2. How to use the THI Method in the template file in MS Excel

The "Template_THI method.xls" is designed to calculate the THI for TMFs in the certain country/region taking into account available data on each tailings facility, geological data, and site hazards

(see Section 2.1 of the Methodology). The file is developed in form of MS Excel and can be obtained by request from German Environment Agency, contact information for request: Mr. Gerhard Winkelmann-Oei, email: gerhard.winkelmann-oei@uba.de.

The template for THI_{Basic} (the tab "Basic THI", file "Template_THI method.xls") includes two tables:

- Table 1 "Database of national TMFs" is placed in the columns from "A" to "H" of the tab. The user puts the available data on tailings, site features, and location area into these cells.
- Table 2 "Calculation of Tailings Hazard Index of national TMFs" includes the columns from "L" to "O" of the tab. These cells contain all two THI constituents for THI basic and the THI is automatically calculated according to Eqs. A 2.1, A 2.2 and Table 1 as well as the TMF hazard/risk rank, defined as the sequence order of each TMF site in the TMF list sorted by THI decrease.

The template for $THI_{Extended}$ (the tab "Extended THI", file "Template_THI method.xls") includes two tables:

- Table 1 "Database of national TMFs" is placed in the columns from "A" to "O" of the tab. The user puts the available data on tailings, site features, and location area into these cells.
- Table 2 "Calculation of Tailings Hazard Index of national TMFs" includes the columns from "Q" to "AE" of the tab. These cells contain all THI constituents and the THI is automatically calculated according to Eqs. A 2.2 – A 2.6 and Tables A 2.1 – A 2.8 as well as the TMF hazard/risk rank, defined as the sequence order of each TMF site in the TMF list sorted by THI decrease.

For the correctness of THI calculation all TMFs should have the same set of data. In case of absence of some information the missing data have to be replaced with the values that meet the worst case in terms of hazard/risk taking into account TMF specifics and all relevant information. For example, if there are no data on materials stored, their Hazard Class should be assigned the maximum value. If the TMF contains a known material, but with no additional information on its toxicity the user defines Hazard Class by accepting the typical value for this material.

Table 1 "Database of national TMFs"

The rows of the Table 1 contain the information and data on each TMF. Below see the column captions (Fig. 6), and explanations and requirements to the data of user input.

1. General information about TMF

Sequence number (No) is the number corresponding to the sequence number of the TMF in the file. It must begin with 1 (the number of the first TMF in the list).

Name of the TMF site is the name of the TMF, which may contain an abbreviated or coded name used to identify the tailings owner.

Location of the TMF site section includes the region and city/district, and geographic coordinates where the site is located. The official/actual mailing address may be input for textual identification of the TMF location in the column (region and city/district). Besides, the user should input the geographic coordinates into the columns "Latitude" and "Longitude" for mapping of all TMFs.

Figure 6: Headings of the columns in Table 1 (for Basic THI just grey cells used)

a)

No	Name of the TMF site	Location of the TMF site		
		Region, city/district	Latitude	Longitude

b)

Volume of stored tailings materials, Mio m^3	Tailings materials		TMF status
	Material stored	Hazard Class	

c)

Site conditions	
Reference peak ground acceleration (PGA)	Flood frequency (HQ-500)

d)

Dam			Commissioning year
Factor of Safety	Embankment material	Crest width, m	

2. Data for the THI calculation

Volume of stored tails (in Mio m^3) specifies the amount of tailings materials in the facility.

Tailings materials include information on the material stored in this TMF and its class of hazard. Material stored is text information used for description of the material (mandatory information). Class of hazard is determined according to Table 1 of Section 2.1 of the Methodology above. The user has to put the cursor in the cell, press button with arrows and select the appropriate value.

TMF status depends on how the TMF is managed. The cell contains one of the following options "Active", "Closed", "Rehabilitated", or "Abandoned/Orphaned". When filling in this cell the user should strictly adhere the wording answer to the actual situation on the site (See Section Terminology). The user has to put the cursor in the cell, press the button with arrows and select the appropriate value.

Site conditions include the two columns described below.

Reference peak ground acceleration (Reference PGA) is defined as the relation of PGA to the gravitational acceleration g (9.81 m/s^2) (See also Section 2.1 above). The parameter PGA equals to the maximum ground acceleration that occurred during returning period when earthquake shaking at the TMF site. The values of reference PGA are decimal numbers from 0 to 1.

Flood frequency HQ-500 quantifies flood event frequency with a five-hundred-year return period. If the TMF site is located on the area once affected by a HQ-500 flood event then THI_{Flood} is set to 1 otherwise THI_{Flood}=0 (Table 4).

Dam section includes three columns described below.

Factor of safety (FoS) is the preferable criterion to evaluate dam failure hazard (number). In case of FoS availability the value of THI_{Dam} is calculated by Eq. A 2.5 (see Section 2 above) taking into account the TMF age calculated with the value of Commissioning year (see below). If FoS is unavailable the user should put nothing in the appropriate cell; then THI_{Dam} will be calculated with the parameters Embankment material and Crest width (see below).

Embankment material is the alternative parameter to evaluate dam failure hazard/risk and used only together with Crest width. The Embankment material cell contains one of three following options ("rock", "non-rock" or "undefined"). This parameter is used only if the parameter Factor of Safety is unavailable. If the value of Factor of Safety is available the user may put nothing in the Embankment material cell. The user has to put the cursor in the cell, press the button with arrows and select the appropriate value.

Crest width is the alternative parameter to evaluate dam failure hazard/risk and used only together with Embankment material. Crest width is defined as the minimum width of the dam crest in the most critical dam zone (if feasible); otherwise as the minimum dam crest width. This parameter has positive numerical values. This parameter is used only if the parameter Factor of Safety is unavailable. If the value of Factor of Safety is available the user should put nothing in the Crest width cell.

If the user indicated all three parameters (Factor of safety, Embankment material and Crest width) in Table 1, the calculation will be automatically made with Factor of safety because it is the preferable parameter.

Commissioning year is the year when the TMF has been commissioned.

Table 2 "Calculation of Tailings Hazard Index of TMFs"

Table 2 (Fig. 7) is calculated automatically using the data entered in Table 1; the cells with THI calculation results are protected. The "THI" column contains the final calculation result by Eq. A 2.1 (see Section 2). The column "TMF hazard/risk rank" contains the TMF rank in the TMFs database, ranked according to the THI. The values in this column depend on the THI values of all TMFs, so the rank of TMF hazard/risk changes automatically following modification of any data on any other TMF.

The chart "THI Evaluation" visualizing the THI of all TMFs listed in Table 1 (Fig. 6) is updated automatically when data are modified. The user can easily select the top hazardous TMFs by using the numerical filter in the column "THI" and the additional chart automatically plotted that shows THI values sorted by decreasing the value (tabs "THI_Basic ranking" or "THI_Extended ranking" of the file "Template_THI method.xls").

Figure 7: Headings of the columns in Table 2 (for Basic THI just grey cells used)

a)

THI_Cap	THI_Tox	THI_Manag	THI_Site	
			THI_Seismicity	THI_Flood

b)

THI_Dam			THI_Age	THI	TMF hazard/risk rank
Factor of Safety	THI_DamMaterial	THI_DamWidth			

The “Template_THI method.xls" should be used as follows.

1. Delete the example provided.
2. Input data into cells of the columns of Table 1. (If you need more rows, put cursor on the rows numeration of the last row in the Table 1 (before column A), press right mouse button and choose “Insert”).
3. Check the consistency and uniformity of data input. All required parameters in the allowed range have to be present in all relevant cells. The cell with the TMF number will be highlighted if required information in the row is missing.
4. Make the analysis of calculation results and graphs.

Appendix 2. TMF Checklist CONTENTS

General comments

1. It is intended that this Appendix 2 to be used in printed form to mark the answers of Checklist questions. The user then should input the selected answers in the Excel file "Template for calc TMF safety_TMF Checklist method.xls" to obtain an automatic result for the TMF safety level evaluation. The file can be obtained by request from German Environment Agency, contact information for request: Mr. Gerhard Winkelmann-Oei, email: gerhard.winkelmann-oei@uba.de.
2. The TMF Checklist includes three groups of questions A, B, and C.
3. The Group A includes general questions from Parts A and B of the document “Safety Guidelines…” [12]; the sequence of questions in the Group B generally follows the sequence of clauses in Part B of this document.
4. Each question either refers to TMF Safety Guidelines or it is proposed by the developers (Ukrainian team) as amendments to the current version of TMF Safety Guidelines. The special column is introduced in the tables of Excel file "Template for calc TMF safety_TMF Checklist method.xls".
5. Group C questions are based on Section B.4 of the document “Safety Guidelines…” [12].

Group A questions (“BASIC CHECK”)

Subgroup A1 questions (“Basic Visual Inspection”)

This table contains an additional column "Recommendation" to guide Checklist users regarding the expected basis of answers to the Group “Visual inspection” questions. The list below is intended for the use on-site in paper form. After completion of the site visit, the selected answers must be entered by the user to the spreadsheet in MS Excel file "Template for calc TMF safety_TMF Checklist method.xls" for an overall evaluation of the TMF safety level.

Table 21: Subgroup A1 questions (“Basic Visual Inspection”)

No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
		Cross-checking of data						
1	Does the design documentation correspond to actual locations of TMF elements?	Matching of charts and maps to the displayed TMF elements on-site						
2	Is there evidence of a well-functioning record keeping process?	Checking of how are records kept and to whom are the results are reported						
		Water management						
3	Is there a functioning dam water management system that appears to be in good condition?	Type of dewatering system (active pumping or gravitational). Decanting systems installed (number of decanters, dimensions, materials, condition). Dewatering tunnel: age, dimensions, construction specifications, condition. Integrity of tunnel lining (as far as accessible)						
4	Does the dam have drainage facilities and emergency spillways that allow water to pass at the maximum level in TMF?	Same items						

No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
5	Are there functional and sound water diversion (tunnel) structures?	Actual water diversion structure. Age, dimensions, construction specifications, condition. Portal protected with rake / grill against driftwood. Excessive sediment accumulation in tunnel.Integrity of tunnel lining (as far as accessible)						
6	Are there functional and sound water diversion or emergency water release structures?	Presence / functionality of emergency spillway in case of overtopping. Surface water diversion dam: Is a diversion present and functional? Age, dimensions, construction specifications, conditions. Approximate storage capacity. Evidence of damage, recent overtopping, erosion. Upstream rakes / grills for timber capture and retention. Excessive sediment accumulation in dam						
7	Are all natural surface water inflows captured and diverted to beyond the TMF borders?	Perimeter drainage ditches installed to capture and evacuate surface runoff from the slopes (if applicable): conditions and functioning. Damage (e.g. siltation, cracks, deformations, subrosion / washout of foundations, destruction through vandalism)						
8	Are there additional storages near the TMF for accumulating water from emergency spillways?	The presence of storages for accumulating water from emergency spillways, their condition, lining, filling, controling devices						
		Environmental Impact Assessment						
9	Is the surrounding area free from evidence of TMF impacts on the environment?	Dispersion of tailings by wind and water flows, Quality of exfiltration waters (colour, odour), Condition of vegetation and soil						

No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
		Dam and screens						
10	Do the dam surface and the dam walls appear to be in sound condition?	General conditions (vegetation, materials on surface); Signs of slumping, irregular slope angle, excessive erosion (ruts, channels, gullies); Seepage and water exfiltration						
11	Is the TMF structure free from evidence of movement, failure or instability?	Flaws in levelness and straightness of dam crest and berms; Irregularity of slope angles. Offsets, kinks, cracks in roads, drainage channels and pipelines in TMF vicinity						
12	Is there evidence of starter dam or dams (e.g. rock fill)?	Material used for raising (tailings / hydrocycloned tailings, external materials). Coarser materials may well indicate improved stability over 'standard' tails						
13	Is there evidence of carefully managed material selection for the dam wall?	Same items						
14	Is the dam free from evidence of leakage, seepage, or piping?	Seepage observable through dam. Quantity and size of seepage areas. Elevation in relation to dam height. Approximate volumes of seepage though dam (damp spot / dripping / trickle / steady flow, the latter in liters/second). Material (tailings / other mixed with seepage)						

No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
		Substances and toxicity						
15	Is the TMF free from evidences of acidic or base tailings material?	An acidic lagoon water is usually characterized by red / orange hues, and one that is alkaline is typically characterized by blue / green hues. Evidences of excessive corrosion or dissolution of materials on metal and concrete elements in contact with lagoon water						
16	Are facilities functioning for collection, control and neutralization of acid or base waters (if applicable)?	Availability and conditions of the facilities for collecting, control and neutralization of acid or base water						
17	Are substances hazardous to aquatic eco-systems removed / neutralized before their disposal to TMF (if applicable)?	Availability and conditions of the facilities for collecting and neutralization of the substances hazardous to aquatic eco-systems						
18	Is drainage water cleaned before discharge?	Conditions of drainage facilities, presence and condition of facilities for cleaning drainage water						
		Monitoring						
19	Is there evidence of a functioning monitoring system?	Monitoring method: visual observation routine, groundwater observation (wells, piezometers), topographic observation (survey points, visual aids, e.g. peg-lines, 3D targets), geotechnical instrumentation (e.g. inclinometers, extensometers), monitoring and documentation routine: Which parameters are measured, where, how frequently, by whom?						

No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
20	Is slope slippage/movement and soil subsidence monitored?	Availability and condition of benchmarks for checking slope slippage/movement and soil subsidence						
21	Are the lagoon parameters in agreement with the design parameters?	Absolute width of beach, beach / lagoon ratio, freeboard between lagoon surface and dam crest						
22	Is the situation downstream of the tailings dam monitored?	Access to the control over water evacuation from diversion tunnel, dewatering tunnel, perimeter drainages and spillways (if applicable)						
23	Is the situation downstream of the tailings dam stable?	Water evacuation from diversion tunnel, dewatering tunnel, perimeter drainages and spillways (if applicable). Signs of washout / regressive erosion						
24	Is there no evidence of external hazards that pose risks to the TMF?	Deposition of waste, including potentially hazardous types, risks from slope instabilities, Impacts / risks from nearby mine waste tips (e.g. acid rock drainage, geotechnical instability)						
		Emergency planning						
25	Is there evidence of emergency preparedness?	Existence of an emergency plan. Availability and condition of equipment to facilitate alert in emergency situations. A match between the equipment and the emergency plan and preparedness to respond, communication equipment and monitoring system						
26	Are tailings facilities isolated or guarded so as to prevent unauthorized access to the TMF?	The manner of fencing and/or manned protection to prevent unauthorized access to the TMF area						

* If a question is not applicable, the user should place a “1” in this column "not applicable" and explain in the "Data source" column why such question(s) considered inapplicable for the TMF being assessed.

Subgroup A2 questions ("Basic Document Check")

This table contains an additional column "Recommendation" to guide Checklist users regarding the expected basis of answers to the Group "Document check" questions. The list below is intended for the use on-site in paper form. After completion of the site visit, the selected answers must be entered by the user to the spreadsheet in MS Excel file " Template for calc TMF safety_TMF Checklist method.xls" for an overall evaluation of the TMF safety level.

Table 22: Subgroup A2 questions ("Basic Document Check")

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
	Pre-construction and construction						
1	Was the TMF construction license (permission issued) based on a risk assessment?						
2	Has the assessment of TMF location confirmed minimization of its negative impact on environment and any neighbouring population?						
3	Were local geological, hydrotechnical and geochemical conditions taken into account while performing the TMF design?						
4	Were land-use planning, hydrological and geological considerations taken into account while evaluating the potential site(s) for the TMF?						
5	Were appropriate national construction, safety and environmental standards observed while designing the TMF?						
6	Are only competent and licensed organizations with properly certified persons engaged in TMF design, construction and operation?						
7	Were local public communities provided with information on the planned/constructed TMF and made aware about risks posed and relevant emergency plans to be drawn up?						
8	Did the operator develop a TMF operations and management plan (operation manual) at the pre-construction phase?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
9	Was a risk assessment performed for each TMF system component based on the TMF operation manual developed by the operator?						
10	Were risks deemed acceptable for all components?						
11	Is there a detailed specification and assessment for physical properties of tailings materials and their volumes to be located within the TMF?						
12	Is there a detailed specification and assessment for chemical/geochemical properties of tailings materials to be located within the TMF?						
13	Was an evaluation of the dam design performed, and the dam design approved by an independent external expert?						
14	Were valid and applicable safety requirements observed while designing the systems for tailings material transportation?						
15	Is the TMF constructed according to design specifications, including those for construction operations?						
16	Was a TMF lining constructed according to the approved design process (if applicable)?						
	Operation and management						
17	Is the TMF operated and managed according to approved operation and management plan (TMF operation manual)?						
18	Is disposal of tailings materials containing toxic substances in compliance with appropriate safety requirements?						
19	Is the tailings delivery system operated according to the TMF operation manual?						
20	Is the dam maintained and operated according to the TMF operation manual?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
21	Do activities for water treatment and monitoring follow the TMF operation manual?						
22	Are drainage facilities operated, monitored and maintained according to the TMF operation manual?						
23	Is the TMF inspected by the operational staff according to pre-set and approved rules listed in the TMF operation manual?						
24	Are TMF components able to provide safe storage of tailings materials in case of floods taking into account all events recorded over at least the last 100 years or projected with a 1:100 year return period?						
25	Are TMF operational staff regularly trained?						
26	Does the TMF operator apply environmental management systems based on international standards?						
27	Does the TMF operator implement safety audits for the tailings facilities based on international standards?						
	Emergency planning						
28	Is the internal emergency plan elaborated and/or implemented by the TMF operator?						
29	Has an emergency response procedure been developed, which is intended to inform and alarm the staff, neighbouring communities and competent authorities in the case of emergency?						
30	Is the external emergency plan prepared in cooperation with competent authorities and local communities?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
	Closure and rehabilitation						
31	Does a closure plan exist?						
32	Does the closure plan include ongoing safety inspections?						
33	Has the TMF been closed according to the closure plan (if applicable)?						
34	Does a rehabilitation plan exist?						
35	Has the rehabilitation of the TMF completed according to the rehabilitation plan (if applicable)?						

* If a question is not applicable, the user should place a “1” in this column "not applicable" and explain in the "Data source" column why such question(s) considered inapplicable for the TMF being assessed.

Group B questions (“DETAILED CHECK”)

Subgroup B1 questions ("Detailed Visual Inspection")

This table contains additional column "Recommendation" to guide Checklist users regarding the expected basis of answers to the Group “Visual inspection” questions. The list below is intended for the use on-site in paper form. After completion of the site visit, the selected answers should be entered by the user to the spreadsheet in MS Excel file "Template for calc TMF safety_TMF Checklist method.xls" for an overall and categorial evaluation of the TMF safety level.

Table 23: Subgroup B1 questions (“Detailed Visual Inspection”)

No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
		Cross-checking of data						
1	Is the TMF site located beyond the zones/areas subject to negative atmospheric conditions (floods, strong winds, and extreme temperature)?	TMF site location, proximity of water bodies and water courses, valleys, and landscape.						
2	Does the design documentation correspond to actual locations of TMF elements?	Matching of charts and maps to the displayed TMF elements on-site.						
3	Have all TMF infrastructure components (roads, ponds, sanitary facilities, pipelines etc.) been displayed in the design documentation?	Matching of charts and maps to the displayed TMF elements on-site.						
4	Is there evidence of a well-functioning record keeping process?	Checking of how are records kept and to whom are the results are reported.						
		Water management						
5	Do the drainage facilities match the TMF operation manual?	Actual conditions of drainage facilities, their matching the documentation.						

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No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
6	Is there a functioning dam water management system that appears to be in good condition?	Type of dewatering system (active pumping or gravitational). Decanting systems installed (number of decanters, dimensions, materials, condition). Dewatering tunnel: age, dimensions, construction specifications, condition. Integrity of tunnel lining (as far as accessible).						
7	Does the dam have drainage facilities and emergency spillways that allow water to pass at the maximum level in TMF?	Same items						
8	Are there functional and sound water diversion (tunnel) structures?	Actual water diversion. Age, dimensions, construction specifications, condition. Portal protected with rake / grill against driftwood. Excessive sediment accumulation in tunnel. Integrity of tunnel lining (as far as accessible).						

No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
9	Are there functional and sound water diversion or emergency water release structures?	Presence / functionality of emergency spillway in case of overtopping. Surface water diversion dam: Is a diversion present and functional? Age, dimensions, construction specifications, conditions. Approximate storage capacity. Evidence of damage, recent overtopping, erosion. Upstream rakes / grills for timber capture and retention. Excessive sediment accumulation in dam						
10	Are all natural surface water inflows captured and diverted beyond the TMF borders?	Perimeter drainage ditches installed to capture and evacuate surface runoff from the slopes (if applicable): conditions and functioning. Damage (e.g. siltation, cracks, deformations, subrosion / washout of foundations, destruction through vandalism).						
11	Are there additional storages near the TMF for accumulating water from emergency spillways?	Are there storages for accumulating water from emergency spillways, their lining, filling, controlling devices						
		Environmental Impact Assessment						
12	Is the surrounding area free from evidence of TMF impacts on the environment?	Dispersion of tailings by wind and water flows, quality of exfiltration waters (color, odor), condition of vegetation and soil						
13	Is the zone of TMF impact free from evidences of soil erosion?	Appearance of topsoil in the zone of TMF impact						

No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
14	Is humus layer removed for the future rehabilitation and stored (if applicable)?	Condition of the location where removed humus layer is stored						
		Dam and screens						
15	Do the dam surface and the dam walls appear to be in sound condition?	General conditions (vegetation, materials on surface); signs of slumping, irregular slope angle, excessive erosion (ruts, channels, gullies); seepage and water exfiltration						
16	Is the TMF structure free from evidence of movement, failure or instability?	Flaws in levelness and straightness of dam crest and berms; irregularity of slope angles. Offsets, kinks, cracks in roads, drainage channels and pipelines in TMF vicinity						
17	Is there evidence of a starter dam or dams (e.g. rock fill)?	Material used for raising (tailings / hydro-cycloned tailings, external materials), Coarser materials may well indicate im-proved stability over 'standard' tails						
18	Is there evidence of carefully managed material selection for the dam wall?	Same items						
19	Is the dam free from evidence of leakage, seepage, or piping?	Seepage observable through dam. Quantity and size of seepage areas. Elevation in relation to dam height. Approximate volumes of seepage though dam (damp spot / dripping / trickle / steady flow, the latter in liters/second). Material (tailings / other mixed with seepage)						

No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
20	Is the TMF equipped with impervious screens (lining)?	Presence of impervious screens and lining in the impoundment, their conditions						
21	Is there cover layer on the TMF surface to reduce/prevent from dusting (if applicable)?	Presence of the cover layer on the TMF surface, its condition; dusting evidences						
		Substances and toxicity						
22	Is the TMF free from evidence of acidic or base tailings material?	Acidic lagoon water is usually characterized by red / orange hues, and alkaline is characterized by blue / green hues. Evidences of excessive corrosion or dissolution of materials on metal and concrete elements in contact with lagoon water						
23	Are the facilities functioning for collecting, control and neutralization of acid or base water (if applicable)?	Availability and conditions of the facilities for collecting, control and neutralization of acid or base water						
24	Are substances hazardous to aquatic ecosystems removed / neutralized before their disposal to TMF (if applicable)?	Availability and conditions of the facilities for collecting and neutralization of the substances hazardous to aquatic ecosystems						
25	Is drainage water cleaned before discharge?	Conditions of drainage facilities, presence and condition of facilities for cleaning drainage water						

No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
		Monitoring						
26	Is there evidence of a functioning monitoring system?	Monitoring method: visual observation routine, groundwater observation (wells, piezometers), topographic observation (survey points, visual aids, e.g. peg-lines, 3D targets), geotechnical instrumentation (e.g. inclinometers, extensometers), monitoring and documentation routine: which parameters are measured, where, how frequently, by whom?						
27	Does the monitoring network ensure the regular acquisition of contamination indices for water, soil, and air?	Availability and condition of checkpoints, automated inspection stations						
28	Are the wells for checking ground water level and composition in the TMF site in operational condition?	Availability, quantity, and condition of the wells in the TMF site, matching the wells and design documentation						
29	Are the wells for checking pore pressure in the dam in operational condition?	Availability, quantity, and condition of the wells in the TMF dam, matching the wells and design documentation						
30	Is slope slippage/movement and/or soil subsidence monitored?	Availability and condition of benchmarks for checking slope slippage/movement and soil subsidence						
31	Are the lagoon parameters in agreement with the design parameters?	Absolute width of beach, beach/lagoon ratio, freeboard between lagoon surface and dam crest						

No	Question	Recommendation (Factors and parameters to be taken into consideration to answer the questions)	Answer					Data source (requisites of documents or photos as evidences)
			not applicable*	yes	mostly yes	mostly no	no	
32	Is there evidence of a well-functioning system downstream of the tailings dam?	Stable, well controlled water evacuation from diversion tunnel, dewatering tunnel, perimeter drainages and spillways (if applicable)? Signs of washout / regressive erosion						
33	Is the surrounding area free from evidence of external hazards that pose risks to the TMF?	Deposition of waste, including potentially hazardous types, risks from slope instabilities, Impacts / risks from nearby mine waste tips (e.g. acid rock drainage, geotechnical instability)						
		Emergency planning						
34	Is there evidence of emergency preparedness?	Existence of an emergency plan. Availability and condition of equipment to facilitate alert in emergency situations. A match between the equipment and the emergency plan and preparedness to respond, communication equipment and monitoring system						
35	Is there equipment in operable condition that terminates tailings material delivery in case of pipeline rupture?	Availability and condition of equipment to terminate tailings material delivery in case of pipeline rupture						
36	Are tailings facilities isolated or guarded so as to prevent unauthorized access to the TMF?	The manner of fencing and/or manned protection to prevent unauthorized access to the TMF area.						
37	Is TMF equipped with necessary fire extinguishing facilities (if applicable)?	Availability and condition of fire extinguishing facilities						

* If a question is not applicable, the user should place a “1” in this column "not applicable" and explain in the "Data source" column why such question(s) considered inapplicable

for the TMF being assessed.

Subgroup B2 questions ("Detail Document Check")

Table 24: Subgroup B2 questions ("Detailed Visual Inspection")

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
Pre-construction and construction							
Licensing							
1	Was the TMF design prepared by a licensed company?						
2	Was the TMF design prepared by properly certified and skilled staff?						
3	Have competent authorities performed an expert evaluation of the TMF design?						
4	Was a TMF operation manual developed before construction of tailings facilities?						
5	Were all phases of the TMF life cycle (design, construction, operation, clo-sure, and rehabilitation) considered in design documents?						
6	Does the TMF design contain a risk assessment?						
7	Was the risk assessment prepared on the basis of the TMF operation man-ual?						
8	Was the risk assessment evaluated by competent authorities?						
9	Does the TMF design contain an environmental impact assessment (EIA)?						
10	Was the EIA developed by a competent institution that has an appropriate license/permission?						
11	Has the TMF operator obtained a license for construction of tailings facili-ties?						
12	Have state competent authorities performed an expert evaluation of EIA?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
13	Have competent NGOs and/or independent experts performed an expert evaluation of EIA?						
14	Was the opinion of local NGOs and potentially affected population taken into account concerning TMF construction?						
	Environmental impact assessment and land-use planning						
15	Was the environmental impact assessment (EIA) performed before issuing permission for construction of the TMF?						
16	Does the EIA address the potential physical impact of the TMF on the environment?						
17	Was the EIA process open for the general public and interested or affected persons to comment and provide input on the assessment?						
18	Was the TMF construction project approved by local authorities?						
19	Is the TMF site located outside area(s) subject to negative atmospheric conditions (floods, strong winds, and extreme temperature)?						
20	Is the TMF site located beyond the direct proximity of protected areas or ones containing rare, important or valuable biological habitats, ways of their migration?						
21	Is the TMF site located outside areas of the lands with high agricultural value?						
22	Have possibilities been considered to locate the TMF in such place where after-effects of possible accidents would be minimal?						
23	Are productive or municipal facilities located outside the area of the TMF impact?						
24	Are historical and cultural heritage objects located beyond the area of TMF construction?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
25	Does the EIA take into account geochemical character of the tailings, the physical and geotechnical character of the TMF?						
26	Is there a detailed map of the TMF and neighboring area?						
27	Was the TMF design described in detail indicating its elements on plans and maps?						
28	Were downstream infrastructure, cadastral boundaries, potential underlying mineralization, site topography and hydrogeology taken into account in the EIA?						
29	Has the assessment of tailings location during design phase confirmed the absence of TMF negative impact on the environment?						
30	Was a TMF water balance prepared while making the EIA?						
31	Has the EIA confirmed the safety of the tailings deposition method?						
32	Is the TMF management during storm events included in the EIA?						
33	Does the EIA address TMF closure issues such as intended post-operational land use, long-term physical, geotechnical, geochemical, and biological stability?						
34	Does the TMF design or pre-design analysis include a detailed estimation of alternative tailings disposal options including non-implementation of TMF?						
	Hazard identification and risk assessment						
35	Does the risk assessment cover the whole TMF and neighbouring (potentially affected) areas?						
36	Were possible accident scenarios assessed for each TMF component?						
37	Were the most vulnerable TMF components and nearby natural objects identified in terms of natural and man-induced hazards?						
38	Were natural risks and hazards typical for the TMF location area assessed?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
39	Was the probability of extreme natural disasters considered in emergency scenarios?						
40	Does the design documentation contain a description of tailings materials including their physical and chemical parameters?						
41	Does the TMF design contain a list and classification of toxic and hazardous compounds contained in tailings materials?						
42	Were toxic and hazardous substances contained in tailings materials evaluated quantitatively?						
43	Were procedures elaborated to neutralize hazardous compounds in tailings materials before their disposal in the TMF (if applicable)?						
44	Does the TMF design exclude joint storing of different hazardous compounds according to current legislation (if applicable)?						
45	Has the expert assessment of tailings materials excluded their impact on surface water?						
46	Does the TMF design exclude unfavorable side reactions that can occur among different tailings materials or tailings materials and membranes/impervious screens?						
47	Does the TMF design exclude soil contamination by tailings materials and process water?						
48	Is the use of the TMF for storing, processing and/or secondary handling of toxic substances excluded?						
49	Is the planned location of the TMF outside a watercourse (freshwater or groundwater) or wetland?						
50	Has the expert assessment of the tailings materials confirmed the absence of their impact on ground water?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
51	Is the introduction of polluted ground water into surface water bodies via subsurface flow prevented/excluded?						
52	Did the flooding risk assessment exclude flooding hazard for the TMF?						
53	Was storm water drainage management considered in the TMF design (if applicable)?						
54	Were hazards in the event of an accident due to the physical/mechanical properties and behaviour of the stored solid material (slurry transport, liquefaction phenomena) evaluated?						
55	Has the expert assessment of the tailings materials excluded their impact on soil conditions?						
56	Is the area adjacent to the TMF free from soil erosion?						
57	Is the permeability of soils under the TMF bottom sufficiently low to prevent contaminant leakages?						
58	Were seismic and geological risks assessed for the TMF (e.g. soil collapsing or tectonic faults)?						
59	Were previous natural disasters for the TMF site and their after-effects reviewed?						
60	Were possible accident scenarios described including criteria and process of their selection?						
61	Were data concerning accidents and incidents at similar TMFs taken into account?						
62	Were the safety activities developed, which are intended to prevent or limit possible accident scenarios?						
63	Were measures developed to prevent major accidents along with an assessment of their efficacy?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
64	Is there an evaluation of how the proposed safety measures limit the potential impact/effects of possible accidents?						
65	Were the most probable accident scenarios defined during the design phase?						
66	Were major accident scenarios assessed along with their possible after-effects?						
67	Was the probability assessed for actualization of basic accident scenarios taking into account the proposed preventive actions and their efficacy?						
68	Were risks taken from different studied scenarios evaluated as acceptable?						
69	In case of revealed unacceptable risk related to TMF construction, was an alternative location of TMF considered?						
70	Does the TMF design take into account neighbouring active, abandoned or rehabilitated TMF(s) (if applicable)?						
71	Was the possibility taken into account for an accident occurring at a neighbouring TMF that may result in emergency scenario at the TMF being assessed (“domino effect”)?						
72	Were possible trans-boundary effects considered for the likely accident?						
73	Is the assessed hazard/risk of surface and ground water pollution below regulatory limits for the whole TMF lifecycle?						
74	Is ambient air pollution controlled during TMF construction and operation?						
75	Does the TMF design include measures addressing the TMF surface during its filling to reduce dust generation with tailings materials (if applicable)?						
	Dam safety						
76	Were tailings material parameters taken into account when designing the dam and/or retention pond?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
77	Were geological, hydrogeological, hydrological, and geophysical conditions taken into account while designing the dam and retention pond?						
78	Are local water sources located beyond the impact zone of the tailings pond when the TMF is operating?						
79	Was emergency water escape/release taken into account while designing the dam and retention pond?						
80	Does the TMF design prevent changes to surface runoff due to dam construction or water pond displacement (if applicable)?						
81	Does the stability and strength assessment for the dam fulfil applicable safety criteria?						
82	Did the assessment of the dam slope show it to be in an acceptable safety range?						
83	Was stability and strength assessed for the dam foundation during the design phase?						
84	Was stability of the tailings material (including liquefaction) assessed at the dam designing phase?						
85	Did an assessment of the dam erosion show the design to be within a safety range?						
86	Were water recovery systems and emergency spillways assessed for the dam foundation during the design phase?						
87	Was slope slippage/movement assessed for the dam during the design phase?						
88	Have the flood data for at least a 100-year period (historical or projected) been used as the basis when calculating the emergency discharge capacity for the dam?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
89	Was Factor of Safety (FoS) deemed as acceptable in the particular country taken into account during calculations of dam safety?						
90	Are there documents that detail the design and routing of the tailings delivery system?						
91	Are there maps indicating location of the tailings delivery system?						
92	Was the dam raising method selected taking into account local conditions?						
93	Were soils at the site tested on their applicability for dam construction?						
94	Were additional reservoirs designed for water intake from emergency outlets (if applicable)?						
95	Was the possibility considered for repeated use (recycling) of hazardous substances and process water from the TMF?						
96	Is the operational life-time defined for the tailings delivery system?						
	Construction						
97	Is construction procedure completed according to design documents?						
98	Is the site for TMF construction monitored according to a schedule defined in the TMF design or operating manual?						
99	Was the humus layer completely removed before dam construction and is it stored/used (if applicable)?						
100	Were internal drain facilities built according to the TMF design?						
101	Does the accepted construction procedure ensure the maintenance of safety requirements as set forth for the environment and neighbour population?						
102	Did authorized bodies monitor the quality of construction works within scheduled terms?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
103	Were safety margins checked against scheduled terms taking into account the implementation of design solution on-site?						
104	Is the TMF equipped with impervious screens (e.g. membrane or low permeability compacted clay layer)?						
105	Has the bottom sealing layer sufficiently low permeability to prevent leakage from the TMF?						
106	Is there a protective cover-layer over the TMF surface in order to prevent or reduce dust emission or water infiltration (if applicable)?						
107	Was the TMF commissioned according to applicable regulatory requirements?						
	OPERATION AND MANAGEMENT						
	Management						
108	Has a detailed waste management plan been developed for the TMF?						
109	Have competent authorities evaluated and approved the TMF operation manual and waste management plans?						
110	Is there a procedure to review and regularly update the TMF operation manual and waste management plan, and then obtain the approval by competent authorities?						
111	Are relevant competencies for personnel described in the TMF operation manual?						
112	Does the TMF operation manual contain technical procedures and specification of hardware for delivery and accumulation of tailings materials?						
113	Does the TMF operation manual contain all monitoring procedures for internal inspection?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
114	Was an expert assessment made concerning dam failure (washout) as a result of flooding (if applicable)?						
115	Are water management plans and guidelines included in the TMF operation manual?						
116	Does the TMF operation manual contain reporting procedures for non-compliance and failures?						
117	Does the TMF operation manual contain corrective actions to be applied in case of non-compliances?						
118	Does the TMF operation manual contain an internal emergency plan?						
119	Does the TMF operation manual contain parameters needed to assess operation efficiency and suitability to operation conditions (if applicable)?						
120	Are any changes of the operation manual based on performance analysis documented (if applicable)?						
121	Is the TMF performance assessed and described during significant seasonal events?						
122	Are TMF management data collected during significant seasonal events used for planning rehabilitation activities?						
123	Does the TMF operation manual detail the procedures to prevent or reduce acid or base drainage water production, and procedures to collect and treat such water (if applicable)?						
124	Does the treated acid or contaminated drainage water meet the permit conditions (if applicable)?						
125	Are substances classified as hazardous absent in the TMF?						
126	Are hazardous substances stored separately from each other (if applicable)?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
127	Are appropriate safety activities taken if hazardous substances stored jointly (if applicable)?						
128	Are water-hazardous compounds eliminated / neutralized before their discharge from or to the TMF (if applicable)?						
129	Is storage of acidic materials in the TMF excluded?						
130	Were effective procedures elaborated to monitor, decrease or prevent formation of acidic aqueous solutions (if applicable)?						
131	Does the neutralization plant have a volume equal at least double water volume of acid water according to actual needs (if applicable)?						
132	Do pipelines remain air-tight and stable during long-term mechanical, chemical, thermal and biological impacts?						
133	Is the lowest pipeline part located above the maximum flooding level for the last 100 years (or equivalent projected 1:100 year flooding level)?						
134	Is pipeline and pump condition regularly checked and confirmed in a written documentation?						
135	Is there equipment in operable condition that terminates tailings material delivery in case of pipeline rupture?						
136	Is there a replacement pipeline for tailings transportation at the TMF in case of accident (if applicable)?						
137	Does the dam prevent water leakage or transfer from the TMF into neighbouring water bodies (if applicable)?						
138	Do guidelines for dam raising operations exist, and are they implemented (if applicable)?						
139	Can the dam prevent TMF overfilling in case of extreme precipitation events or flooding?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
140	Do developed and implemented activities provide effective drainage water treatment?						
141	Does the drainage water from the TMF comply with regulatory require-ments for surface water after its final treatment?						
142	Do special measures protect ground and surface water from pollution in case of emergencies?						
143	Are safety requirements met while removing drainage water?						
144	Are there separate accumulators for polluted drainage water?						
145	Are these accumulators equipped with low-permeable barriers to prevent leaks (if applicable)?						
146	Are all natural surface waters inflows collected and diverted away from and outside the TMF (if applicable)?						
147	Are there reliable data concerning the chemical composition of drainage water?						
148	Is the drainage system operated according to the TMF operation manual?						
149	Does the dam have drainage facilities and emergency spillways able to discharge water at its maximum level in the TMF?						
150	Does the TMF operation manual define the TMF maximum filling level?						
151	Is the TMF equipped with catching tanks / ponds intended to collect emer-gency overflows?						
152	Do these accumulating tanks/ponds have sufficient capacity for the whole water volume at maximum flooding/precipitation events based on those that have occurred at least during the last 100-year period (or equivalent projected 1:100 year flooding events)?						
153	Is normal operation ensured for TMF components during flooding?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
	Monitoring						
154	Does the monitoring schedule cover local geological, hydrological and climatic conditions?						
155	Does the monitoring schedule include the description of sampling location and frequency?						
156	Does the monitoring schedule include the parameters related to minimum capacity/freeboard, pore pressure, groundwater level, drainage system, and surface water diversion?						
157	Does the monitoring schedule include the dam and slope stability parameters (height, length, cracks and evidence of erosion, crest displacement, etc.)?						
158	Does the monitoring schedule include the observation of nearby territories in the tailings lagoon area?						
159	Are lagoon parameters (filling depth, beach width) monitored on a regular basis according to the TMF operation manual?						
160	Is the monitoring system equipped with automated monitoring stations?						
161	Do monitoring tools provide well-timed detection of hazardous leaks from pipelines?						
162	Are monitoring data regularly collected?						
163	Does the monitoring procedure verify dam crest condition (used materials, irregularities, evidence of erosion etc.)?						
164	Does the monitoring procedure verify slope parameters (geometry, condition, vegetation, erosion, and seepage)?						
165	Does the monitoring procedure verify pore pressure in the dam on a regular basis?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
166	Are composition and physical-mechanical properties checked for dam and tailings materials accumulated in the TMF?						
167	Does the monitoring procedure verify groundwater level and composition at the TMF site on a regular basis?						
168	Is composition of surface water monitored for water bodies located within the TMF impact area (if applicable)?						
169	Is drainage water composition and amount monitored?						
170	Are conditions of the TMF drainage system monitored on a regular basis?						
171	Are physical and mechanical parameters checked for soils forming the dam and the TMF underlying soils?						
172	Are conditions of the protective cover layer monitored (if applicable)?						
173	Is seismic activity monitored at the TMF?						
174	Are the monitoring data used for the ongoing evaluation of hazards and for the updating of risk assessment(s)?						
175	Are operational documents updated using monitoring results?						
176	Is the network and schedule of observations updated as a result of TMF monitoring?						
177	Are these changes estimated by “cost-efficiency” criteria?						
178	Is possible trans-boundary transportation of contaminants taken into account during TMF monitoring?						
	Education and training of personnel						
179	Is there a program for regular staff training and advanced training?						
180	Are the TMF operating staff regularly trained?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
181	Are regular staff trainings and advanced trainings performed according the approved program documented?						
182	Is a two-way approach implemented for the staff training (informing technicians about issues of environmental and safety issues and vice versa)?						
183	Do the TMF operational staff have proper skills in technology of TMF design (if applicable)?						
184	Do the TMF operational staff have proper skills in approved procedures for safe operation and risk management (if applicable)?						
185	Do the TMF operational staff have proper qualification in the field of rules and regulations concerning safety management and environmental performance (if applicable)?						
186	Do the TMF operational staff have proper skills for management systems and tools at such facilities (if applicable)?						
187	Do the TMF operational staff have proper skills for assessment of operational activity (if applicable)?						
188	Do the TMF operational staff have proper skills for environmental (including basic hydrology) and health issues (if applicable)?						
189	Do the TMF operational staff have proper skills to control TMF safety and environment conditions (if applicable)?						
190	Do the staff responsible for TMF operation have proper skills concerning communication and submission of internal reports to the executive management (if applicable)?						
191	Do the staff responsible for TMF operation have proper skills concerning public relations (if applicable)?						
192	Is attention drawn to the uncertainties inherent to TMF hazards during the training?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
193	Is the program for regular staff training and advanced training complemented with consolidation and checking of obtained skills?						
194	Is the TMF operating staff trained in accident response procedures?						
195	Is the local population engaged in emergency response training?						
196	Does the staff training program provide a common level of understanding for all relevant personnel?						
	EMERGENCY PLANNING						
	General principles						
197	Is a Major Accident Prevention Policy and Safety Management System developed and documented for the TMF?						
198	Were emergency plans prepared before issuing the license for TMF construction and operation?						
199	Is an emergency plan developed and documented for all phases of the TMF life cycle?						
200	Are there procedures developed and documented for validation, review and acceptance of emergency plans before the start-up of TMF operation?						
201	Are there procedures developed and documented for validation, review and acceptance of emergency plans if accidents or emergency situations appear at the TMF or similar facilities?						
202	Are there procedures developed and documented for validation, review and acceptance of emergency plans in case of substitution of rescue services or their management staff?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
203	Are there procedures developed and documented for validation, review and acceptance of emergency plans in case of new technical knowledge arising or new risks being revealed?						
204	Are there procedures developed and documented validation, review and acceptance of emergency plans in case of events beyond design limits, which are caused by natural or human-induced reasons?						
205	Are there procedures for validation, review and acceptance of emergency plans in case of errors in management procedures being found?						
206	Are there procedures developed and documented for validation, review and acceptance of emergency plans if hardware is modified (if applicable)?						
207	Are there procedures developed and documented for validation, review and acceptance of emergency plans at regular time intervals, according to the procedure set forth in the emergency plan?						
208	Is there an abridged or digital version of the emergency plan for easy access in the event of emergency cases?						
209	Does the emergency plan evaluate downstream inundation risk due to flood and upstream conditions that might result from land displacements (if applicable)?						
210	Is “domino effect” taken into account related to sequential accidents in a dam cascade (if applicable)?						
211	Are conditions assessed, which may appear at slow, rapid and practically instantaneous dam failure?						
212	Does the emergency plan contain a scope and aims for emergency cases?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
213	Does the emergency plan contain the contact details and responsibilities of each member of the organization for emergency response (chain of responsibility and authority for actions to be taken)?						
214	Does the emergency plan contain evaluation of emergency scenarios as well as procedures and physical resources to respond them?						
215	Does the emergency plan contain evaluation of risks and potentially affected areas?						
216	Does the emergency plan arrange communication activity and notification procedures for the TMF operational staff?						
217	Does the emergency plan list hardware and resources needed and available for emergency response activities?						
218	Does the emergency plan contain procedures for emergency response for each determined emergency scenario?						
219	Are the activities prioritized in the emergency plan so as to eliminate potential emergency situations?						
220	Does the emergency plan contain procedures for remediation of the affected areas after the cessation of emergency conditions?						
	Internal emergency planning						
221	Is the internal emergency plan site-specific and developed for each specific situation?						
222	Is the emergency plan tested and evaluated as per schedule?						
223	Were estimations performed prior to the development of the internal emergency plan to determine the most likely mode of dam failure and water peak outflow (if applicable)?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
224	Did the estimations identify chemicals and other pollutants that might be released during the TMF failure?						
225	Does the internal emergency plan contain estimations of equipment and construction materials needed to deal with dangerous releases, and emergency repairs of the TMF?						
226	Does the internal emergency plan foresee measures for clean-up of any material that might be released from a TMF?						
227	Is the internal emergency plan ready to be activated in a coordinated fashion with the external emergency plan in the event of a major accident?						
228	Are plans for notification of key personnel, local authorities, emergency services and the public included to the emergency plan and prepared for all types of dam failure conditions?						
229	Were the procedures established to agree external emergency services with the internal emergency plan?						
230	Does the TMF operation manual include the internal emergency plan?						
231	Is the internal emergency plan regularly reviewed by senior management of the TMF?						
232	Do the on-site personnel receive adequate training in emergency procedures and reporting on incidents?						
233	Does the TMF operator submit reports based on the monitoring data to local authorities?						
234	Is immediate alerting provided by the TMF operator when reaching critical thresholds for parameters specified in the TMF operation manual?						
235	Has the TMF operator prepared sufficient physical resources and manpower to respond to emergencies and eliminate their after-effects?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
	External emergency planning						
236	Was the external emergency plan submitted to local authorities and local emergency services for the purpose of its familiarization, review and agreement?						
237	Was the local community given the opportunity to participate in the preparation and revision of the external emergency plans?						
238	Were external emergency plans aligned with and/or harmonized with similar ones for neighbouring regions?						
239	Is there a plan for alerting operational staff, rescue services, local authorities and mass media?						
240	Does the alarm plan contain alerting procedures for deviations from normal operation?						
241	Does the external emergency plan contain information about competent authorities in neighbouring regions, including bordering countries, which should be informed in emergency case?						
	CLOSURE AND REHABILITATION						
242	Is there a plan for TMF closure and rehabilitation approved by competent authorities?						
243	Were criteria set for the completion of TMF operation?						
244	Is a procedure specified to agree, approve and update TMF closure plans?						
245	Are tailings materials to be used as a secondary raw (later processing)?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
246	Are plans developed for land rehabilitation intended post-operational land-use, long-term physical, geotechnical, and biological stability, and ecosystem rehabilitation (if applicable)?						
247	Do the closure and rehabilitation plans contain monitoring procedures?						
248	Is Factor of Safety set by applicable regulations considered in all calculations for closure and further monitoring stages?						
249	Is there an internal inspection plan for the TMF after its closure?						
250	Does the plan contain evaluation of risks connected with TMF closure and rehabilitation?						
251	Are there the personnel responsible for controlling/monitoring the closed/rehabilitated TMF?						
252	Are local terrain features (geological, hydrological, morphological) taken into account when establishing closure activities?						
253	Were measures considered and applied to ensure long-term stability of physical, geotechnical and biological parameters of the site after TMF closure?						
254	Do the data obtained during inspection of the TMF closure match regulatory parameters (if applicable)?						
255	Is the physical stability of the TMF checked during closure?						
256	Is the TMF chemical stability checked during closure (if applicable)?						
257	Were measures for rehabilitation of the ecological system after TMF closure developed and documented?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
258	Were options considered concerning TMF site usage after its decommissioning?						
259	Is there a plan for TMF reclamation and landscaping?						
260	Is the plan for TMF reclamation and landscaping implemented (if applicable)?						
261	Were economically feasible activities developed and documented to decrease effects of the long-term TMF impact on the environment?						
262	Is it planned to cover the rehabilitated TMF site with artificial topsoil?						
263	Do the inspection data of the TMF rehabilitation match regulatory parameters (if applicable)?						
264	Is the physical and mechanical stability of the TMF monitored after rehabilitation?						
265	Is the TMF chemical stability monitored after rehabilitation (if applicable)?						
266	Is the surrounding environment monitored during and after rehabilitation?						
267	Do the trends of environment restoration during and after rehabilitation meet the expected conditions?						

* If a question is not applicable, the user should place a “1” in this column "not applicable" and explain in the "Data source" column why such question(s) are considered inapplicable for the TMF being assessed.

Group C questions ("CHECK OF INACTIVE SITES")

Subgroup C1 questions ("Visual Inspection of Inactive Sites")

This subgroup is equivalent to the subgroup B1 "Detailed Visual Inspection"

Subgroup C2 questions ("Document Check of Inactive Sites")

Table 25: Subgroup B2 questions ("Document Check of Inactive Sites")

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
Assessment of and priority tasks for abandoned sites							
1	Did the TMF inspection verify the mechanical stability of the facilities during and after closure (if applicable)?						
2	Was the closure procedure completed according to the TMF closure plan (if applicable)?						
3	Did the TMF inspection verify the properly documented rehabilitation process after closure (if applicable)?						
4	Is the inactive TMF regularly inspected by the competent authorities (if applicable)?						
5	Was the initial screening carried out at the abandoned/orphaned TMF after it was identified for checking?						
6	Does the initial screening include a walkover survey of the containment dam, the beach, the water management system and the hydrographical catchment area?						
7	Does the initial screening assess the vulnerability factors for nearby or downstream communities?						
8	Does the initial screening assess land uses and any important natural areas / wildlands requiring special protection?						
9	Is public access restricted to the inactive TMF?						
10	Were the main structures and parameters inspected as per clauses 105 of "Safety Guidelines…" (p. 25)?						
11	Are the inactive TMF components classified by degree of risk?						

No	Question	Answer					Data source (requisites of documents or photos as evidences)
		not applicable*	yes	mostly yes	mostly no	no	
12	Did the visual risk assessment performed for the inactive site determine the need for its further detailed evaluation?						
13	Is a risk management strategy developed based on the initial risk assessment?						
14	Are management programs developed and documented to decrease the risks revealed during assessment?						
15	Have the risks of the inactive TMF been assessed and rehabilitation actions been identified (if applicable)?						
16	Is the inactive TMF monitored and maintained by qualified personnel (if applicable)?						
17	Is there an emergency plan for the inactive TMF including procedures for remediation (if applicable)?						
18	Is the inactive TMF monitored in the "post-closure" period according to the approved procedures (if applicable)?						
	Management of abandoned sites						
19	Are measures taken to authenticate an operator/owner of the abandoned TMF?						
20	Are competent authorities nominated to carry out assessment and monitoring of the TMF?						
21	Is the TMF catalogued in an inventory indicating its location and key parameters?						
22	Are the abandoned TMF borders clearly labelled?						
23	Is there a monitoring schedule for the abandoned TMF, which specifies its scope and terms?						
24	Are internal and external emergency plans developed for the abandoned TMF by competent authorities?						

* If a question is not applicable, the user should place a “1” in this column "not applicable" and explain in the "Data source" column why such question(s) are considered inapplicable for the TMF being assessed.

Appendix 3. How to use the TMF Checklist

Each TMF Checklist group of questions has a different user and purpose, which are described in Table 26.

Table 26: Users and purposes of the TMF Checklist Groups

Group/Subgroup	Elements of group	Purpose	Users
Group A Subgroup A1 "Basic Visual Inspection"	- Questionnaire, - Evaluation Matrix	Preliminary and prompt evaluation of the safety level of a large number of TMFs (in the case of documentation availability)	State competent authorities
Group A Subgroup A1 "Basic Document Check“	- Questionnaire, - Evaluation Matrix	Preliminary and prompt visual evaluation of the TMF safety level (in case of documentation absence)	State competent authorities
Group B Subgroup B1 “Detailed Visual Inspection”	- Questionnaire, - Evaluation Matrix - Measure Catalogue	Comprehensive and detailed evaluation of the TMF safety level aimed to identify the need for taking measures	State inspectors and TMF operators
Group B Subgroup B2 “Detailed Document Check”	- Questionnaire, - Evaluation Matrix - Measure Catalogue	Comprehensive and detailed evaluation of the TMF safety level aimed to identify the need for taking measures	State inspectors and TMF operators
Group C Subgroup C1 “Visual Inspection of Inactive Sites"	- Questionnaire, - Evaluation Matrix - Measure Catalogue	Evaluation of the safety level of inactive TMF aimed to identify the need for taking measures	State inspectors and TMF operators
Group C Subgroup C2 “Document Check of Inactive Sites"	- Questionnaire, - Evaluation Matrix - Measure Catalogue	Evaluation of the safety level of inactive TMF aimed to identify the need for taking measures	State inspectors and TMF operators

All elements of the TMF Checklist (Questionnaire, Evaluation Matrix and Measure Catalogue) are put in the Excel format for the practical application by the user.

The user is encouraged to use Excel file "Template for calc TMF safety_TMF Checklist method.xls" that can be obtained by request from German Environment Agency, contact information for request: Mr. Gerhard Winkelmann-Oei, email: gerhard.winkelmann-oei@uba.de.

The template is developed for user-friendly application of the TMF Checklist and provides an automatic calculation of the relative TMF safety level using numerical analysis of the answers to the questions of the Groups A, B and C.

Recommendations for different users of the TMF Checklist

This section "How to use the TMF Checklist" also takes into account the cases for applying the THI method (Section 2) before working with Checklist and divided within the meaning of the types of users, which are as follows:

- State competent authorities;
- State inspectors; and
- TMF operators.

For the users representing "State competent authorities"

Before starting to work with the TMF Checklist it is recommended to apply the Method of evaluation of "Tailings Hazard Index" (THI) in the Excel file (see Section 2.2). The file can be obtained by request from German Environment Agency, contact information for request: Mr. Gerhard Winkelmann-Oei, email: gerhard.winkelmann-oei@uba.de.

The result of the THI evaluation will be:

- Creation of the TMFs database of the country/region in the recommended format of the Excel file "Template_THI method.xls" (if the THI method is applied first time).
- Ranking of all known TMFs according to their THI in the national/regional database.
- Identification of the top hazardous TMFs.

The top hazardous TMFs are identified as the objects with maximum values of THI; the number of such objects should be determined individually by the threshold applied to the total number of TMFs in the country/region. The TMFs database should be periodically updated by adding new identified TMFs and/or by adding the TMF parameters that were changed (improved or worsened).

Then, the user can proceed to use the TMF Checklist as follows:

1. Apply the Group A (**Basic check)** to the top hazardous TMFs identified by the THI Method. The result of the Group A application will be

- Evaluation the safety level of the country's/region's TMFs.
- Ranking of these TMFs in terms of the urgency of detailed check based on the “MSR” and “Credibility” ranks.
- Selection of a few most hazardous TMFs with minimum “MSR” and “Credibility” ranks which are subject to detailed individual check by Groups B or C taking into account the inspecting staff capacity.

2. In the periods between inspections the changes of TMF state should be monitored to regularly update the previous evaluation results.

As a result of the above actions, the user will have TMFs database ranked by their THI and evaluated on their safety level. This will allow the user "State competent authorities" making the necessary decisions about further actions that may include more detailed evaluation of individual TMFs (Groups B or C of the TMF Checklist) and elaboration of individual investment programs.

For users “State inspectors” and “TMF operators”

The users “State inspectors” and “TMF operators” apply the TMF Checklist in order to evaluate the safety level of an individual TMF in a more detailed manner as follows.

Apply either the Group B or C to the sites selected by the Group A depending on the TMF status. The result of their application will be

- Detailed evaluation of the safety level for a few individual TMFs selected by the Group A. Evaluation of the whole life-cycle of TMF is performed with the Group B, evaluation of inactive TMFs is performed with Group C.
- Elaboration of individual investment programs for the TMF.
- Prescription of the measures to increase the TMF safety level.

Based on the result of the TMF check (Group B or C and Measure Catalogue) the individual investment program has to be elaborated and recommended/approved in order to improve the TMF safety level.

The evaluation of the TMF safety level is the key point in the TMF Checklist application workflow. Upon having filled the TMF Checklist in a MS Excel file, the user has to report on the works performed and the results obtained. The developed template (Section 4.4) describes the recommended content of “Report on Evaluation of the TMF safety level”. The example of the Report is given in the Appendix 4.

The succession of TMF Checklist application is depicted in Figure 8.

How to use Excel file “Template for calc TMF safety_TMF Checklist method”

Evaluation Matrix for three Groups: A, B and C

1. Select a group of questions of the TMF Checklist (Groups A or B, or C). Each group questions is listed in a separate tab of the file.
2. Delete the example with the answers provided in the template.
3. Answer the questions of the selected TMF Checklist group.
4. Choose the answer (“yes” or “mostly yes” or “mostly no” or “no”) by putting the number “1” in an appropriate cell.
5. If the question is not applicable to the TMF checked exclude it from the evaluated question set by putting the number “1” in the cell "not applicable".
6. Specify the grounds/reasons for accepting the selected answer in the column “Data source” by the provision of requisite documents and/or photographs as evidences supporting the answer provided.

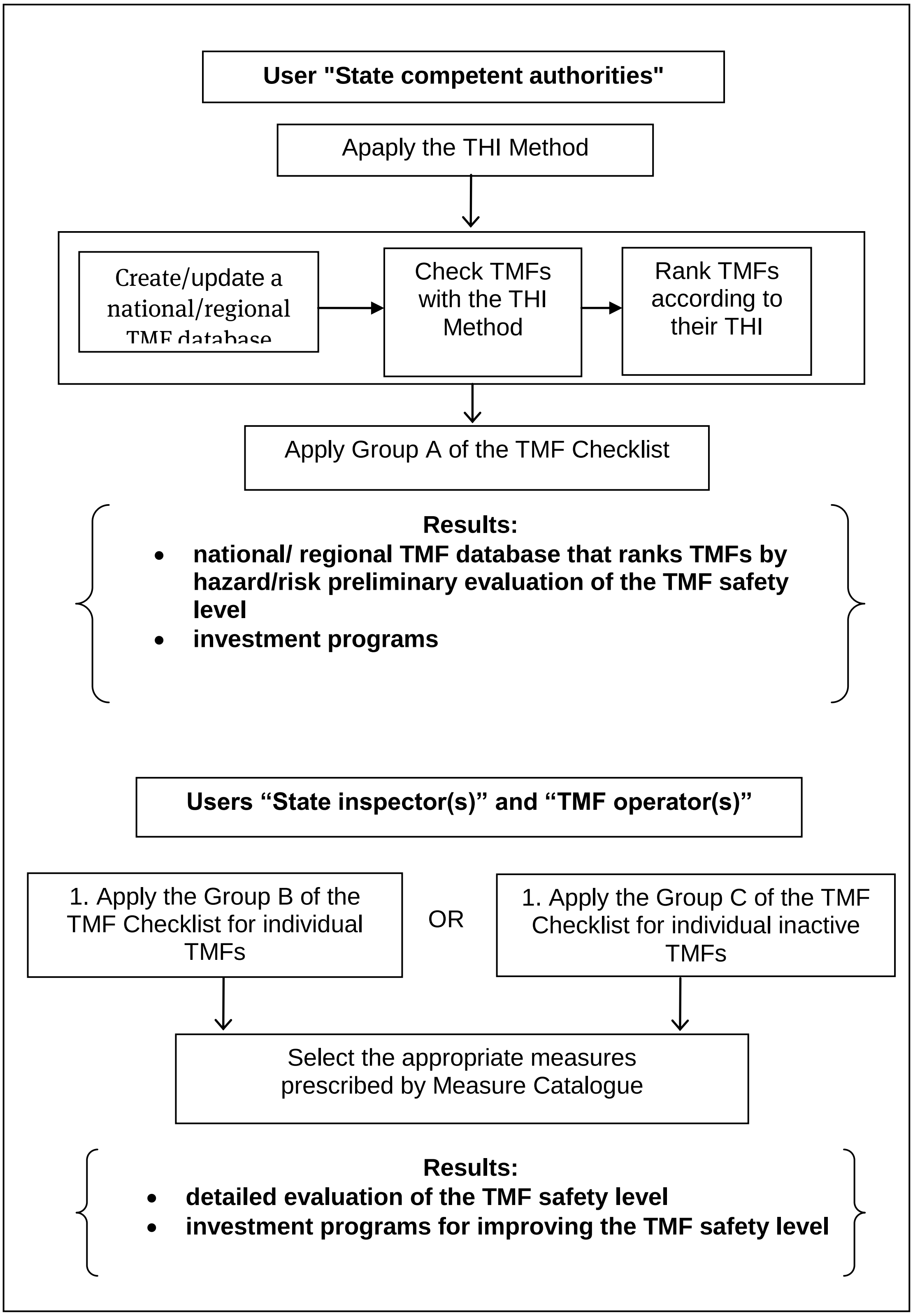
As a result of the above steps the user will automatically get the calculated TMF safety level in numbers and visualized by charts.

Measure Catalogue for the Groups B and C

Each non-positive answer (“mostly yes”, “mostly no”, “no”) of the Group B and C refers to a certain non-compliance with the requirements of the TMF safety. Appropriate measures are prescribed in Measure Catalogue for identified non-compliances. To select the measures for improving the safety level of the checked TMF the user has to click on the hyperlink(s) in the column "Prescribed measures" and go to the appropriate measures in the tab “Measure Catalogue”.

The first tab “How to use this Template” of Excel file “Template for calc TMF safety_TMF Checklist method.xls” contains all the above mentioned recommendations for the use of this template.

Figure 8: TMF Checklist application



Appendix 4. Measure Catalogue

Table 27: Measure Catalogue

No	Problem to be solved	Measures prescribed	Priority
		PRE-CONSTRUCTTION AND CONSTRUCTTION	
1	Design documentation is incomplete	1A. Update design documentation made by a licensed company	Short-term
		1B. Update design documentation involving licensed and skilled staff	Short-term
		1C. Perform expert analysis of design documents for authorities	Short-term
		1D. Prepare or complete design documentation according to regulatory re-quirements	Short-term
		1E. Prepare a detailed map of the TMF site and the surrounding area	Short-term
2	The TMF project was not discussed with local authorities and communities	2A. Discuss the TMF projects with local authorities and public	Short-term
		2B. Inform local communities and NGOs on the essence of the TMF design and get their opinion/consent	Short-term
3	Environmental impacts caused by the TMF were not assessed	3A. Assess pollution risk to ground waters	Short-term
		3B. Assess pollution risk to surface waters	Short-term
		3C. Assess pollution risk to soils near the TMF site	Short-term
		3D. Assess pollution risk to air quality	Short-term
		3E. Study the feasibility of implementing protective screens, lining, and top covers	Short-term
		3F. Assess flooding risk for the TMF	Short-term
		3G. Install protective screens and top covers	Mid-term
4	Natural and man-made risks were not taken into account in accident scenarios	4A. Perform the study per possible accident scenarios and their after-effects	Short-term

No	Problem to be solved	Measures prescribed	Priority
		4B. Assess possible local, geological, and climate risks to the TMF	Short-term
		4C. Assess possible man-made risks to the TMF	Short-term
		4D. Assess the TMF impact on the environment and health of population	Short-term
5	Alternative options of TMF disposition were not considered	5A. Consider alternative options of TMF location and give appropriate recommendations	Short-term
6	Local conditions and climatic extremes were not taken into account while designing the dam and retention pond	6A. Calculate the water balance of the TMF	Short-term
		6B. (Re)Assess stability of the dam and tailings pond taking into account the properties of tails, used soils, appropriate safety criteria, and local condition	Short-term
		6C. Modify the designs of the dam and tailings pond	Short-term
		6D. Create additional reservoirs for catching precipitation and flood waters	Mid-term
7	Impacts of nearby TMFs were not taken into account for accident scenarios	7A. Assess the impact of nearby TMFs, other hazardous sites near the TMF site, and/or possible trans-boundary effects	Short-term
8	Hazardous materials were not identified completely	8A. Identify hazardous substances and mixtures stored in TMF	Short-term
		8B. Evaluate the essential properties needed to assess joint storage of hazardous substances	Short-term
		8C. Draft or modify the design of the storage facility for hazardous substances and mixtures	Short-term
9	Hazardous materials including acidic tailings are not neutralized or isolated before disposal	9A. Study the feasibility of neutralizing (isolating) hazardous substances before their disposal to the TMF	Short-term
10	Properties of soils at the site and soils used for TMF construction were not studied or taken into account	10A. Study the properties of soils at the TMF site and soils used for construction	Short-term

No	Problem to be solved	Measures prescribed	Priority
		10B. Assess stability of TMF technical components considering site soil properties and appropriate safety criteria	Short-term
		10C. Assess the feasibility of measures to stabilize/strengthen the dam	Short-term
11	Pipeline documentation is incomplete	11A. Update or design documentations for pipeline locations and routing	Short-term
12	Construction procedure is/was not observed properly	12A. Provide on-site monitoring of adherence to safety regulations and margins during construction phase	Short-term
		12B. Include the construction procedure into design documents	Short-term
		12C. Study the feasibility of modifying the design of TMF components including the dam and the tailings pond	Short-term
		12D. Perform the works to remove incompatibilities with the dam design	Mid-term
		12E. Put the TMF into operation according to international or national regulatory requirements	Mid-term
13	Humus layer was not removed and stored properly at the site	13A. Study the feasibility of removing humus layer for future rehabilitation	Short-term
		13B. Allocate and equip the site for storing the removed humus layer for future rehabilitation	Mid-term
		13C. Remove humus layer and store it for future rehabilitation	Mid-term
14	The TMF is not equipped with protective screens	14A. Study the feasibility of constructing the top cover that reduces air dusting	Short-term
		14B. Study the feasibility of constructing the protective bottom shield to prevent pollutant leakage into ground water	Short-term
		14C. Construct, if justified, the top cover	Mid-term
		14D. Construct, if justified, the bottom protective screen	Mid-term

No	Problem to be solved	Measures prescribed	Priority
		OPERATION AND MANAGEMENT	
15	The TMF operation manual is incomplete or not amended regularly	15A. Prepare/Update the TMF operation manual according to requirements	Short-term
		15B. Check the consistency of the TMF operation manual	Short-term
		15C. Perform the expert assessment of the TMF operation and waste management plans, and approve them	Short-term
		15D. Update/Modify the TMF operation manual with procedures regulating acid mine drainage operations	Short-term
16	Hazardous materials and substances are stored inappropriately	16A. Define the measures intended to isolate and neutralize hazardous materials and substances	Short-term
		16B. Change locations of the sites used for storing hazardous materials	Mid-term
		16C. Create the capacities (spaces) for joint storage of hazardous materials equipped with additional isolating baffles	Mid-term
17	Acidic water collection and neutralization is absent	17A. Analyse the feasibility of neutralizing acid/base tailings materials	Short-term
		17B. Consider the applicability of neutralization technologies to tailings materials	Short-term
		17C. Create the tanks for storage of alkalis and other neutralizing agents or increase their capacity	Short-term
		17D. Install and put into operation equipment for neutralization of acidic (water hazard) solutions and materials using alkali solutions before the disposal to the TMF	Mid-term
18	Transportation facilities including pipelines do not comply safety requirements	18A. Conduct testing of special parts of the pipeline (tees, nozzles) including fittings and document the results under the design pressure and under the excessive pressure.	Short-term

No	Problem to be solved	Measures prescribed	Priority
		a) testing is performed with water, test pressure exceeds the maximum allowable working pressure of a pipeline by 1.3 times;	
		b) testing is performed with nitrogen or air, test pressure exceeds the maximum allowable working pressure of the pipeline by 1,1 times	
		18B. Measure the wall thickness in selected parts of the pipeline and check the sufficient wall thickness by calculation and non-destructive test (f. e. ultrasound)	Mid-term
		18C. Measure the pipe length regarding to possible thermal expansion	Mid-term
		18D. Equip the pipelines with internal coatings (coverings) resistant to corrosion	Short-term
		18E. Install compensators to changes in pipelines caused by thermal expansion	Mid-term
		18F. Prepare the plans per rational routing the most important pipelines while minimizing the number of intersection points	Short-term
		18G. Check correct positioning of certain points of the support and location of supporting structures	Short-term
		18H. Perform maintenance of supporting structures	Short-term
		18I. Create barriers and protection against hits (concrete walls, steel beams, earthen dams)	Short-term
		18J. Install pipelines above the ground with a casing pipe and the catching ditch in which the fluid leakage can be detected by the personnel or sensors	Mid-term
		18K. Install the pipeline in such way that the water level at the maximum flood within the last 100 years is below the lower edge of the pipeline	Mid-term
		18L. Check pipeline and pump condition in regular intervals and confirm them in written	Mid-term
		18M. Check the systems for tailings transportation, except pipelines, on meeting the applicable safety requirements	Mid-term

No	Problem to be solved	Measures prescribed	Priority
		18N. Develop the methods for emergency shut-off of tailings materials transportation in case of pipeline rupture	Short-term
19	Dam characteristics are insufficient to retain tailings materials	19A. Draft/Implement the design for dam raising	Short-term
		19B. Increase the height of separating earthen walls	Short-term
		19C. Strengthen the dam using grouting and/or drainage curtains	Mid-term
		19D. Assess the possible dam failures and dam stability	Short-term
		19E. Equip the TMF with emergency spillways and additional tanks and ponds for collecting emergency overflows	Mid-term
		19F. Detect locations of piping, water pathways/leakage through the dam body and locations of slope instability	Mid-term
20	Drainage water is not treated and/or removed in an appropriate way	20A. Elaborate the list and schedule of the measures for drainage water treatment	Short-term
		20B. Perform regular visual inspection of the equipment located in the areas of storage and handling that is connected to the drainage system	Short-term
		20C. Take samples of drainage waters from production equipment before the inlet into the surface waters and discharge into the settling ponds	Short-term
		20D. Equip the dewatering devices on retaining constructions with simple locks	Short-term
		20E. Install or modernize available facilities for drainage water treatment	Mid-term
		20F. Permanently monitor drainage water streams using automatic analysers	Short-term
		20G. Create an opportunity for the time-limited separation or blocking of diverting channels in case of accident.	Short-term
21	Drainage facilities do not meet operating conditions or requirements	21A. Collect and analyse the available data on the intensity of precipitation and floods if possible for the last 100 years, or sufficient to support calculations of a 1:100 year return event	Short-term

No	Problem to be solved	Measures prescribed	Priority
		21B. Elaborate technical measures for adjusting the water level in the tailings pond in case of heavy rainfalls and to prevent dusting of dry tails	Short-term
		21C. Install additional drainage facilities	Mid-term
		21D. Create accumulating ponds for catching water in case of severe floods	Mid-term
		21E. Increase capacity of the accumulating ponds to contain waters in case of severe floods	Mid-term
		21F. Increase throughput of TMF drainage facilities	Short-term
		21G. Create or repair the upper ditch to reduce surface water run-off into the tailings pond	Short-term
		21H. Make physical-chemical analysis of drainage water	Short-term
		21I. Provide, if justified, discharge of drainage water back to the tailings pond	Mid-term
		21J. Develop the list of technical measures on recovery and/or re-use of process water	Short-term
		21K. Repair/Modernize existing drainage facilities according to design documents or the new drainage design	Short-term
22	TMF are not secured properly	22A. Equip the TMF with facilities preventing unauthorized access	Short-term
		22B. Create sprinkler systems for fire-fighting purposes	Short-term
23	Monitoring schedule and/or network is incomplete	23A. Bring the monitoring plan in compliance with the design and applicable requirements	Short-term
		23B. Eliminate inconsistencies in the TMF monitoring schedule	Short-term
		23C. Check the conformity of checkpoints to the design documentation	Short-term
		23D. Analyse technical conditions of the monitoring network	Short-term
		23E. Perform an expert assessment on upgrading the monitoring network	Short-term
		23F. Equip the TMF site with additional wells and checkpoints for monitoring basic parameters (see Recommendations to TMF monitoring)	Mid-term

No	Problem to be solved	Measures prescribed	Priority
		23G. Carry out technical upgrading of checkpoints	Mid-term
		23H. Regularly check monitoring parameters (see Recommendations to TMF monitoring)	Mid-term
		23I. Submit regularly monitoring data to local authorities and emergency departments	Mid-term
		EMERGENCY PLANNING	
24	Emergency plan is not developed or incomplete	24A. Modify/Review the emergency plans to take into proper account monitoring data, environment impact assessments and effectiveness of measures	Short-term
		24B. Develop procedures for the emergency plan	Short-term
		24C. Develop the procedure(s) missing in Emergency plan according to applicable requirements	Short-term
		24D. Install an automated early warning system on critical parameters.	Mid-term
		24E. Integrate a TMF early warning system into the alert system for local government / Ministry of Emergency Situations	Mid-term
		24F. Develop the procedures for warning and evacuation of population in case of threats caused by accidents at the TMF	Short-term
		24G. Establish the procedure for reporting on accidents and emergencies	Short-term
		24H. Regulate the procedure for informing the public about accidents and emergency situations	Short-term
		24I. Work out and implement measures limiting the access to hazardous TMF elements	Mid-term
		24J. Specify high-priority activities to eliminate potentially emergency situations	Short-term
		24K. Consolidate resources for emergency response	Mid-term

No	Problem to be solved	Measures prescribed	Priority
		24L. Include the procedures for elimination of emergency after-effects into the emergency plan	Mid-term
25	TMF staff does not have the proper qualification and skills	25A. Develop the program for training and advanced training of the TMF staff	Short-term
		25B. Regularly perform training for TMF staff and document it	Mid-term
		25C. Implement two-way approach for staff training informing mining engineers of issues in environmental and safety management and, conversely, giving environmental personnel the insights needed to deal with TMF issues	Mid-term
26	Strategy for accident prevention has not developed	26A. Develop Major Accident Prevention Policy and Safety Management System adopted for the TMF	Mid-term
27	Safety measures were not developed and documented to prevent from emergencies and accidents	27A. Develop appropriate safety and protective measures in case of emergencies during construction and operation	Short-term
		27B. Justify protective measures in terms of "cost-effectiveness"	Short-term
28	Procedures for validation, review, and acceptance of emergency plans have not been developed and documented	28A. Develop the procedures for validation, review, and acceptance of emergency plans	Short-term
		28B. Document the damage to facilities in case of accidents	Short-term
		28C. Maintain the documentation on damage to facilities in case of accidents and emergencies	Short-term
		28D. Develop and approve the procedure and provisions for regular auditing of the TMF	Short-term
		28E. Appoint staff responsible for auditing the TMF	Short-term
29	Emergency plans are not complete, agreed or updated	29A. Develop/Update the emergency plan taking into account specifics and features of the TMF site	Short-term
		29B. Regularly submit monitoring data to local emergency departments	Mid-term

No	Problem to be solved	Measures prescribed	Priority
		29C. Update the emergency plan	Short-term
		29D. Perform the expert assessment of accidental cases occurred previously	Short-term
		29E. Mutually agree internal and external emergency plans	Short-term
30	The preparedness of responding to emergency situations is insufficient	30A. Develop the response plan in case of emergencies	Short-term
		30B. Develop the program of trainings and field exercises of responding to emergency situations for TMF staff	Short-term
		30C. Regularly conduct trainings and field exercises to enhance the TMF staff preparedness to emergencies	Mid-term
		30D. Accumulate resources for responding to emergency situations	Short-term
		CLOSURE AND REHABILITATION, ABANDONED TMF	
31	The TMF closure plan is absent or insufficient	31A. Develop an action and monitoring plan for TMF closure	Short-term
		31B. Amend the TMF closure plan according to applicable requirements	Short-term
		31C. Develop the plan of landscaping and restoration of water resources during TMF closure	Short-term
		31D. Study the feasibility of using tailings materials as secondary raw	Short-term
		31E. Reassess the preservation and further monitoring stages using Factor of safety set by national regulations/requirements	Mid-term
		31F. Develop the schedule and regulations of accomplishing the engineering measures for mitigating the after-effects of TMF operation	Short-term
		31G. Include monitoring procedures into the closure and rehabilitation plans	Short-term
		31H. Appoint personnel responsible for control over the closed / rehabilitated TMF	Short-term
32	TMF stability was not checked during closure	32A. Perform an expert assessment on TMF stability during closure	Short-term
		32B. Develop/Implement measures to ensure TMF stability during closure	Short- and mid-term

No	Problem to be solved	Measures prescribed	Priority
33	Long-term stability of the TMF is not ensured after closure	33A. Develop a long-term strategy and action plan for rehabilitation of the TMF site	Mid-term
34	Reclamation and landscaping plans are absent or incomplete	34A. Establish the cause of non-implementing the plan for TMF reclamation and landscaping, revise this plan	Long-term
		34B. Elaborate technical measures for rehabilitation of the TMF using suitable topsoil	Long-term
		34.C. Elaborate technical measures for phyto-rehabilitation of the TMF site	Long-term
35	Protective measures for mitigation of TMF after-effects are not applied	35A. Develop/Implement the measures ensuring TMF stability after closure	Long-term
		35B. Develop/implement the schedule and network to monitor the environment during and after TMF rehabilitation	Long-term
		35.C. Employ the technologies that minimize the volume and toxicity of tailings materials with maximum extraction of useful components	Long-term
		35.D. Employ biological methods of TMF remediation including phytoremediation, life barrier of perennial trees etc. if applicable	Long-term
36	The TMF is abandoned and not maintained properly	36A. Assign a competent body or find a company responsible for maintenance and care of the TMF	Short-term
		36B. Check the documentation of the abandoned TMF	Short-term
		36C. Define the emergency protection strategy for the abandoned TMF	Short-term
		36D. Perform the initial screening procedures for the abandoned TMF and document the results	Short-term
		36E. Define monitoring and maintenance procedures for the abandoned TMF	Short-term
		36F. Inspect the main structures of the abandoned TMF	Short-term
		36G. Develop risk management strategy based on the assessment of risks posed by the abandoned TMF	Short-term

Appendix 5. Example of the Report on Safety Level Evaluation of a TMF

Report on Safety Level Evaluation

of the Tailings Management Facility No 2

of State Enterprise "Potassium Plant" JSC "Oriana", Kalush, Ukraine

Content:

Introduction

As a part of the international project "Improving the safety of industrial tailings management facilities based on the example of Ukrainian facilities", the 2nd seminar training was held during the period 04 - 07th of November, 2014 in Ivano-Frankivsk city (Ukraine). The Ukrainian inspectors and representatives of Ministries and regional authorities, Tailings management facility (TMF) operators and international experts from Armenia, Georgia, Romania, Sweden, the ICPDR and the World Bank participated in the seminar training.

The groups of experts (trainees) evaluated the TMF safety levels with methodological assistance from the Ukrainian project team (trainers) for two TMFs; these being TMF No 1 and No 2 of the State Enterprise (SE) "Potassium Plant" JSC "Oriana" in Kalush city. A representative of the company accompanied each group; thereby experts (trainees) were able to interview these persons during TMF evaluation. This Report summarizes the findings of the TMF No 2 safety level evaluation, performed on the basis of the Methodology for improving TMF safety (Draft), version 4.0 dated 15-10-2014 (the latest version of the methodology available at the time of TMF evaluation).

The evaluation objective is to improve the TMF safety level through the examination of minimum set of the TMF technical safety requirements (applying the TMF Checklist) and developing recommended technical measures for implementing of European standards for the safe operation of TMFs (using the Measure Catalogue).

The main evaluation tasks to be implemented were:

- to detect non-compliances with the minimum set of the safety requirements at the TMF applying the TMF Checklist;
- to identify the troublesome spots/areas of the evaluation object;
- to select appropriate technical measures for implementing of European standards for the safe operation of TMFs from Measure Catalogue.

Evaluation procedure

As per the TMF Methodology, version 4.0 dated 15-10-2014 (the latest version of the methodology available at the time of TMF evaluation) TMF safety level evaluation involves the following working steps:

1. Elaboration of the TMF Evaluation Program.
2. Familiarization with the TMF:

- elaboration and send out of the list of general information required for TMF safety level evaluation;
- receipt of the “Brief summary of the TMF company”.

3. Visiting the TMF site.

Preparatory works for the visit to the TMF site included the following steps:

- studying the “Brief summary of TMF company” provided by the TMF operator;
- elaboration of the “Site-visit Plan” including the “Work plan on the site” and a preliminary list of documents requested for evaluation; and
- sending the “Site-visit Plan” to company managers.

The site-visit includes the following sequence of activities:

- introductory meeting;
- interview of staff;
- receipt, review, and study of documents;
- visual inspection of the TMF (photographing);
- taking notes on the information received after inspection;
- holding a concluding meeting.

4. Reporting on evaluation results:

- work on the TMF Checklist: filling the Checklist in MS Excel file (Groups A or B or C) on the basis of the documents and information of the company (interviewing, photos), selecting the measures for improving the TMF safety level;
- generating the final report in MS Word.

1. TMF Evaluation Program

The Ukrainian project team (trainers) developed and sent to the company SE “Potassium Plant” JSC “Oriana” the “Program of the TMF evaluation” on 18th of August, 2014 that is presented in Table 28 below.

Table 28: Program of the TMF evaluation

“Program of the TMF evaluation” using the TMF Checklist		
Name of the evaluation site/object: TMF No 2 of SE “Potassium Plant” JSC “Oriana”		
Site location (address and GIS coordinates): Ukraine, Ivano-Frankivsk Oblast, Kalush, 14 Promyslova Str.; GIS coordinates are 49°03'06''N, 24°17'13''E		
User Name (inspector / auditor): 1. Ukrainian project team (trainers). 2. Group of experts (trainees).		
Period of evaluation: from 18 August, 2014 to 15 November, 2014		
No	Stage of the TMF evaluation procedure	Terms (depend on the evaluated object)
1	Preparation of the “Request for general information about evaluation object (company and TMF)”	18 August, 2014
2	Elaboration and sending the “Site-visit Plan”	20 – 25 August, 2014
3	Site-visit to the object	Three site-visits are planned: 02 – 04 September, 2014 22 – 25 October, 2014 06 November, 2014
4	TMF evaluation using the TMF Checklist Methodology (MS Excel file) including the studying documents and information received during previous stages.	October – November, 2014
5.	Sending the additional request for TMF documents.	November, 2014
6.	Preparation of a report in MS Word.	08 – 15 November, 2014
Date of Program preparation: 18 August, 2014		

2. Familiarization with the TMF

Prior to the start of the application of the TMF Checklist trainers and trainees had familiarized themselves with the evaluation object (TMF No 2 of SE “Potassium Plant” JSC “Oriana”). For these purposes a list of general information required for TMF safety level evaluation was developed. The list was sent to the TMF operator as a request to obtain required information as a brief summary of the TMF company being evaluated. In response to this request the “Brief summary of TMF company” was received on 20th of August, 2014, which is outlined below.

Brief summary of TMF company

Kalush city and district are located in the north-western part of the Ivano-Frankivsk Oblast in western Ukraine, at the foot of the Carpathian Mountains. It is a major centre for the chemical industry, parts of which have ceased operations. In 2009, the area of mining activities in Kalush was declared an “emergency ecological situation zone”. The basis of this action was an emergency ecological situation pre-

vailing in this area due to the potassium salts' extraction and concentration on the Kalush-Holynske minefield.

There are a number of (open cast) mine sites around Kalush. One such site is adjacent to SE "Potassium plant" JSC "Oriana" and was established in 1967. Potassium-magnesium production continued until the plant was shut down in October 2001. Since then it has remained inactive. The salt deposits that were mined in the Dombrovski Open-Cast Mine were a prime source for SE "Potassium Plant" JSC "Oriana". There are five retaining structures for storage of liquid mining waste in the Kalush area: three TMFs and two saline solution ponds.

Brief information on TMF No 2 of SE "Potassium Plant" JSC "Oriana" is provided in Table 29. The Layout of the evaluation object is presented in Annex A to the Report. The general information provided by the TMF operator is indicated in Table 30 below.

Table 29: TMF No 2 brief information

Year of construction:	1984
Project documentation:	Available but not complete
Surface area:	48 ha
Volume:	10.7×10^6 m^3
Contents:	TMF No 2 is filled with solids and brine. Solid phase 9 $x10^6 m^3$; liquid phase $1.7\times10^6 m^3$
Leakage:	In 2006 a flood caused erosion
	Only partial repair works were carried out

Table 30: TMF No 2 general information provided by the TMF operator

No	Category	Information provided by the TMF operator
1	Technical information and design documentation: flowcharts, description of the production process used at the enterprise, specification of input raw materials, chemical and physical composition of tails, etc.	TMF No 2 is filled with solid waste and brine. The initial capacity of TMF is 6.5 million m3, and the total base area was 70 ha. The dam's height reached 15 m at the crest elevation of 323.0 m above see level (a.s.l.) and its maximum filling level of 321.5 m. The length of the dam's perimeter along the axis was 2985 m. The TMF's floor is made with deepening up to 4-5 m, with a base level of 304.0 m a.s.l. In 1993 the second phase of TMF's raising was started in order to increase the capacity up to 10.5 million m^3. The dam's height reached an altitude of 332 m a.s.l. During raising operations a liner such as high density polyethylene HDPE was not utilised. The drainage ditch has failed at present and is non-operational. The system of supervisory wells has not operated also for a long time. The Emergency plan for TMF No 2 is developed
2	Geographical site information: climatic conditions, including weather extremes, wind speed, precipitation, and floods.	TMF No 2 is located between the Kropyvnyk railway station and TMF No 1. The surface area where the TMF is located is flat with some surface slope towards Kropyvnyk river. The area's altitude ranges from 307 m to 312 m a.s.l. Climatic conditions: Kalush has a temperate continental climate. The average annual temperature is 7 – 10 °C. The area is characterized by hilly terrain consisting of Kalush valley and

No	Category	Information provided by the TMF operator
		hills of Voinyliv. Altitude ranges from 278 to 350 m a.s.l. The average annual rainfall is 788 mm, including 613 mm in the warm period and an average of 175 mm in the cold season. There is a great risk of spring floods, as the current levels of winter snowfall in the Carpathian Mountains are high. The area has suffered serious flooding – such as that which struck large areas in western Ukraine in the second half of 2008.
3	TMF Deposition Plan: maps, schemes, cadastral borders, adjacent infra-structures.	The Lay-out of the evaluation object is presented in Annex A to the Report
4	Geological and hydro-geological conditions: seismic activity, land-slides, faults, karst areas, soil properties, ground-water regime, etc.	The geological structure of the site location of TMF No 2 includes allu-vial-dealluvial loams and sandy loams which are underlain by a gravel-pebble aquifer. The latter lies in turn on Neogene clays. The thickness of loams and sandy loams is from 7.2 to 12.7 m, of gravel-pebble sedi-ments from 3.8 to 8.9 m. The hydrogeology of the area is characterized by a single pressure aqui-fer concentrated in gravel-pebble deposits
5	Ecological environment: flora, fauna, water and land ecosystems.	It has been observed that brine is seeping through the dam in places, especially at the eastern and western sides, the karst processes have started to develop along the dam on the TMF territory that leads to the formation of subsidence and brine filtration through the dam's body. The lower dam slopes in loaded areas are exposed to water erosion. All of these processes leads to environmental pollution
6	Social environment: loca-tion, condition and size of communities and settle-ments; land use, access to the TMF territory.	TMF No 2 is located in the area of Kalush city. The city is located in western portion of the Ivano-Frankivsk Oblast, within the region of Western Ukraine at the foothills of Carpathian Mountains. It is a city of regional subordination with total area 6453.5 ha and population of 67 900 people. Distance to the nearest settlement is 0.85 km. The TMF area is accessi-ble to anyone

No	Category	Information provided by the TMF operator
7	Risks to: surface water bodies, groundwater, air, soils, and biota.	Overflow of brine through the dam's body may occur during intense rainfall, which may lead to slopes erosion, dam destruction and brine penetration to the external ponds in large volumes. If the level is allowed to rise and no actions are taken, the impoundment will eventually overflow. As the TMF is filled with brine, equilibrium will be reached between the seepage water and the salt in the waste. The dam's structural stability can be considered as good under normal loading conditions. However, under high groundwater pressure and/or earthquake loading, the stability might be significantly reduced. Precipitation collected along the slopes has caused surface erosion. The western part of the dam is furthermore affected by subsidence caused by underlying the Novo-Holin mine. Future significant subsidence may cause cracking of the retaining structure and may result in a severe spill through the failure. Due to intense precipitation in Prykarpattia in March and April 2005 significant rainfall erosion channels were formed in a protective dam's body of TMF No 2, the brine level in TMF increased significantly and exceeded the projected level of brine and filling level. This it turn led to the decrease of tailings dam stability and can lead to unpredictable large scale environmental consequences
8	Stored material: hazardous substances and materials stored in the TMF.	TMF No 2 is filled with solid waste and brine. During the operation stage of the Dombrovski open-cast mine and production of potassium salts TMF No 2 was receiving waste products, brine of Dombrovski open-cast mine and precipitation with total volume of 7,96 million m3 per year. The solid fraction of waste (halite, tailings, sludge, gypsum, etc.) deposited in the TMF in amount up to 1,16 million m3 per year. Clarified brine in amount of 6,81 million m3 per year was returned to the plant
9	TMF history: construction and operation periods, contractor(s), accidents occurred.	In order to avoid brine filtration from TMFs, a stabilized polyethylene membrane has been laid at the bottom and inner slopes of the dam protected by a layer of sandy loam. There is also a polyethylene membrane between five and seven meters on the slopes of the starter dam. A watertight cut off wall was applied as watertight measure while raising the dam. In order to capture the filtering brine a drainage tray with precast concrete components was placed at the foot of the dam's bottom slope that was raised on the reclaimed beach. The near-wall space of trays from the side of dam's body was layered with gravel. The pumping-over of drainage flow was performed in TMF. At present the drainage system is destroyed and non-operational
10	TMF management: bodies/persons responsible for TMF operation/maintenance.	Volodymyr Yurkiv – Readjustment Manager, SE "Potassium Plant" JSC "Oriana" Igor Korchynskyi – Director of SE "Potassium Plant" JSC "Oriana"

3. Visiting the TMF site

The Ukrainian project team (trainers) developed and sent the "Site visit plan" including the "Work plan on the site", and a preliminary list of documents requested for evaluation to the company on 25th of August, 2014.

The evaluation object was visited three times. The Ukrainian project team (trainers) visited TMF No 2 on 02 – 04th of September, 2014 and on 22 – 25th of October, 2014. During the 2nd seminar training, the group of experts (trainees), with methodological assistance of Ukrainian project team (trainers), has visited the evaluation object on 06th of November, 2014. All site visits were held according to the proposed time schedule and sequence of activities, namely:

- introductory meeting;
- interview of staff;
- receipt, review, and study of documents;
- visual inspection of the TMF (photographing);
- taking notes on the information received after inspection;
- holding a concluding meeting.

All planned preparatory works under the "Program of the TMF evaluation" were accomplished; by that result the group of experts (trainees) proceeded to the stage "TMF Checklist application".

4. Evaluation results and recommended measures

Upon the receipt of all necessary information (site documents, staff interviews and photos) and after site visits the group of experts (trainees) proceeded to the office work in order to evaluate the TMF safety level using TMF Checklist.

The trainees applied the following sequence of actions for evaluation:

1. Filling the TMF Checklist in the MS Excel file (Groups A, B and C) on the base of documents and TMF company information (interviews and photos) in order to evaluate the TMF safety level and select the recommended measures to improve the TMF safety level.
2. Upon filling the TMF Checklist in the MS Excel file the trainees generated this Report on the work performed and the results obtained, drew conclusions and outlined plans for further actions to improve the safety at the TMF site.

The evaluation results of TMF Checklist application for TMF No 2 of SE "Potassium Plant" JSC "Oriana" are presented below in Tables 31 – 32 and Figure 9.

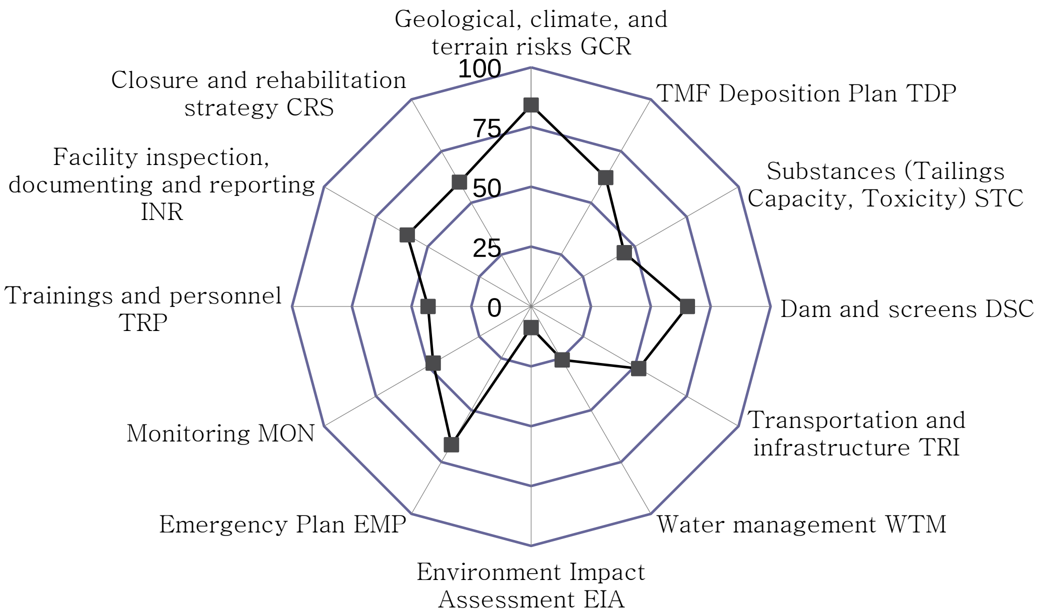
Table 31: The overall evaluation of the TMF safety level

Maximum score, items	846
Total number of questions	282
Total score, items	451
The number of ambiguous answers ("mostly yes" and "mostly no")	118
Credibility, %	58.2
Total score Safety	**451**
Overall Safety evaluation, %	**51.7**

Table 32: Categorial evaluation of the TMF safety level by Group B

No	Category	Abbreviation	Question quantity	Evaluation result, %
I	Geological, climate, and terrain risks	GCR	19	84.2
II	TMF Deposition Plan	TDP	15	62.2
III	Substances (Tailings Capacity, Toxicity)	STC	23	44.9
IV	Dam and screens	DSC	25	65.3
V	Transportation and infrastructure	TRI	9	51.9
VI	Water management	WTM	22	25.8
VII	Environment Impact Assessment	EIA	19	8.8
VIII	Emergency Plan	EMP	48	66.7
IX	Monitoring	MON	31	47.3
X	Trainings and personnel	TRP	17	43.1
XI	Facility inspection, documenting and reporting	INR	29	59.8
XII	Closure and rehabilitation strategy	CRS	25	60.0

Figure 9: Spider diagram of the categorial evaluation (the values of all categories are in per cent)



Recommended actions

Analysing each TMF Checklist question that was not answered with a clear positive response (answers "no", "mostly no", or "mostly yes") the following recommended measures prescribed by the Measure Catalogue were selected (Table 33). According to the result of the TMF evaluation, the individual investment program aimed at improving the TMF safety level should be elaborated by TMF operator and then approved by competent authorities.

Table 33: Recommended measures to improve TMF No 2 safety level

No	Recommended measures
Short-term measures	
1	1C. Perform expert analysis of design documents for authorities
2	1D. Prepare or complete design documentation according to regulatory requirements
3	2A. Discuss the TMF projects with local authorities and public
4	2B. Inform local communities and NGOs on the essence of the TMF projects and get their opinion
5	3A. Assess pollution risk to ground waters
6	3B. Assess pollution risk to surface waters
7	3C. Assess pollution risk to soils near the TMF site
8	3D. Assess pollution risk to air quality
9	3F. Assess flooding risk for the TMF
10	4A. Perform the study per possible accident scenarios and their after-effects
11	4D. Assess the impact of TMF on the environment and health of population
12	5A. Consider alternative options of TMF location and give relevant recommendations
13	6A. Calculate water balance of the TMF
14	7A. Assess the impact of nearby TMFs, other hazardous sites near the TMF site, and/or possible trans-boundary effects
15	10C. Assess the feasibility of measures to stabilize/strengthen the dam
16	12A. Provide on-site monitoring of adherence to safety regulations and margins
17	12C. Study the feasibility of modifying the design of TMF components including the dam and the tail-ings pond
18	14B. Study the feasibility of constructing the protective bottom shield to prevent pollutant transport in ground waters
19	15C. Perform the expert assessment of the TMF operation and waste management plans, approve them
20	20B. Perform regular visual inspection of the equipment located in the areas of storage and handling that which is connected to the drainage system
21	20C. Take samples of wastewaters from production equipment or the waste stream before the inlet into the surface waters and discharge into the settling ponds
22	21A. Collect and analyse the available data on the intensity of precipitation and floods, if possible, for the last 100 years, or sufficient to support calculations of a 1:100 year return event
23	21B. Elaborate technical measures for adjusting the water level in the tailings pond in case of heavy rainfalls and to prevent dusting of dry tails
24	21H. Make physical-chemical analysis of drainage water
25	23A. Bring the monitoring plan in compliance with the design and requirements
26	23D. Analyze technical conditions of the monitoring network
27	23E. Perform an expert assessment on upgrading the monitoring network
28	24A. Modify/Review the emergency plans to take into proper account monitoring data, environment impact assessments and effectiveness of measures

No	Recommended measures
29	25A. Develop the program for training and advanced training of the TMF staff
30	28E. Appoint staff responsible for TMF auditing
31	29A. Develop/Update the emergency plan taking into proper account the specifics of the TMF site
32	29C. Renew the emergency plan
33	29E. Mutually agree internal and external emergency plans
34	30B. Develop the program of trainings and field exercises of responding to emergency situations for TMF staff
35	31H. Appoint personnel responsible for controlling the closed/rehabilitated TMF
36	32A. Perform an expert assessment on TMF stability during closure
37	32B. Develop/Implement measures to ensure TMF stability during closure
Mid-term measures	
38	21C. Install additional drainage facilities
39	21E. Increase capacity of the accumulating ponds to contain waters in case of severe floods
40	23H. Regularly check monitoring parameters
41	24K. Consolidate resources for emergency response
42	25B. Regularly perform training for TMF staff and make corresponding records
43	25C. Implement two-way approach for staff training informing mining engineers of issues in environmental and safety management and, conversely, giving environmental personnel the insights needed to deal with TMF issues
44	29B. Regularly submit monitoring data to local emergency departments
45	33A. Develop a long-term strategy and action plan for rehabilitation of the TMF site
Long-term measures	
46	34B. Elaborate technical measures for rehabilitation of the TMF using suitable topsoil
47	35A. Develop/Implement the measures ensuring TMF stability after closure

Conclusions

As a part of the international project “Improving the safety of industrial tailings management facilities based on the example of Ukrainian facilities”, the group of experts (trainees) evaluated the safety level of TMF No 2, SE “Potassium Plant” JSC “Oriana” in Kalush, Ivano-Frankivsk Oblast. They have examined the minimum set of the TMF technical safety requirements. Through the application of the TMF Checklist the following conclusions have been made:

1. Overall Safety evaluation equals 51.7%. The TMF safety level is identified as “Unacceptable”.
2. The following troublesome issues of TMF No 2 are identified as a result of evaluation:

- Environment Impact Assessment;
- Water management;
- Training and personnel;
- Substances (Tailings Capacity, Toxicity);
- Monitoring.

All of the listed above categories have an evaluation result below 50% and are critical (highly important) for TMF safety. The TMF operator's attention and priority measures should be focused on the lowest percentage categories.

3. The recommended measures to improve TMF safety are listed above in section "4. Evaluation results and recommended measures". Among them there are 37 short-term measures, 8 mid-term and 2 long-term measures. It is recommended that short-term measures be completed no later than 3 months after prescription as available resources of the TMF operator are sufficient to provide low-cost measures or actions.
4. According to the result of TMF safety level evaluation the individual investment program aimed at improving the TMF safety level should be developed by the TMF operator and then approved by competent authorities.

References

Regulatory documents:

1. Methodology for improving TMFs safety (Draft), version 4.0 dated 15-10-2014 (the latest version of the methodology available at the time of TMF evaluation).
2. Checklist System for Safety Reports. Instructions for preparation and inspection of a safety report (SR) in accordance with UNECE Convention on the transboundary effects of industrial accidents and the EU Directive 96/82/EC (SEVESO II) by a consistent Checklist system. Umweltbundesamt, 54 p.
3. Checklisten für die Untersuchung und Beurteilung des Zustandes von Anlagen mit wassergefährdenden Stoffen und Zubereitungen (2006). Umweltbundesamt.
4. Classification of mining waste facilities (2007) Final Report. Prepared by DHI Water Environment Health in cooperation with SGI, Swedish Geotechnical Institute and AGH, University of Science and Technology, Krakow. European Commission, DG Environment, 204 p.
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11. Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities (2009) European Commision, 517 p.
12. Safety guidelines and good practices for tailings management facilities. (2014) UNECE. New York and Geneva, 34 p.
13. Tailings pits and sludge stores. National Standard of Ukraine. ДБН В.2.4-5:2012. Part I. Planning. Part II. Building. (2012) Kyiv, 70 p.
14. ISO 19011:2011 – Guidelines for auditing management systems. Second edition 2011-11-15. Reference number ISO 19011:2011(E), 52 p.

Company documents used for evaluation of TMF safety levels:

1. Brief information on tailings management facilities No No 1, 2, 3 and Dombrovski open-cast mine of SE “Potassium Plant” JSC “Oriana” in Kalush. (2014) Kalush and Dnipropetrovsk, 16 p. This document was prepared by the Ukrainian project team (trainers) based on data and documents obtained from the company including interviewing the staff and on the basis of other sources of scientific and technical information.

Annex A (to the Example of Safety Level Evaluation of the Tailings Management Facility No 2 of State Enterprise "Potassium Plant" JSC "Oriana", Kalush, Ukraine)

Figure 10: The layout of the TMF site (1:30 000)

Appendix 6. Development and application of the educational course on TMF safety

The educational course “Safety of Tailings Management Fasilities” was developed within the project “Improving the safety of industrial tailings management facilities based on the example of Ukrainian facilities” (2013-2015) for training and re-training of TMF Checklist users. The project team conducted two educational trainings as part of the testing of the TMF Methodology (Table 34).

This course has been deeply revised within the project "Raising Knowledge among Students and Teachers on Tailings Safety and its Legislative Review in Ukraine" (2016-2017) based on the results of trainings conducted at National Mining University (Dnipro, Ukraine). The developed course was included in the curricula of four universities participating in this project which are “National Mining University”, Prydniprovska State Academy of Civil Engineering and Architecture, the National Metallurgical Academy of Ukraine and Dnipropetrovsk State Economic and Agrarian University. A new e-learning tool based on the TMF Methodology has been developed and hosted on the NMU online Moodle platform.

Table 34: Educational trainings on testing the TMF Methodology in Ukraine

Place of testing conduction	Date	Object	Participants
The city of Lviv	May 13-15, 2014	Operational TMF. Central Concentrating Factory "Chervonohradska", PJSC “Lviv coal company”, Chervonohrad	10 trainees from Ukraine, Georgia and Armenia
The city of Ivano-Frankivsk	November 4-7, 2014	Two non-operational TMFs. Subsidiary “Potassium plant” OJSC “Oriana”, Kalush	12 trainees from Ukraine, Georgia and Armenia
The city of Dnipro	October 3-7, 2016	Operational TMF. Thermal Power Plant “Prydniprovska”, Dnipro	20 students, 4 tutors, international experts
The city of Dnipro	November 22-26, 2016	Operational TMF. Thermal Power Plant “Prydniprovska”, Dnipro	20 students, 4 tutors

The objective was to train representatives of the TMF operators, state inspectors, ecological auditors of Ukraine and other countries–that are potential Checklist users– in how to apply the TMF Methodology in the practice.

The following materials required to guide the collection of theoretical information and explaining the procedure of practical application are provided to the course participants:

- the training program with training stages, module structuring, and timetable;
- materials for preliminary familiarization with the topic that support the preparatory part of the training;
- texts of the lectures;
- examples of calculations using Methodology templates.

And in addition, the participants are provided with the following opportunities for learning:

- individual consultations of the trainers;

- site visits to the TMF sites accompanied by lecturers that were part of the development team for the Methodology and TMF personnel.

Regarding the permanent progress in technologies the content of the course is constantly updated and made more detailed taking into account the audience preparation level, country/region specifics by adding new theoretical and practical modules, recommendations and tests to consolidate knowledge.

The intended users of the Methodology are the representatives of competent authorities, inspectors, TMF operators and independent auditors, students of environmental and mining curricula. The course participants may have distinctly different levels of preparation and work experience. Therefore, the course was developed for the participants with different levels of education, occupation, and work experience in fields related to TMF operation.

This flexible course provides an opportunity to obtain full and consistent information; these include the introduction to the TMF issues, importance, scopes, operation problems of the TMFs as high-risk facilities, and application of the Methodology in practice.

As the course is multidisciplinary, it is vitally important to have different modifications that are adapted to specific requirements of different groups of trainees. This can be done using separate educational modules. The quantity of the modules, their sequence, details, and time to be spent for each module can be modified.

The course "Safety of Tailings Management Facilities" that comprises the lectures and questions for knowledge consolidation is provided as a separate document to the TMF Methodology.

By accomplishing this course the trainees are:
to know:

- the minimum set of requirements applicable to TMF safety based on the UNECE guidelines;
- the basic provisions of EC Directives and the best available techniques in mining waste management

and to be able to:

- recognize the hazards/risks related to TMF operation;
- rank the hazards of TMFs using Tailings Hazards Index (THI);
- identify the core elements of the TMF Checklist and correctly fill in its questions;
- evaluate the tailings safety based on the TMF Checklist;
- develop an investment program to improve TMF safety using Measure Catalogue;
- and correctly report on the evaluation of TMF safety.

The course consists of four education modules. The first module "TMF as the global challenge" provides basic information on the TMF structure and their importance in the international context. The second module "Legislative regulation of TMF safety" reviews the legislative frameworks of TMF operation and related problems in different countries, focusing on European and Ukrainian legislations. The third module "The essence and structure of the TMF Methodology" outlines the method of Tailings Hazard Index (THI), the TMF Checklist, safety evaluation criteria and Measure Catalogue. The fourth module "Practical application of the TMF Checklist" describes how the TMF Checklist should be practically applied, and provides the relevant example.

Each education module is followed by a set of test questions for knowledge consolidation.

Course activities comprise three parts.

1. Preparatory part based on distance learning (1-3 months ahead of the training) to be accomplished using remote communication (emails, Skype, etc.) with trainees:

- distribution of information packages that include the links to the sources of basic information on TMF issues, relevant international and national documents (UNECE Safety Guidelines…, the UNECE Convention on the Transboundary Effects of Industrial Accidents, national laws in waste of extractive industries, general approach of the Methodology, etc.) as well as the TMF Methodology, Checklist template in MS Excel for safety level evaluation, a summary of the TMF to be visited during the site visit;
- online consultation that includes the answers to questions of participants, comments and clarifications on the material provided for better understanding;
- assessment of the training effectiveness and students knowledge by a preliminary knowledge consolidation test and evaluation of trainees' readiness for the face-to-face session and the practical part of the course taking into account their previous experience).

2. Practical part – face-to-face session (2-3 days):

   - classroom training that includes lectures on key TMF problems and the essence of the TMF Methodology (1-2 days);
   - visiting the TMF site to conduct practical field training accompanied by trainers and TMF staff (1 day);
   - TMF safety level evaluation including the results of processing TMF documentation and field training and making the presentation on evaluation (first half of the last day of face-to-face session);
   - knowledge consolidation test and evaluation of the training (second half of the last day of the face-to-face session).

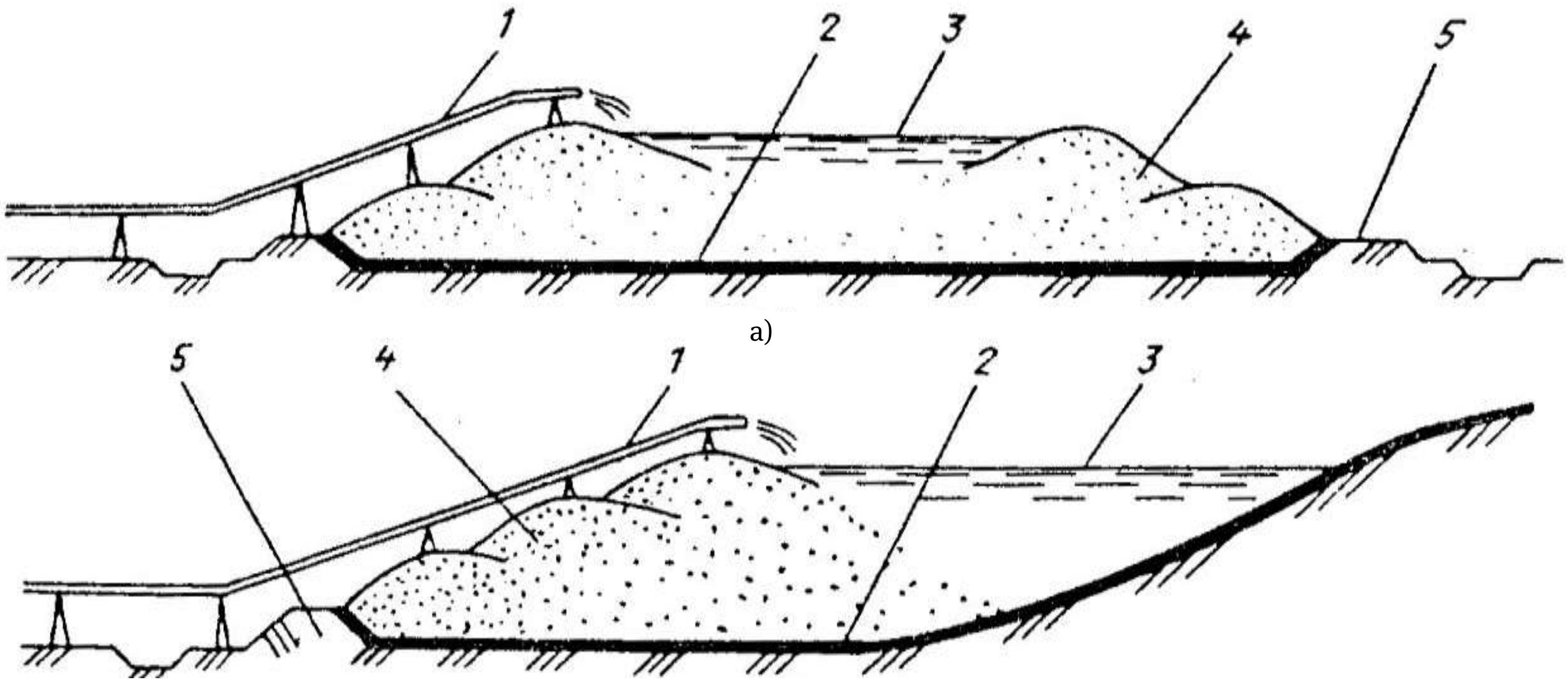
3. Post-training part that comprises consulting of participants by the trainers, which is important for implementation of the "train-the-trainer" approach.

The outlined sequence of training activities tested during two previous projects (Table 34) confirmed their relevance of selected forms of interaction "trainer-student/trainee" and the set of lectures. The selection of theoretical and practical tasks for preliminary independent studying and work in face-to-face session allowed participants to achieve the goals and objectives of the course in efficient and timely manner.

For the purpose of further development and application of the TMF Methodology in practice to improve the safety of Tailings Management Facilities on the national and/or international level it the trainings and workshops are organized in the UNECE region.

Appendix 7. Sketches of TMF and dams

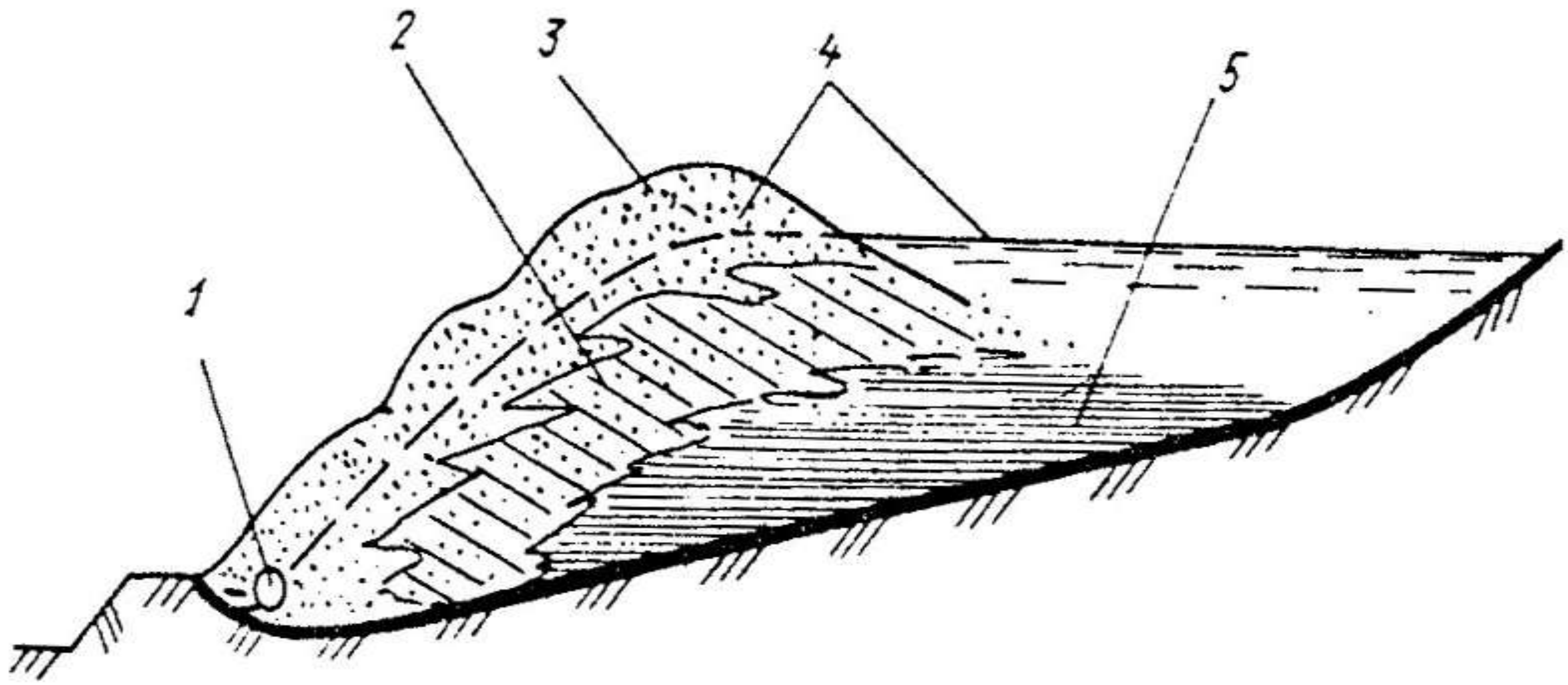
Figure 11: Structure of upstream impoundment (a) and ravine-type impoundment (b) of TMF



b)

1 – Tailings delivery system (pipeline)
2 – Low-permeability screen
3 – Water level in the impoundment
4 – Raised embankment
5 – Starter dam

Figure 12: Distribution of different fractions in the upstream tailings facilities



1 – Drainage
2 – Fine-grain sand and sludge fraction
3 – Coarse sand fraction
4 – Water level in the impoundment pond and the dam
5 – Sludge fraction

Figure 13: Sketch of major tailings dam types (reproduced from Vick, S.G. (1983). Planning, Design, and Analysis of Tailings Dams, John Wiley & Sons, New York, 1983, 369 p.)

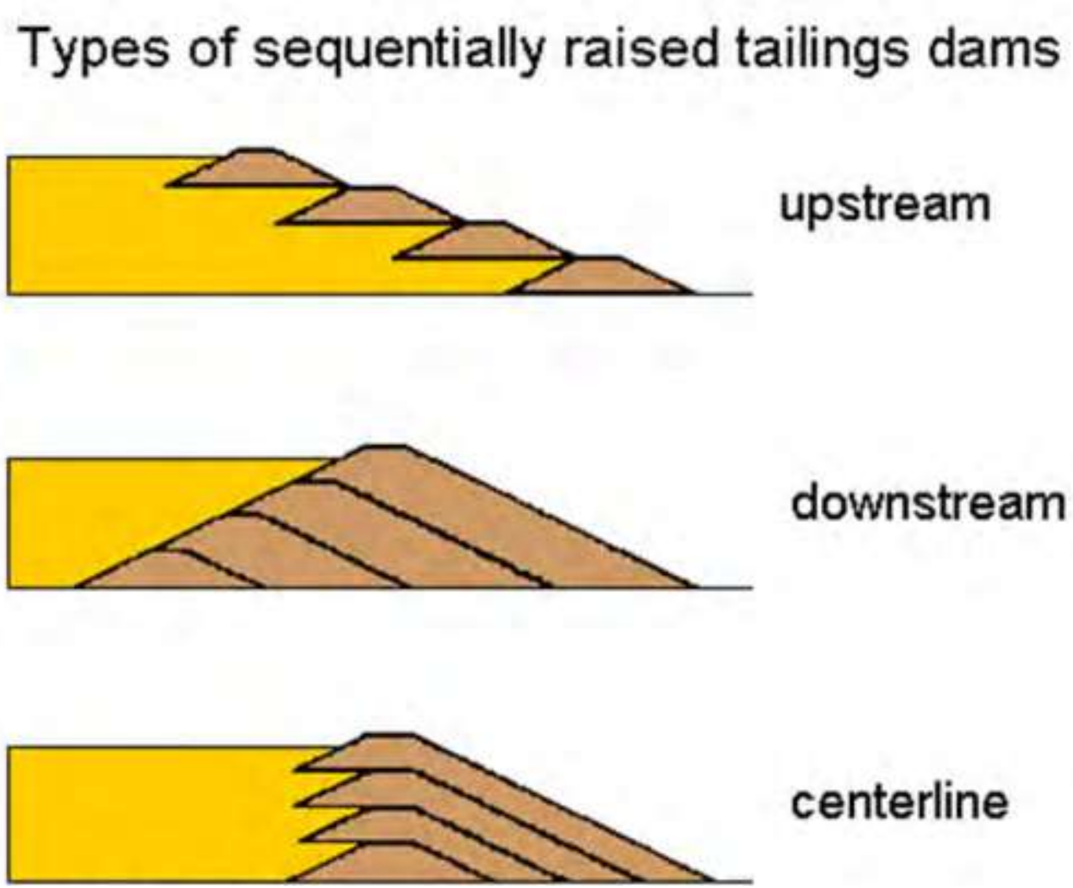
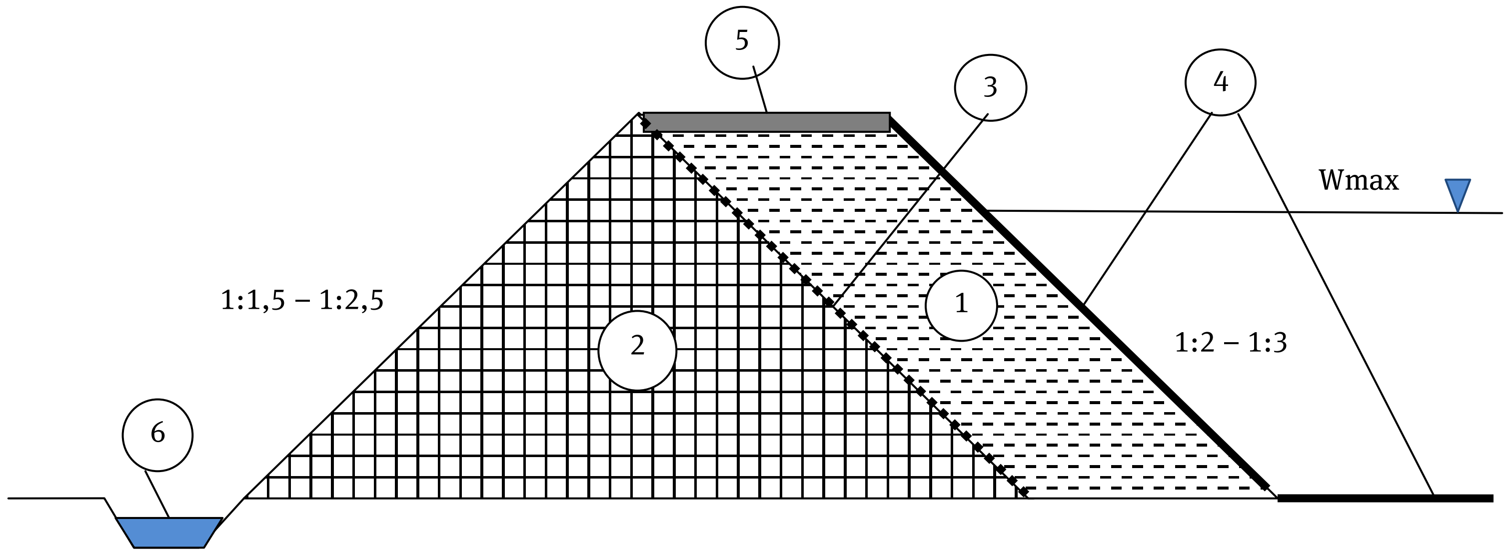


Figure 14: The sketch of the dam of a tailings pond/ mineral precipitate sludge



1 – Sealing section
2 – Support embankment (Blast rock)
3 – Filter and filter cloth
4 – Plastic or bitumen lining
5 – Crest (wedge, fastening crashed rock)
6 – Seepage collection drain
Wmax – maximum level of water in the tailings pond