SAFETY OF TAILINGS MANAGEMENT FACILITIES IN THE DANUBE RIVER BASIN

ICPDR IKSD
International Commission for the Protection of the Danube River
Internationale Kommission zum Schutz der Donau

Umwelt Bundesamt

INTRODUCTION

What are TMFs?

Mining is one of the most traditional industrial sectors in the world, and today only continues to grow in importance with the spread of smart technologies that require specific metals. However, mining also represents a significant source of various forms of mining waste. One type of the mining waste is the mining tailings that is the fine-grained waste material derived from a mining processing plant and is frequently transported by hydraulic methods to and deposited and handled in **Tailings Management Facilities (TMFs).** Reliable estimates put the number of TMFs worldwide at about 3,500.

How do TMF accidents happen?

Ideally, TMFs should ensure the safe long-term storage of mining waste. However, leaks and collapses can occur, stemming from both unfavorable natural conditions and manmade deficiencies in TMF design, construction and operation. Due to the hazardous nature of present substances and/or the sheer amounts of waste stored, TMFs can thus pose a risk to both environment and population – and this includes active, closed, abandoned or even rehabilitated sites. Notably, such accidents can directly impact human health, environmental resources and infrastructure, plus pollution of water bodies can have a significant transboundary effect, or lead to long-term water and soil pollution. The economic cost associated with cleaning up the contamination after a TMF failure may reach hundreds of millions of Euros.

Towards solution: the UNECE Safety Guidelines and the UBA TMF-Methodology

To address the rising concerns about TMF safety, the **Join Expert Group of the Industrial Accident and Water Conventions of the United Nations Economic Commission for Europe (UNECE)** developed the **Safety Guidelines and Good Practices for Tailings Management Facilities.**[1] These include recommendations to operators on technical standards for the safe design of TMFs and to authorities for the national regulations on issuing permits ensuring the safe operation of TMFs. To support the implementation of the guidelines, the **German Environment Agency (UBA)** elaborated a long-term strategy to improve TMF safety and developed a methodology for the evaluation of TMF safety along with a checklist serving as a toolkit for competent authorities and operators responsible for the safety of TMFs **(TMF-Methodology).**[2]

What is being done in the Danube River Basin?

The **International Commission for the Protection of the Danube River (ICPDR)** has been dealing with a wide variety of accidental pollution issues since its establishment in 1994, working to control and prevent hazardous accidents relating to water within the Danube River Basin (DRB). The ICPDR's further commitment to the EU's **Water Framework Directive** (WFD, 2000)[3] and the EU **Floods Directive** (FD, 2007)[4] saw all cooperating countries take on WFD and FD obligations, unifying efforts to meet 'good status' for waters and to mitigate flood risk, including adequate preventative measures against such incidents.

WHAT IS THE DANUBE TMF PROJECT?

More than 300 TMFs are located in the DRB, for which adequate safety conditions and measures have to be put in place. Past accident events dramatically demonstrated how serious impacts on people and water resources TMF failures could have, leading the ICPDR to implement the **Danube TMF Project**, on the initiative of and in cooperation with the UBA, to help Danube countries improve safety conditions of the TMFs.

On the long-run, this will ensure that a common set of minimum standards and safety requirements are respected in the DRB.

Building on the TMF-Methodology developed by the UBA, the main tasks of the Danube TMF project were:

- to amend the already existing "Tailings Hazard Index" method and to develop a "Tailings Risk Index" method;
- to update and evaluate the draft TMF inventory of the DRB;
- to revise the TMF Checklist for more adequate examinations on the technical safety requirements of operating TMFs;
- to revise and update the recommended technical measures to implement international standards for the safe operation of TMFs (Measure Catalogue).
- to provide recommendations for the Danube countries on how to ensure the safe design and operation of TMFs.

This brochure presents key outcomes of the Danube TMF project, including assessment of historical accidents, some basic tools to assess hazard and risk, an updated version of the TMF Checklist tool, a TMF inventory for the DRB and a pilot capacity building activity.

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[1] Safety guidelines and good practices for Tailings Management Facilities. United Nations Economic Commission for Europe, http://www.unece.org/environmental-policy/conventions/industrial-accidents/publications/industrial-accidents/official-publications/2014/safety-guidelines-and-good-practices-for-tailings-management-facilities/docs.html

[2] Improving the safety of industrial tailings management facilities based on the example of Ukrainian facilities. German Environment Agency, https://www.umweltbundesamt.de/publikationen/improving-the-safety-of-industrial-tailings.

[3] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, European Commission.

[4] Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, European Commission.

ANALYSIS OF HISTORICAL TAILINGS DAM FAILURES

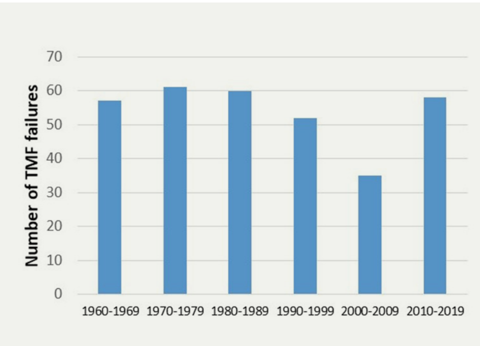
A substantial number of TMF accidents have occurred in the past, many of which could have been avoided or partly controlled if adequate safety measures had been put in place. Therefore, comprehensive data collection[5] and analysis on TMF accidents has been undertaken to better understand these disasters, including analysis of satellite images taken before and after accidents to investigate in detail the potential runout distances on the field before reaching water bodies.

Number and Severity of TMF failures

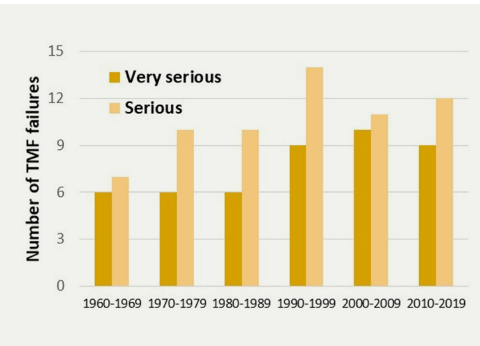
During the last 60 years, more than 320 accidents have been reported in total, resulting in almost 2,600 deaths. A reduction in mining activity between 1989-2009 led to a decrease in incidents, yet the last decade has seen failures peaking at their highest recorded level (58 failures). 7 TMF failures were measured in 2019 alone, two of which involving multiple deaths. The failure trend is rising therefore actions need to be taken to avoid a high number of serious accidents. Moreover, the number of serious (having release greater than 100,000 m³ and/or loss of life) and very serious (having release at least 1 million m³ and/or release that travelled 20 km or more and/or multiple deaths) accidents show a clear increasing tendency over the last decades.

In the last 20 years the human life loss has also significantly increased. During the last 10 years, there were 480 deaths because of 21 serious TMF failures. Moreover, while the rate of failures with life loss remained almost unchanged over 40 years (from 1960 until 1999) with average of 13%, over the past 20 years the number of accidents that claimed lives began to grow and reached almost a double amount of 20% during the last two decades. The long-term specific life loss (number of deaths per accident) both related to all accidents and the serious events has a dramatic value of 8 and 53, respectively and they remained significant in the last two decades.

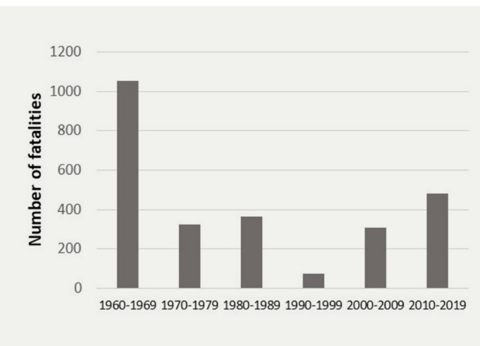
Number of TMF dam failures by decades from 1960 to 2019.



Number of very serious and serious TMF dam failures by decades from 1960 to 2019.



Reported human life loss because of TMF dam failures by decades from 1960 to 2019.



Released volumes and runout distances

In the last 10 years, the amount of released tailings has significantly increased. Of the 250 million m³ of tailings materials released in the last 60 years, 40% were released during the the last decade (100 million m³). Assessment of the past accidents shows that the proportion of direct runout distances (transport distance of the released materials on field before reaching a surface water body or retained by landscape objects or terrain barriers) less than 10 km is almost 90%. This indicates that a distance of 10 km could be a suitable threshold for delineation of a direct risk zone downstream of TMFs.

HISTORICAL INCIDENTS

Brazil: 259 killed in Minas Gerais State following Latin America's worst ever mining disaster in January 2019.

China: 56 reported TMF pollution accidents between 2006 and 2014.

Romania: TMF dam breach at Baia Mare Gold Processing Facility in 2000 saw 100,000 m³ of cyanide-contaminated water spilled into the Someş River, killing large quantities of fish in Hungary and Serbia and seriously damaging the aquatic ecosystem of the Tisza and the Danube.

Hungary: on 4 October 2010, TMF dam near the town of Ajka collapsed causing significant devastation in several municipalities, dangerous pollution to reach several water bodies, and the deaths of 10 people with almost 150 injured.

60	320	2,600
years	TMF failures	fatalities

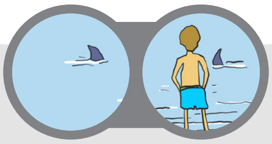
[5] Database on Tailings Storage Facility Failures 1915-2020. Center for Science in Public Participation, http://www.csp2.org/tsf-failures-from-1915.

TMF HAZARD & RISK ASSESSMENT

Hazard vs. Risk

Within the framework of the TMF-Methodology developed to assess the potential dangers of TMF accidents, hazard and risk are differentiated and separately assessed.

The process of TMF Hazard Assessment seeks to sort and prioritise TMFs according to their calculated hazard potential. TMF Risk Assessment however, considers the broader implications of incidents should they happen.



HAZARD

THE TAILINGS HAZARD INDEX (THI) METHOD

The Tailings Hazard Index (THI) method offers a simple index-based calculation tool to assess the hazard potential of a number of TMFs. Building on the results of the historical TMF failure analysis, and agreed and revised by international experts, this method enables a large number of TMFs to be prioritised to identify hazard hot-spots. It has also already proven useful in directing limited resources to potentially more hazardous TMFs.

The THI method takes the following crucial parameters into account and sums them to get the overall THI factor:

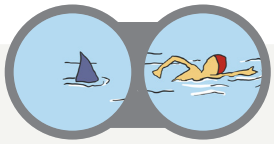
1. Total Capacity of TMFs
This is related to the volume of stored tailings materials in the facility.

2. Toxicity Of Substances of the stored tailings
This is evaluated based on the Water Hazard Class (WHC) of the materials in the tailings according to Germany's national classification, integrating all potential threats to aquatic ecosystems, including bioaccumulation.

3. TMF Management Status
This evaluates the management conditions of the TMFs assigned as Rehabilitated, Closed, Active, or Abandoned.

4. Natural Conditions
This is related to natural hazards, and is calculated by combining hazard indexes for seismic activity and flooding.

5. Dam Safety Parameters
This is directly related to the commonly used "Factor of Safety" (FoS), which has to be determined already at the TMF design stage and refers to stability of a dam slope.



RISK

THE TAILINGS RISK INDEX (TRI) METHOD

TMFs pose a potential threat to human life, environment, and economy located downstream, so taking into account the scale of such risks is essential during licensing of a TMF. Disaster risk is considered as the combination of the severity and frequency of a hazard, the population, resources and assets exposed to the hazard, plus their inherent vulnerability to damages. The Tailings Risk Index (TRI) is thus used to quantify the risk of TMFs, taking into account the socio-economic and environmental values located near to a TMF. The TRI can be used to indicate generalized half-quantitative overviews of larger areas (e.g. transboundary river basins), or to indicate the most dangerous TMFs at national level.

The TRI methodology consists of the following steps:

1. Definition of a risk zone of 10 km around the TMF
In accordance with the runout length analysis of the past accidents a 10 km radius is considered for the potential risk zone.

2. Identification of downstream settlements and waterbodies within the risk zone These can be identified by using Geographic Information System (GIS) techniques or by visual inspection of any available digital or hard copy maps (e.g. satellite, terrain).

3. Population Exposure index for the population within the risk zone is determined based on the total number of inhabitants of the identified settlements.

4. Environment Exposure index for the environment is calculated based on the mean discharge rate/water surface area of the closest stream/lake water body downstream in the risk zone.

5. TRI The TRI is determined by summing the THI and the Exposure Indexes for population and environment.

TMF CHECKLIST

TMF safety requires regular inspections to be performed according to national regulations, in line with the EU Extractive Waste Directive[6] and taking into account international safety requirements and Best Available Techniques (BAT)[7].

One of the main elements of the TMF-Methodology is a Checklist for examinations of a minimum set of TMF technical safety requirements, combined with potential technical measures to implement international standards for the safe operation of TMFs. The Checklist allows performing a detailed evaluation of the TMF safety level and recommends protective and preventive measures based on BAT. However, application of the methodology itself can be seen as only one of the first steps that has to be taken to improve the safety of TMFs, but more importantly, concrete measures have to be implemented.

Briefing at the Romaltyn Mining Company's headquarters before visiting the Aurul TMF.

The Checklist includes three sub-elements:

Questionnaire

The questions of the Questionnaire encompass a minimum set of the requirements critical for TMF safety, which allows evaluating the TMF conditions. Questions are sorted by the TMF life cycle and each subsection contains relevant questions applied to the specific stage.

Safety Evaluation Tool

The Safety Evaluation Tool gives the assessment of TMF in compliance with applicable safety requirements. The Evaluation Matrix evaluates the answers to the questions from both the compliance and credibility aspect based on a simple scoring system. It includes both overall and categorical evaluation using specific categories, which allows thorough checking all TMF elements.

A Measure Catalogue for taking actions to improve TMF safety

This includes a list of recommended actions to be taken in cases where TMFs are non-compliant with safety requirements or regulations. Experts should determine the appropriate actions for each problem detected at the TMF, and measures are prioritised according to short-, medium-, and long-term relevance.

ADVANTAGES OF USING THE CHECKLIST

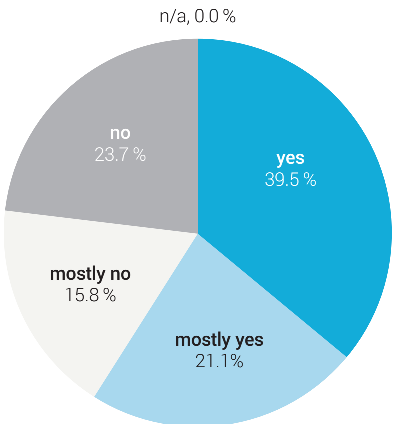
All users (competent authorities, inspectors and operators) work with the same inspection procedure allowing a consistent safety evaluation

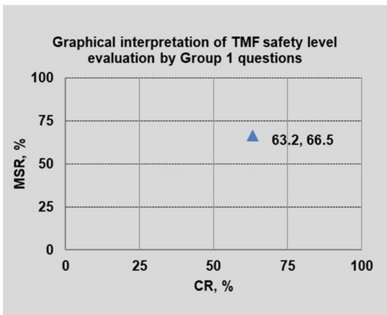
TMF operators can detect non-compliance with minimum set of the safety requirements

All users work with the same Measure Catalogue accumulating best available technologies in sustainable mining

Overall evaluation of the Checklist answers.

Proportion of the answers given to Group 1 questions.





[6] Directive 2006/21/EC of the European Parliament and of the Council of 15 March 2006 on the management of waste from extractive industries and amending Directive 2004/35/EC, European Commission.

[7] Best Available Techniques (BAT) Reference Document for the Management of Waste from Extractive Industries in accordance with Directive 2006/21/EC, EU Joint Research Centre, https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/best-available-techniques-bat-reference-document-management-waste-extractive-industries.

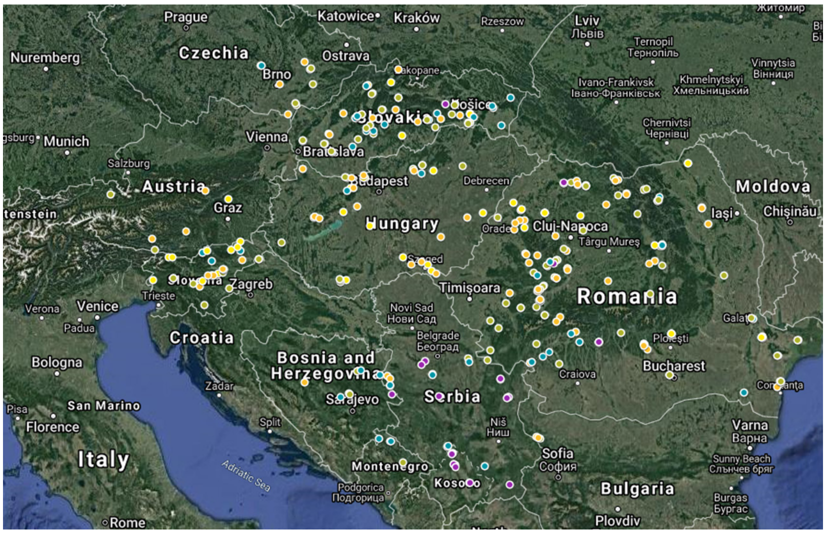
KEY FINDINGS

- In total, 343 TMFs were identified within the Danube River Basin territory of 10 countries, out of which 95 are active TMFs. The total volume of tailings materials is more than 1500 million m^3. Most of identified TMFs (248 or 72%) are inactive, many of them were already rehabilitated or are currently under rehabilitation.
- In total, 146 TMFs have very low (THI≤8) or low (8<THI≤10) hazard. Additional 115 TMFs have medium hazard (10<THI≤12), whereas high (12<THI≤14) and very high (THI>14) hazard was determined for 82 TMFs.
- Most of top 10% hazardous TMFs with the highest THI values are located in Serbia. Out of the 34 high-priority TMFs, 23 can be found in Serbia, 5 in Romania, 3 in Slovakia, 2 in the Czech Republic and 1 in Bosnia and Herzegovina. The vast majority of these TMFs store slurry or sludge of non-ferrous and precious metal ore extraction with heavy metals as major contaminants.
- The TMF number and the amount of tailings materials in Austria, Bosnia and Herzegovina, Bulgaria, Czech Republic and Montenegro are relatively small. Nevertheless, there are a few hazardous TMFs also in these countries.
- Hungary and Slovenia have significant numbers of TMFs, but of lower hazard due to lower toxicity of waste, lower amount of tailings and closure and rehabilitation efforts.
- On the contrary, the number and/or amount of TMFs and the calculated hazard index in Romania, Serbia and Slovakia are much higher, these countries are of high concern regarding TMF safety and they should be in focus of future activities on safety improvement and capacity building.
- TMF distribution according to TRI classes is similar to that based on the THI. Very low and low risk was calculated for 128 TMFs, 133 TMFs have medium risk and 82 facilities show high and very high risk.
- The top 10% of high risk sites is dominated by sites in Romania (12) and Serbia (11) – though such sites can also be found in other countries, making the TRI list more balanced in comparison to the THI top 10% list.

TMF INVENTORY FOR THE DANUBE RIVER BASIN

The ICPDR has been developing an inventory on TMFs throughout the Danube River Basin in order to undertake a hazard and risk assessment using both THI and TRI methods. This assessment aims at identifying and prioritizing TMF hotspots in the basin.

Data for this assessment is being collected in two steps: basic data for the preliminary THI and TRI assessments were initially collected from open access sources. Secondly, the basic data sets are being revised and approved by all concerned Danube countries making use of official national information. Therefore, the current inventory is to be considered as a preliminary database. The inventory and the related assessments will be completed once official TMF data from all countries are available and appropriate population and water body data in the 10 km risk zones are collected for each identified TMF.



TMF hazard map for the DRB countries.

Color scheme: ● very high hazard (THI>14), ● high hazard (12<THI≤14), ● medium hazard (10<THI≤12), ● low hazard (8<THI≤10), ● very low hazard (THI≤8).

Visual check of the Aurul TMF: main drainage channel with impervious HDP screen (geo-membrane)

CAPACITY BUILDING IN ROMANIA

Within the project, a regional demonstration training event was organised for 1st – 3rd October, 2019 in Cluj, Romania for invited national TMF operators and environmental inspectors. The training event included theoretical lectures, field exercises at the Baia Mare TMF and desk exercises to introduce, test and amend a detailed checklist methodology. In total, 24 trainees from Romania, Hungary, Ukraine, the Czech Republic and Serbia (observer country) plus 16 trainers, international experts and project partners participated in the training event.

On the first day, a comprehensive programme of lectures was provided to familiarise the participants with the checklist methodology. In addition, a site visit was organised to Baia Mare on the second day to test a specific checklist designed for visual inspection. During the site visit, participants were divided into three groups and each group performed a separate inspection on the facility. The trainees had their own checklist and answered the questions independently. Each group was accompanied by two trainers and a local TMF operator who provided explanations of the questions. Finally, a practical evaluation exercise on the third day completed the training programme. The participants evaluated the overall and categorical safety conditions of the TMF, compared the results of the visual inspections, exchanged their impressions on the site visit and provided recommendations on how to improve the checklist methodology.

IMPRINT

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The authors are grateful to the UBA and the ICPDR for supporting the project implementation.

More details and all references can be found in the Danube TMF Project Technical Report.

https://www.sendaiplatform.org/

Visual check of the Aurul TMF: decant structure with water level measurement system.

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