Implications of Earthquakes on the Stability of Tailings Dams

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Abstract

Analyses of earthquakes show the need of detailed assessment of the vulnerability different industry sectors. As part of this assessment implication of earthquakes for the mining industry and especially the stability of the tailings ponds was investigated. Based on the serious dam failures a decision tree was developed to categorize the loss scenarios. To test the decision tree and to understand the impact of a tailings dam failure a 3D model for a hypothetical scenario was built for East Germany. The model clearly showed the local and regional impact on the environment.

Key words: Earthquakes, Tailings, Insurances, Dam Stability, Loss scenario, Germany, Decision tree

Introduction

Assessments for insurance losses from earthquake catastrophes showed in recent decades the need for a more detailed assessment of vulnerability to earthquakes. General analyses of earthquakes often consider only the vulnerabilities of industries and not the surface installations of mines and so special attention must be given especially to tailings ponds and tailings dams, for example. This is because in a loss-scenario the damage caused by a collapse of a tailings dam can be very serious and include wide ecological and economic losses. Prominent examples are the collapse of tailings dams in Aznalcollar, Spain and Baia Mare, Romania and the resulting contamination with tailings water and sludge. Therefore, it is necessary to understand precisely the earthquake exposure of such tailings facilities.

Table 1 *Summary of important loss scenarios of tailing failures caused by earthquakes.*

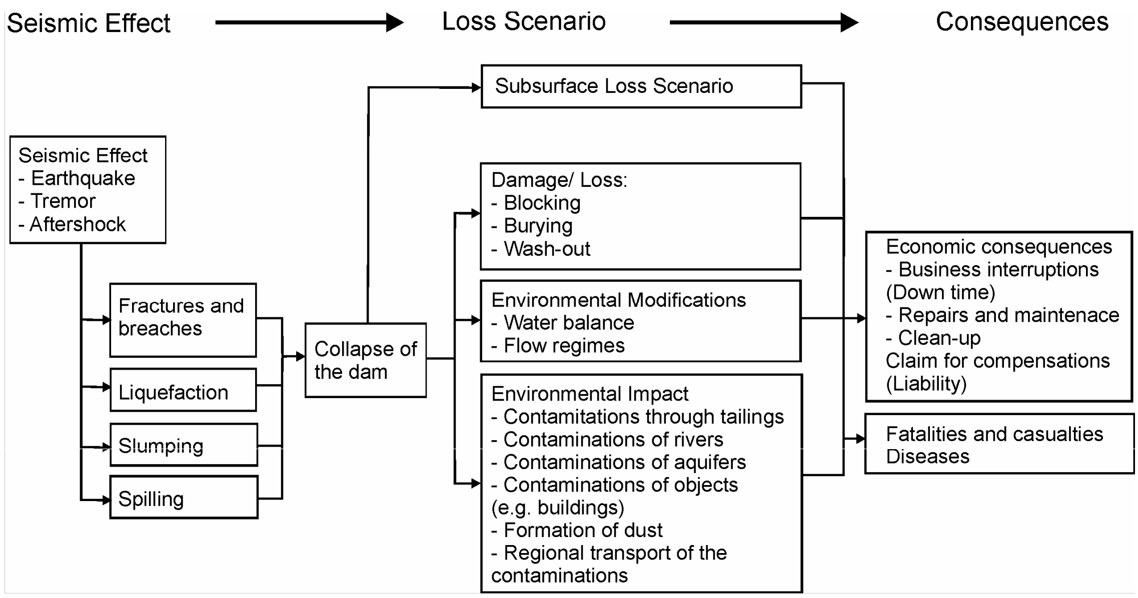
Date	Location	Magnitude	Description	Reference
10. Jan. 1928	Chile	8.3 (?)	- Flood wave of 2,800,000 m^3 tailing material - 500 m wide gap in the 61 m high dam - 54 fatalities - Cause: Liquefaction	ICOLD 2001
28. Mar. 1965	El Cobre, Chile	$m_L = 7.1$	- Collapse of two dams of El Cobre copper mine - Two flood waves of 350,000 m^3 (new dam) and of 1,900,000 m^3 (old dam) - Downstream flow of 12 km - The town of El Cobre was destroyed - More than 200 fatalities	IDRISS 2003 NEIC 2008
19. Mar. 1971	Chungar Peru	$m_L = 4.8$	- Landslide causes the break of a tailing dam - Tailing mud destroyed the surface facilities of the mine and flew into the shafts - Only 25 miners survived	SZ 22. Mar. 1971 NEIC 2007
17. Jan. 1994	North-ridge, USA	$m_L = 6.7$	- Collapse of the 24 m high dam of the Tapo Canyon Tailing - 60 m wide breach - Downstream flow of extended hundred meters in a canyon - Considerable losses for the owner and a downstream water treatment facility	Harder & Stewart 1996 NEIC 2008
Apr. 1995	Philip-pines	$m_b = 6.2$	- Collapse of a dam of the Surigao del Norte gold mine - Several earthquakes damaged the internal dam structure - Crest of the dam was a road - Soaking of internal structure of the dam with infiltrating liquids (water) - Collapse of the dam with a time lag	BRGM 2000 NEIC 2008

Methods

A research programme was carried out to collect data on global loss-scenarios where tectonic earthquakes triggered the collapse of a tailings dam (Tab. 1).

The results showed that it was possible to categorise and classify the reasons for and the consequences of collapses of tailings dams. The main surface-loss scenarios are fractures and breaches, liquefaction, slumping and spilling. The subsurface operations could also be affected by flooding of the mine or the destruction of facilities needed for the subsurface operations. Overall these research results, together with the dependency between the design of the tailings dam and the loss-scenarios, are used firstly to develop a decision-tree to assess vulnerability, as well as ecological and economic consequences of collapses (Fig. 1).

Figure 1 *Decision tree to assess the loss scenarios for failures of tailing dams.*



Furthermore, this knowledge was used to assess the exposure of tailings dams from mines in former East Germany. The earthquake activity in that region was utilised to model a hypothetical case of a tailings dam collapse (Fig. 2). A special exposure exists of mapable fault systems in that area which could be activated (Fig. 2B).

The resulting 3-D model clearly showed the impact of such loss-scenarios and highlighted possible problems of the migrating water and mud wave in a densely populated area (Fig. 3A – Fig. 3D).

Figure 2 *Earthquake intensities for Germany (A) and for the area of the hypothetical case of the dam collapse (B) (Munich Re 2000, BGR 2004).*

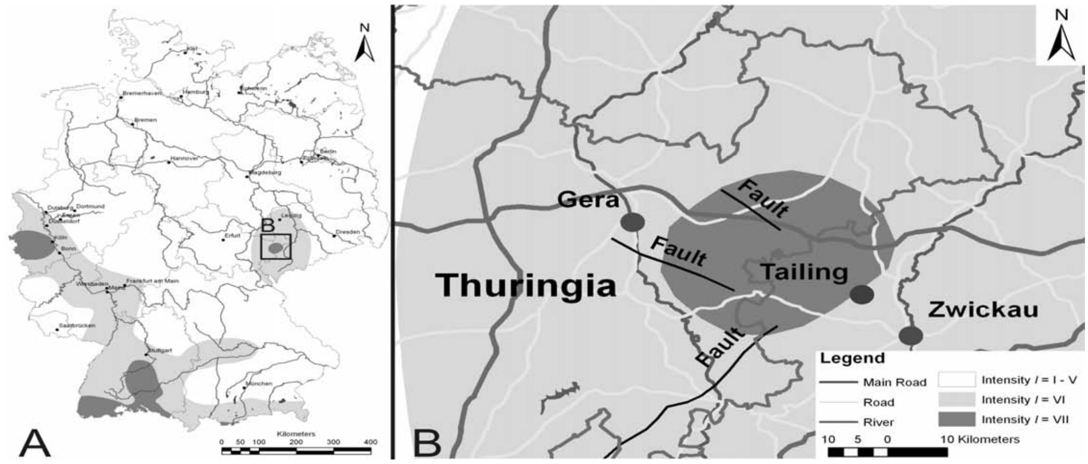
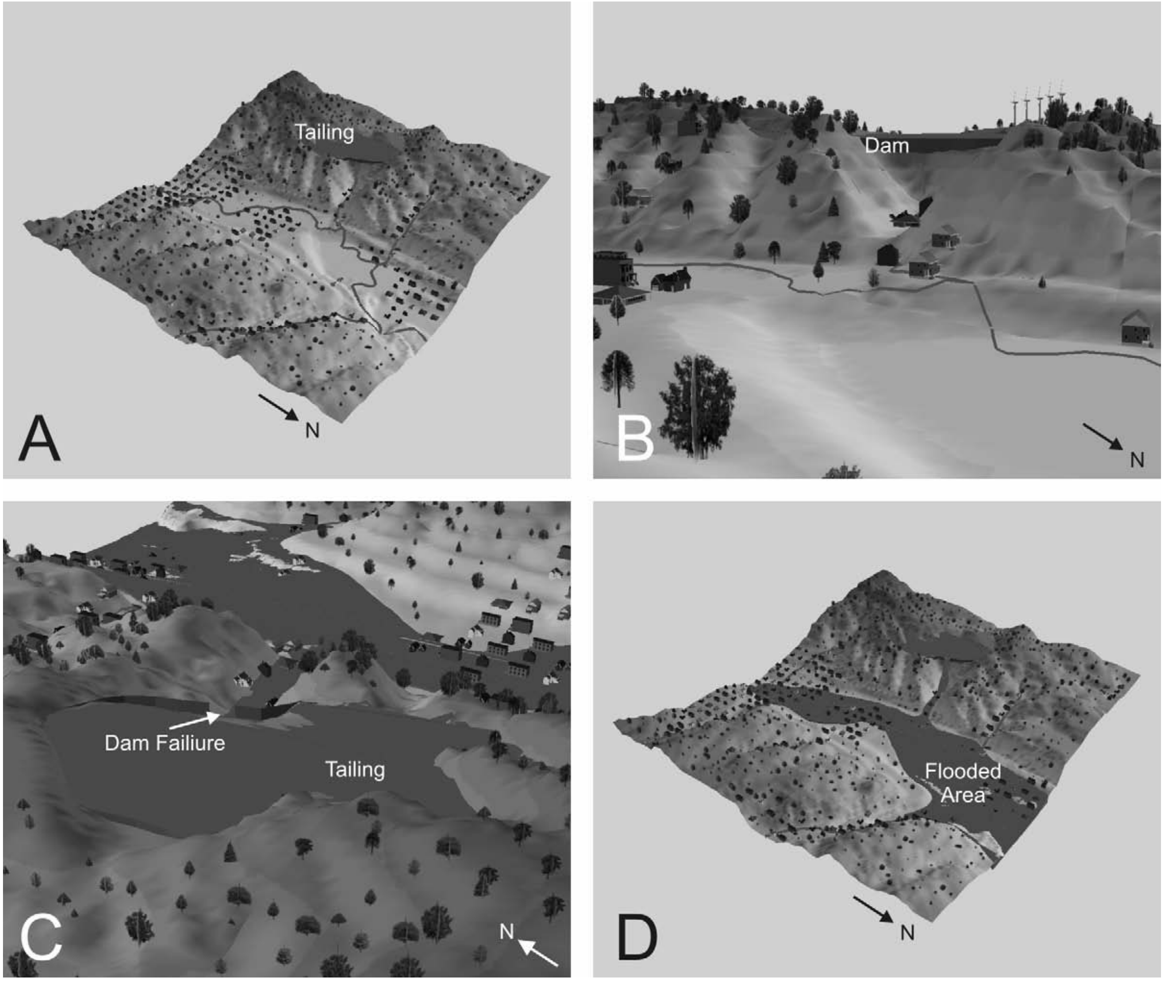


Figure 3 *Extension of the flood wave in the 3D model.*



Conclusions

In summary, the exposure of German tailings facilities to earthquakes is low, especially because of the effective standards and regulations which are used to operate them. However, a collapse of a tailings dam could lead to a wide range of loss-scenarios. Overall, the main earthquake-triggered collapses of dams are breaches and liquefactions. These loss-scenarios could lead to severe local and regional environmental damage and contamination, also leading to high economic losses with high costs for down time and compensation.

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