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Review Article

Rates and Causes of Tailings Dam Failures

Timothy D. Stark , Lucia Moya , and Jiale Lin 

Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, 205 N. Mathews Ave, Urbana, IL 61801, USA

Correspondence should be addressed to Lucia Moya; moya3@illinois.edu

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This paper analyzes two tailings dam databases and recent failures to assess the local and global failure rates of upstream, downstream, and centerline raised tailings dams. Since 2000, the failure rate for all three raising methods has decreased except in Brazil, which helps explain the recent Brazilian regulations banning upstream raising. However, the failure rates also show that the downstream and centerline raising methods of tailings dams are not immune to failure, so, if mining continues, one of these three raising methods will be used, and all have been involved in prior failures. The paper also presents data on failure mechanisms, showing that slope stability, earthquakes, and overtopping are the three primary causes of tailings dam failures. To continue decreasing the failure rate of tailings dams, the following features and practices should be used in all types of tailings dams: drainage systems, engineering analyses, instrumentation, monitoring, inspection, and qualified external peer review to further reduce the failure rates, especially in Brazil. Finally, a section containing data on release volume as a function of dam height and total storage volume is presented.

1. Introduction

In the last eight years, the following four tailings dam failures have occurred:

- (i) Herculano tailings dam failure in Brazil on 11 September 2014
- (ii) Fundão tailings dam failure in Brazil on 5 November 2015
- (iii) Dam B1 tailings dam failure in Brazil on 25 January 2019
- (iv) Jagersfontein dam failure in South Africa on 11 September 2022

In addition to fatalities, these failures caused the significant release of the stored tailings and major environmental damage. For example, the Dam B1 failure caused about 300 fatalities [1], released around 13 million cubic meters of tailings, affected indigenous and nonindigenous populations, negatively impacted an area of more than 250 hectares in a biodiversity hotspot [2], and traveled approximately ten (10) kilometers. Within 10 seconds, the

collapse of Dam B1 was complete, and 75% of the tailings flowed out of the dam in less than 5 minutes. Without warning, the sludge instantly killed dozens of workers when it demolished a downslope cafeteria. Likewise, the tailings from the Fundão tailings dam failure killed nineteen people [1] and traveled hundreds of kilometers to the Atlantic Ocean.

After the failure of a tailings dam, the outflow of the stored tailings can result in a fast-moving mudflow, which can devastate downstream areas. Some of the videos following the Fundao [3], <https://www.youtube.com/watch?v=O7l7OSFyP2w#action=share>, and Dam B1 [4], <https://www.youtube.com/watch?v=Adk0AwcISHo>, failures illustrate the speed of these mudflows. Using the video of the 2019 Dam B1 failure, the velocity of the resulting flow failure was estimated to be 1.3 to 1.5 km/minute (21.7 to 25 m/s). This potential for rapid inundation of downstream areas makes the design, instrumentation, monitoring, inspection, and external peer review of these structures essential to protecting human life and the environment.

All three of the tailings dam failures in Brazil were raised by the upstream method. The Fundao and Dam B1 failures