Simplified dams risk assessments need to remain meaningful.

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ABSTRACT

This paper presents the results of a series of risk assessments third party reviews undertaken by the authors in the recent past, covering tailings storage facilities located in North and South America as well as in Europe. Names and locations are withheld to respect confidentiality. The considered dams were active/non active structures of different ages. A significant proportion of these approximately fifty dams have been the object of repairs due to past incidents. The level of information on each structure varied widely across the sample.

The construction methods were downstream, centerline and upstream cross sections with a majority of upstream, modified upstream and centerline cross sections.

The reviews have oftentimes led to pinpoint a general trend to oversimplify risk assessments leading to unwanted exposures and potential liabilities. As a matter of fact some oversimplified risk assessment become meaningless and misleading. The paper does not discuss the reasons for the detected oversimplifications but describes them and shows their effect on the meaningfulness of the resulting assessments.

The paper reviews five families of commonly detected oversimplifications, namely those bearing on: history of the structures from inception to the date of the assessment, estimation of the likelihood of failure, monitoring and space observation programs results and their analysis, neglecting divergences and evaluation of potential consequences, in particular of a breach and potential catastrophic collapse.

Based on this review the paper then indicates how liabilities emerge for the author of the oversimplified risk assessment and/or its users.

The paper concludes with a series of concrete recommendations on how to avoid oversimplifications, misleading conclusions and ensure risk assessments remain meaningful for the authors, their clients, investors, insurers, and the public.

INTRODUCTION

This paper summarizes the results of numerous third-party reviews of tailings storage facilities (TSFs) risk assessments performed by the authors. Tailings dams are a key component of Tailings Storage Facilities (TSFs) systems and catastrophic failures of dams have occurred with a long-term average of appx. 3.5/yr over the last 100 years or so. The last few events have triggered reactions at various levels. These include the UNEP (Roche et al., 2017), the Global Industry Standard (2020) and statements by ICMM's director Aidan Davy "The clock's very much ticking on implementation and we've got an ambitious timeline". These have been recently followed by the ICMM conformance protocols (2021).

The size of existing active, non-active dams' portfolio and the rules included in the Global standard require due attention is given to their risk assessments, hence motivate this paper. Furthermore, public statements like the following: "The mine plan has a dry stack filtered tailings facility, and co disposal with waste rock with no tailings dam, eliminating the risk of a tailings dam failure" should be shored up by well-developed risk assessments or risk (pun intended) becoming fake news. This being said, we note that the ICMM conformance protocol goes in the direction of limiting this kind of statement.

Of course, what constitute failure must be defined first. In our courses and books (Oboni, Oboni 2020) we insist on the necessity of defining success and failure criteria for projects especially in these times of divergent hazards due to climate change. That is of course necessary before attempting any risk characterization. Is a TSF failure a vivid catastrophic failure like Samarco, Mount Polley or Brumadinho? Or does a failure also include a release of contaminants into the environment through seepage or minor failures?

The third-party reviews we summarize in this paper defined failure as catastrophic collapse of TSF dams. This definition leaves room for conflicts with local residents possibly leading to crises that will inevitably damage the Social License to Operate (SLO) at their locations and perhaps internationally. Again, ICMM conformance protocols seem to go in the right direction in this theme. The TSFs are located in North and South America as well as in Europe. Names and locations are withheld to respect confidentiality. The considered dams are active/non active structures of different ages. A significant proportion of these approximately fifty dams were the object of repairs due to past incidents. The level of information on each structure varied widely across the sample. The construction methods were downstream, centerline and upstream cross sections with a majority of upstream, modified upstream and centerline cross sections.

As discussed below, the reviews led to pinpoint a general trend to oversimplify risk assessments leading to unwanted exposures and potential liabilities. As a matter of fact some oversimplified risk assessment become meaningless and misleading. The paper does not discuss the reasons for the detected oversimplifications but describes them and shows their effect on the meaningfulness of the resulting assessments. The paper reviews families of commonly detected oversimplifications, namely those bearing on history of the structures from inception to the date of the assessment, estimation of the likelihood of failure/probability of failure p_f, forgetting potential hazard divergence, monitoring and space observation programs results and their analysis, evaluation of potential consequences of a breach and ensuing potential catastrophic collapse.

OVERSIMPLIFYING ESTIMATION OF p_f

As mentioned in the introduction, a TSF is a system and its failure is oftentimes seen as the failure of one of its dams (perhaps the main, or biggest one?), forgetting other significant elements of the system, such as water management facilities (diversions, spillways, penstocks), pipelines (tailings, water) and traffic and other agents present on their bodies. Very often we have seen risk assessments conducted on one cross section of a dam, even if the structure was hundreds of meters long, with varying foundation conditions and geometry.

Misleading results source #1: improper system definition and oversimplification.

Several reviews of risk assessments using semi-empirical approaches such as Silva, Lamb, Marr (Silva et al., 2008) (SLM) have highlighted some important deficiencies. Just to be clear, we have tested and recognize the validity of SLM approach in many cases, if applied to a slope and in specific sets of geotechnical and loading conditions. However, precisely because it is a slope approach and not a dam approach, one should not use it for dams, arbitrarily lumping up sub-elements in order to tweak it to work anyways. The same goes for any arbitrary simplification to the well thought out and tested SLM factor of safety-probability of failure relationship.

Misleading result source #2: "forcing" existing methods with arbitrary, untested choices of all kinds.

Another deficiency we have encountered, oftentimes stems out of the initial studies, i.e. well before the risk assessment. It corresponds to neglecting residual strength and undrained conditions in the stability analyses, possible rapid draw-down conditions (in ring dam TSFs, by interdependency between dams) or poorly defined seismic loadings.

Misleading result source #3: neglecting special cases

Source #3 is complex as it covers neglecting special cases such as undrained, residual, static liquefaction, rapid drawdown, seismic loading. It also covers failing to identify deficiencies in the original design due, for example, to too shallow investigations, poor geographic distribution of boreholes and penetrometers, etc.

OVERSIMPLIFYING "HISTORICAL DATA"

There are two types of historical data a risk assessment should refer to: historical data on the TSF (design reports, inspections, monitoring results, history of incidents and accidents, near-misses) and historical data on hazards (climate, meteorology, fire, strikes and terrorism, subcontractors mistakes, unintended deviances).

Misleading result source #4: overly light study of TSF historical data.

We have seen cases where the daunting task of reading and understanding existing archival information was reduced by looking at summary documents only, missing important details, reinterpretations of past results and normalization of deviance. Chronology of construction, history of incidents, repairs, near misses oftentimes offers important clues on possible future behavior.

Misleading result source #5: poor understanding of historical data on hazards.

This leads to confusing business-as-usual, extreme events and divergent events. Unless solid historical data exist on hazards, a common deficiency lies in considering business-as-usual maximum events as extreme events and missing to detect divergences when they start occurring.

OVERSIMPLIFYING InSAR DATA

Interferometric synthetic aperture radar (InSAR) data are not the only space observation result that can be used for dams risk assessment. Other sensors and optical imagery such as infrared and normalized difference vegetation index (NDVI) can prove extremely useful (Yue et al., 2019; Awada et al., 2019).

Furthermore, we have noticed a trend to only use forward looking InSAR, neglecting available long term past observations. As described by Dashora et al. (2007) the CORONA satellite program was the first series of spy satellites for military observation from 1960 to 1972. Declassification of this material in 1995 provides a rich source of data suitable for studying historic behavior of deposition areas, for example, comparing them with today's situation.

Misleading source #6: using only forward-looking monitoring, neglecting historical data.

One of the great advantages of space observation lies in being able to tap into historic data as stated above. InSAR data can already oftentimes go back several years on a given site. Approaching any space observation with a forward-looking analysis equates to disregarding site history. It is like a doctor attempting a diagnosis on a patient without any information on his or her past.

Misleading source #7: using only InSAR, oftentimes without properly understanding all its limitations.

InSAR data interpretation necessitate the inclusion of many parameters. Unless there is a clear line of communication between the imagery provider/interpreter and the end-user, results may be misleading. For example, imagery may reveal micro-changes of the topography while ignoring macro-changes. Deformation data may be reported away from where it occurs because of the pixelization, etc. The simultaneous use of other techniques, based on optical imagery, and interpretations (NDVI) (Dacre et al., 2016) may help dealing with these issues.

FORGETTING DIVERGENCE AND UNCERTAINITES

As the world around us is random, no data acquisition program allows to describe it precisely with one magic number. Uncertainties mean that with better information we can make narrower range predictions, but never lead to a single number. However, risk registers oftentimes use a single number for probabilities. Assuming a distribution is extremely hazardous, as some events are random, and some are uncertain. Running a Monte Carlo simulation with uncertain data can have disastrous implications.

Misleading source #8: divergence can be multifaceted.

The most obvious divergence example that comes to mind today is climate change. Events have occurred with long term average return, meaning that, for example, a rain of a certain intensity/duration will occur on average every 100yrs, 200yrs, and so forth. What about three 200years events in two years? That is neither business-as-usual nor extreme… indeed, the likelihood of three such events in such a short time is extremely low. For that to occur, something has changed, and indeed people invoke climate change. Other divergent events can be drought, winds, freezing, etc. With automation and internet of things, divergence can hide in IT malfunctioning or cyberattacks.

Divergence is lurking and considering it is paramount (Oboni, Oboni, 2021) for management and planning.

OVERSIMPLIFYING CONSEQUENCES

Health, culture, environment, customs as well as ways of life of affected social groups are all considered to be valid failure criteria metrics that should be considered in the evaluation of multidimensional consequences of potential accidents. Multicriteria decision models are present in the literature, incorporating various techniques, such as, for example MAUT (Multi-Attribute Utility Theory), which considers points such as decision maker's preferences. Various dimensions of consequences, i.e. for example human, financial and environmental can be expressed in terms of probabilities (Marsaro et al., 2014). Beside consequences beings based on incomplete metrics, we have seen consequences affected by significant "range bias", leading to most risk identified in one category when probability-impact graphs or oversimplified consequences categorizations were used.

Misleading source #9: consequences of tailings accidents are additive multidimensional.

We have seen studies looking at consequences in overly simplistic ways, binning consequences based on one single dimension, e.g., fatalities. Consequences are always multi-dimensional, including for example, health and safety (H&S), harm to people, physical losses, life-values, and of course corporate values. If dimensions are forgotten, risk comparisons between dams and TSFs will become meaningless impairing rational mitigation planning. Oftentimes worst-case one-dimension consequence is the only scenario assessed and the assumption is that is if the worst case one-dimension consequence scenario is dealt with, then all the risks from the same family will also be tolerable, which oftentimes is wrong.

Misleading source #10: using oversimplified tolerance thresholds.

Risk encompasses probability of failure and its consequences. Using probability only as a tolerance threshold is not sufficient and can be extremely misleading. Tolerance must cover the multidimensional aspects of consequences. Developing a unified metric allowing expression of risk tolerance is paramount, especially if a large portfolio has to be evaluated for mitigation planning.

RESULTING LIABILITIES

Fuzzy risk assessments, oversimplification and arbitrary choices lead to unexpected exposures, liabilities and open the door to legal challenges while hindering SLO, corporate social responsibility (CSR) and environmental, social and governance (ESG) (Oboni, Oboni, 2021). We can see future cases where accidents will be disputed in terms of "quasi-conformance" to ICMM standards and the credibility of the industry will again be exposed to public scrutiny.

The time when "trust us" or "it is a safe dam" statements were acceptable is long gone. We think that ICMM standards should have some clearer definitions especially in the area of tolerance, acceptability, as low as reasonably practical (ALARP) criteria, etc.

RECOMMENDATIONS

This paper would be meaningless if it did not include possible antidotes to the deficiencies we have summarized above. So, we briefly describe them below.

Antidote #1: always spend time to define the TSF system, including all its dams, ancillary water management facilities, geometric and known geotechnical peculiarities and avoid arbitrary selection of one dam cross-section as representative of the whole.

Antidote #2: it is possible to use simplified methods, including those of the semi-empirical kind linking the factor of safety to the probability of failure, but their applicability must be tested and proven. In particular, "forcing" existing methods with arbitrary, untested choices should be proscribed.

Antidote #3: consider special cases such as undrained behaviour, residual strength, rapid drawdown, seismic loading as components of a potential failure and the uncertainties linked to excessive shallow boreholes in the formulation of the probability of failure of the dam.

Antidote #4: overly light study of historical data on the TSF. Today technology offers solutions to rationally and economically undertake in depth analyses of existing archives, drilling information to discover trends, forgotten details, changes.

Antidote #5: The confusion between business-as-usual, extreme events and divergent events requires a study of existing records, possibly from sources conceptually far away from dam engineering. In Latin America and Europe we had good success by using church and missions records, and of course locals and their oral traditions, what is generally known as "thick data" as opposed to "big data".

Antidote #6: Always start a risk assessment hazard identification by going back in time as much as possible. This approach is possible with Space Observation, sometimes going as far back as the Cold War times.

Antidote #7: Maintain a very clear line of communication between the imagery provider/interpreter and end-user. Clearly state the objectives of the analyses and interpretations, discuss limitations due to pixelization and select the appropriate definition.

Antidote #8: Identify potential divergent events, study them a see how such scenarios would impact the risk landscape of the TSF.

Antidote #9: Define success and failure criteria for the dam/TSF. Based on that, define consequence metrics, dimensions and evaluate all failure scenarios for all the dimensions in an additive manner. If using a risk matrix, a practice we do not endorse, the scale of consequence should be normalized between 0 and 1 and then the risks added where there are multiple consequences.

Antidote #10: Ensure the consequence metric is reflected in the tolerance threshold and only then use tolerance to prioritize dams and TSFs, defining which dams represent a tolerable risk, an intolerable but manageable (tactical) risk, or an intolerable (strategic) risk, requiring a system change.

CONCLUSIONS

In this paper we have shown five families of commonly detected oversimplifications in real-life risk assessments that reduce their value and in extreme cases render them meaningless. While describing these, we have described ten misleading sources of information we have observed in numerous reviews we have conducted. Based on these we have then suggested ten "antidotes" capable of increasing value of the risk assessment results, i.e. making them valid decision-making support to generate value and foster sustainable practices. Simple and "blind" compliance to the Global Industry Standard for Tailings Management, or worse, playing with the areas left open to interpretation in the standard and conformance protocol or any other standard is not sufficient to ensure long term value creation. Doing it is conducive to establishing liabilities, potentially criminal and certainly ethical.

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