Mine Water in the Global Industry Standard on Tailings Management

Kevin Leahy[1], Thomas Collin[2], Sia Tanhai[3], Simon Gibbons[4]

[1]*ERM UK Ltd., Suite 15 & 25, New Barclay House, 234 Botley Road, Oxford, OX2 0HP, United Kingdom, kevin.leahy@erm.com*

[2]*ERM UK Ltd., 4th Floor, One New York Street, Manchester, M1 4HD, United Kingdom, thomas.collin@erm.com, ORCID 0000-0002-8883-2594*

[3]*ERM UK Ltd., 5 Callaghan Square, Suite C, 2nd floor, CF10 5BT, Cardiff, United Kingdom, sia.tanhai@erm.com*

[4]*ERM UK Ltd., 1st floor, 40 Queen Square, Bristol, BS1 4QP, United Kingdom, simon.gibbons@erm.com*

Abstract

Brumadinho and Samarco Mariana tailings storage facilities (TSF) failures in Brazil caused deaths and environmental damage, prompting the Global Industry Standard on Tailings Management (GISTM) in 2020. The International Council on Mining and Metals (ICMM) required members to disclose information on extreme and very high consequence TSFs by 2023 and all TSFs by 2025. This study analyses the integrated knowledge base developed for 56 TSFs across various geographies and commodities, assessing data sufficiency across 25 water topics. Despite generally high compliance, systematic gaps exist globally. The findings are relevant to mining companies, environmental professionals, and the ICMM for GISTM compliance.

Keywords: Integrated knowledge base, Global Industry Standard on Tailings Management, Gap analysis

Introduction

The catastrophic failures of the Brumadinho and Samarco Mariana tailings dams in Brazil resulted in hundreds of fatalities and widespread environmental devastation, highlighting the urgent need for improved tailings storage facility (TSF) management. Tailings dams continue to fail at an alarming rate (Islam and Murakami 2021, Rana, *et al.* 2022). These events spurred the development of the Global Industry Standard on Tailings Management (GISTM), released in August 2020 by the International Council on Mining and Metals (ICMM), the United Nations Environment Programme, and the Principles for Responsible Investment (ICMM; UN Environment Programme; PRI 2020). GISTM aims to establish a comprehensive framework for TSF safety, with ICMM requiring its members – some of the largest mining corporations globally – to implement the standard for extreme and very high consequence TSFs by August 2023, and for all TSFs by August 2025.

GISTM comprises six topics and 15 principles encompassing up to 77 requirements for TSFs. Mine water management is explicitly addressed in four critical areas: (i) breach modelling, (ii) the knowledge base, (iii) tailings water management, and (iv) mine water balance. Breach modelling estimates the potential inundation area in the event of a dam failure. The knowledge base demands a comprehensive characterisation of the TSF site, integrating climate data, geomorphology, geology, hydrology, and water usage patterns, among other factors. Tailings water management requires ongoing monitoring of water levels, seepage, pore pressure, and surrounding water bodies, while the mine water balance emphasises the need for a holistic water accounting approach at the catchment and mine site scale.

This paper explores the integral role of mine water in achieving GISTM compliance by drawing from extensive data analysis conducted in developing integrated knowledge bases for TSFs ahead of the

GISTM disclosures. A total of 56 TSFs at 53 mines or former mine sites are used to investigate compliance against water-related topics, and reflect on the wider implications of knowledge gaps for TSF management. The 53 selected mines are from 13 nations across Africa, Australasia, the Americas and Europe, that produced copper, nickel, lead, zinc, aluminium, vanadium, chromium, gold, silver, platinum, molybdenum and cobalt, as well as examples of TSFs at non-metal mines with four from coal mines.

Methods

ERM developed a staged approach to build Integrated Knowledge Bases (IKB) supporting the GISTM Disclosures, including: (i) logging documents held by the mining companies, (ii) logging data against the specific topics, (iii) extracting the relevant information, (iv) conducting a data gap analysis for each topic, (iv) review by the mine team and update of the gap analysis.

In total, 3,502 documents were logged, and 11,646 data inputs were extracted, covering the 56 TSFs, against eight main topics: (1) Basemapping, (2) Environment, (3) Geology, (4) Historic environment, (5) Hydrology, (6) Infrastructure, (7) Site Infrastructure, and (8) Socio-Economic. The focus of this paper is on sub-topics broadly related to water management (Tab. S-1 in Supplementary Material). Following data extraction, knowledge gaps were assessed against each topic, and conversations with mine teams were undertaken to discuss these with the intention to fill these gaps.

Technical data on the 56 TSFs was extracted from the Global Tailings Portal (GRID-Arendal 2020) which has been developed based on responses from the "Investor Mining and Tailings Safety Initiative" launched by The Church of England Pensions Board and The Council on Ethics of the Swedish National Pension Funds (Church of England 2019). Specifically, this included data relating to the status (active, inactive and closed), and the construction year and design (Tab. 1).

The analysis then considered if there was or was not sufficient water-related data such that a given TSF could be considered as compliant with the requirements of the IKB within GISTM and if not then what gaps remained. A data gap is defined as a missing dataset, or one considered insufficient to be complaint with the GISTM requirement. For example, if a TSF lacked groundwater monitoring records, this was classified as a data gap under the "Groundwater Quality". In this analysis, compliance referred to whether a TSF was considered to have sufficient, relevant and up-to-date water-related data to meet requirements within GISTM.

Many aspects of the IKB can be obtained by accessing online databases, either freely or supplied by third parties, such as mapping of water courses, locations of licenced landfills or private well locations. This analysis excludes these generic, free or third-party water data that are generally available. Instead, the 56 TSFs were assessed if there was or was not sufficient data for 25 specific and comparable water topics within, or as a

Table 1 *Location, construction decade and status of the studied TSFs.*

	Construction decade								Status		
Region	Pre-1950	1950	1960	1970	1980	1990	2000	2010	Active	Inactive	Closed
Africa		1			1	3	6	2	12	2	0
Australasia		1		1		3			3	1	1
Eurasia	2	1	2	1					2	1	3
North America	1	1	4	3	1	2		1	6	3	7
South America				1	4	4	1	1	6	2	3
Total	3	4	6	6	6	12	7	4	29	9	14

Notes: 'Active' refers to facilities currently receiving tailings material from on-going mining operations, 'Inactive' are facilities not presently receiving tailings but not yet fully closed, 'Closed' refers to facilities for which the closure plan has been implemented and has been approved by the competent authorities.

sub-set of, the eight categories such that they could be considered as compliant with the requirements of the IKB within GISTM, or if not, what the number of gaps were. The 25 specific topics are listed and defined in Tab. S-1 in Supplementary Material.

Results

Compliance and Status

The average compliance rate across the 25 studied topics was evaluated at 65%, 74% and 70% for active, closed and inactive TSFs respectively (Fig. 1) with a statistically significant difference observed between active and closed TSFs (t-test, $\alpha = 0.1$). This difference is likely to be explained by the additional data required to attain 'closed' status in most jurisdictions, which implies that active TSFs are more likely to have inadequate water data, not only to comply with GISTM but also to attain closure.

Compliance and Geographies

The median compliance values with water topics that are required for a complete IKB, as assessed across the 25 studied topics, were relatively consistent regardless of mine location, including Africa, Australasia, and North and South America (Fig. 2). However, Eurasian mine sites demonstrated a distinct compliance pattern with three sites out of six having a compliance of 36%. Notably, these three sites, located in the same country, achieved the lowest compliance across the sample, hinting at region-specific challenges.

The relatively uniform median compliance across regions suggests that broad challenges to achieving GISTM compliance are shared globally, such as limitations in data availability, monitoring infrastructure, or technical expertise.

Compliance and Construction decade

The most notable observation when assessing average compliance with the TSF construction decade and status (Tab. 2), are the lower levels of compliance for older active facilities. To illustrate, facilities built before the 1980s had an overall compliance of around 50% while active facilities built since the 1980s are around 70% compliant. This may relate to a focus on business-as-usual operations at older active TSFs that probably underwent little or no environmental impact assessment at the time of construction and during early

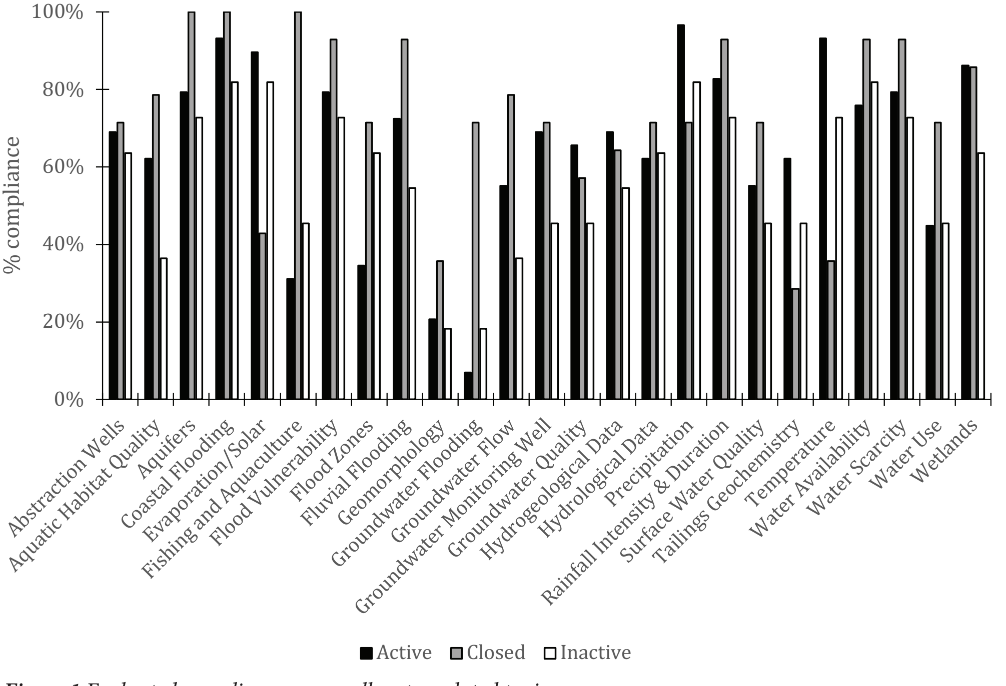
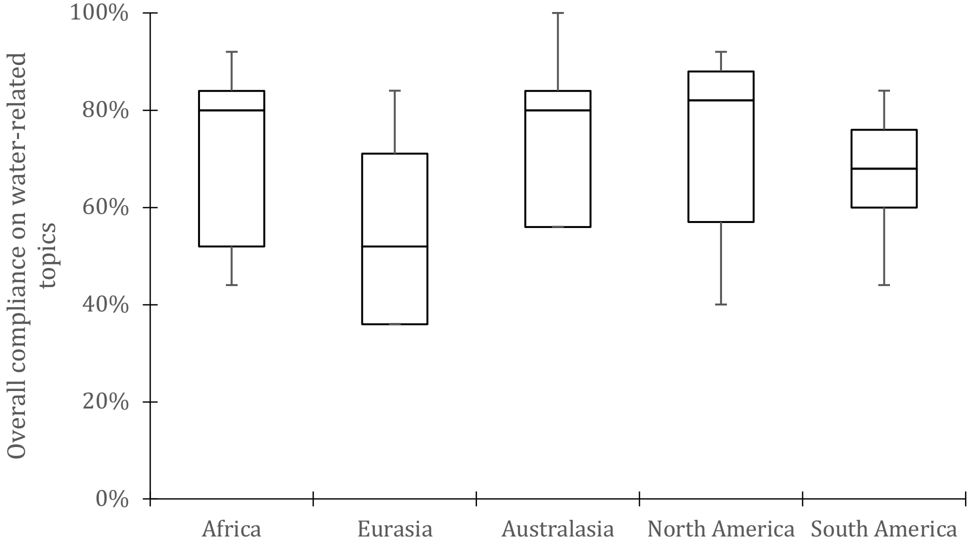


Figure 1 Evaluated compliance across all water-related topics.



Notes: the lower end of the box represent the first quartile (Q1), the median is the line inside the box, and the third quartile (Q3) is the upper end of the box, representing the 25th, 50th and 75th respectively. The whiskers indicate both minimum and maximum values.

Figure 2 *Average TSF compliance reported against geographies.*

operations, with few drivers prior to GISTM to more fully understand the water context.

General Patterns of Compliance

Overall, of the 25 topics assessed, Geomorphology and Groundwater Flooding were the least understood and had the highest number of data gaps (Fig. 1). By contrast, topics relating to Climate Change (i.e. Flood Vulnerability, Rainfall Intensity & Duration, Water Scarcity) were generally covered for most TSFs. Often this data was found to have been obtained from Climate Change Risk Assessments or by utilising third-party data, such as the World Resources Institute's Aqueduct (World Resources Institute 2024). However, reliance on external datasets did not always guarantee that climate change effects were adequately accounted for at the TSF level, potentially leading to site-specific risks being overlooked.

Similar observations were made for the Aquifers and Water Availability topics, which were often addressed using third-party datasets. This highlights an important implication: while leveraging third-party data can bridge knowledge gaps, it should be supplemented by localised assessments tailored to the specific context of each TSF. Without such localised assessments, there is a risk of overlooking critical factors that could compromise TSF safety and water

Table 2 *Evaluated compliance based on status and construction decade.*

Construction decade	Active	Inactive	Closed
Pre-1950s	–	–	87%
1950s	50%	36%	65%
1960s	48%	–	86%
1970s	55%	76%	40%
1980s	73%	56%	72%
1990s	72%	81%	78%
2000s	73%	–	72%
2010s	69%	–	–

management strategies, particularly in areas with complex or poorly understood hydrogeological settings.

Notably, only one TSF out of the 56 studied achieved full compliance with the water-related topics for the IKB, pointing to a significant and systemic gap in meeting GISTM requirements at TSFs globally.

Compliance gaps

A lack of available data was identified as the most prevalent data gap by far, accounting for 79% of all deficiencies. The second most common gap, representing 15%, was categorised as "limited coverage," which referred to instances where data existed but did not encompass the inundation area, estimated by Breach Analysis to simulate the case of TSF failure.

Geomorphology, identified as the least compliant topic (Fig. 1), was predominantly associated with a lack of available data (Fig. 3). However, further discussions with subject matter experts suggested that this issue might not solely result from data unavailability but also from a fundamental lack of clarity regarding what data should be collected and analysed for this topic. This gap underscores the need for clearer guidance on geomorphological parameters. Specifically, it may prompt the need to incorporate a clear definition under Requirement 2.2 of GISTM explicitly outlining the parameters to be assessed ensuring consistency in interpretation across stakeholders.

Notably, "limited coverage" was particularly significant for groundwater-related topics, such as groundwater monitoring wells and groundwater quality (Fig. 1). This gap highlighted that groundwater monitoring was often confined to the immediate vicinity of the TSF, failing to comprehensively evaluate effects within the inundation area. Given the potential correlation between groundwater flow direction and the inundation area—likely influenced by local topography—this limitation raised concerns about inadequate groundwater monitoring downgradient of some TSFs, where seepage could have affected groundwater quality. However, further research is required to explore this causal relationship.

Conclusion

The analysis demonstrates that despite observing relatively high levels of sufficient water data that is required for IKBs within GISTM, there are systematic shortcomings

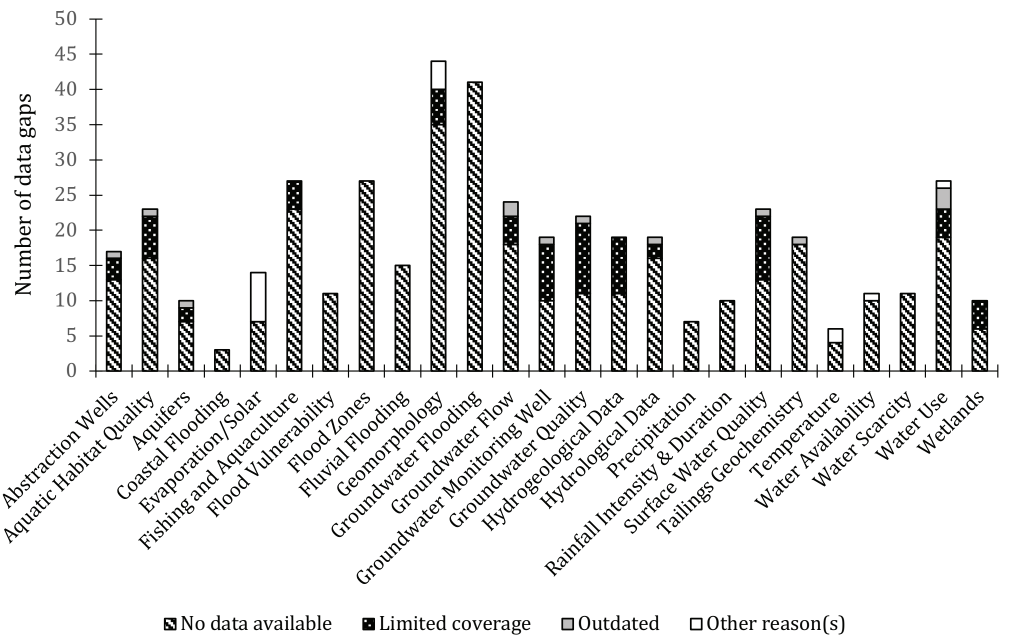


Figure 3 *Reason for identified gaps.*

in the collection of water data. The evidence is that these challenges in gathering sufficient water data for TSFs are a global phenomenon, across geographies and commodities. The study findings also indicate that older active TSFs are less likely to have sufficient data than closed TSFs, not only for compliance with GISTM but also to be able to obtain regulator-approved closure.

Some specific water topics, such as geomorphology, point to not just a lack of data gathering and understanding at the site-level, but also a lack of clear definition as to what is required and why within the GISTM framework. Another important implication is that monitoring well arrays and other water data are often focussed on the immediate surrounds of the TSF, with too little coverage of downstream and downgradient areas, failing to characterise the inundation zone in the event of rare catastrophic failure, and the much more common groundwater plume that is present at most TSFs.

Mining companies operating TSFs within the GISTM framework need to overcome these limitations in data availability by assessing their gaps in compliance and improving monitoring infrastructure and technical expertise, as required, to fill them. Reliance on third-party datasets does not always provide sufficient understanding of complex water issues and risks at the site-level, both to the environment, site operations and wider communities.

Fundamental to GISTM moving forward is the use of data within the knowledge base to support decision making around safe tailings management. The continued reference back to GISTM requirements may well elevate the need to collect more of the right kind of data to better understand risks and it is hoped that new facilities, as they come online, will inherently capture a greater variety of pertinent water data to ensure the safe operation and closure of these facilities in the future.

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