

Wall Street Journal

Dams Grow to Colossal Heights, and so does the risks.

Engineers say Brazilian disaster shows world-wide danger from Hoover Dam-size earthen structures holding ‘tailings’ waste

By Paul Kiernan April 5, 2016

MARIANA, Brazil—Half an hour’s drive from this colonial town in southeast Brazil, trees suddenly give way to what looks like a desert salt flat. It is a 2-mile-wide valley filled with mine waste.

On Nov. 5, an earthen dam holding back this sea of sludge collapsed, releasing a deluge that killed 19 people, destroyed villages and traveled more than 400 miles to the Atlantic Ocean, where it left a reddish-brown plume visible from space. As tall as a 30-story building and holding enough refuse to fill 19 Dallas Cowboys stadiums, the dam was the largest structure of its kind ever to give way.

It won’t be the last. From Chile to Australia to the U.S., the quest for economies of scale has prompted mining companies to [dig larger and deeper pits](#), creating record volumes of waste. To house all that detritus they have constructed some of the most colossal man-made structures on the planet. Known as tailings dams, these earthen embankments hold back sprawling reservoirs of mud, finely ground rock and water—what is left after a mill separates metals from ore.

In theory, tailings dams are intended to last forever. In practice, they fail often enough that industry engineers themselves are sounding alarms. Fifteen months before the Brazilian disaster, Canada suffered its biggest tailings-dam failure at a copper mine that was in full compliance with local regulations. Experts estimate that between one and four breaches occur each year at tailings dams world-wide, roughly 10 times the failure rate of water dams.

The largest tailings dams, at copper mines high in the Peruvian Andes, are already as tall as the Hoover Dam and have permits to rise even further.

“Our dams and dumps are among the highest-risk structures on Earth,” says Andrew Robertson, a Vancouver-based consultant who has designed a number of very large tailings dams for mining companies. He notes that the biggest mines increase their waste output by 10 times every third of a century.

Accidents in countries governed by autocratic regimes often go unreported, particularly in China, experts say. Regulation and enforcement vary wildly among different jurisdictions, often leaving mining companies to police themselves.

“Around the world, it’s a hodgepodge,” says Harvey McLeod, a Canadian engineer who chairs the tailings committee at the International Commission on Large Dams, or ICOLD. “These structures are so complex, that to write a pre-scripted regulation is almost impossible.”



Watch the video: Massive tailings dams, like this functional one near Antonio Pereira, Brazil, are built to hold back the sludge left behind when a mill separates metals from ore. But the dams fail often enough that industry engineers are sounding alarms. Photo: João Pina for The Wall Street Journal

Some closed tailings dams remain stable and more or less blend in with their surroundings. Antofagasta Minerals PLC is reforesting its hulking Quillayes tailings dam in Chile, closed in the past decade, with native plants to absorb toxins and return to the area to something resembling its natural state. The tailings dam at the shuttered Cannon gold mine in Wenatchee, Washington, has been converted into a horseback-riding preserve named Dry Gulch.

Not so Brazil’s Fundão dam, which belonged to Samarco Mineração SA, a joint venture between two of the world’s biggest mining companies: Australia’s [BHP Billiton](#) Ltd. and Brazil’s [Vale](#) SA .

Samarco, which is under criminal investigation in Brazil in connection with the disaster, says the Fundão dam met all legal and regulatory requirements and showed no sign of structural impairment before it collapsed, an account [one of its consultants disputed](#). Vale and BHP Billiton have said the dam was Samarco’s responsibility, not theirs. All three companies have cooperated in relief efforts and promise to rebuild lost homes.





The dam's collapse sent sludge hurtling through the nearby community of Bento Rodrigues, and left markings on trees 50 miles downstream. *PHOTOS: JOÃO PINA FOR THE WALL STREET JOURNAL;*

In March, the companies involved agreed to spend a minimum of 9.46 billion reais, or about \$2.6 billion, on cleanup, mostly to set up an independent foundation to manage the recovery efforts.

The Samarco disaster has prompted a wave of soul-searching in the mining industry. At BHP Billiton's annual meeting in November, Chief Executive Andrew Mackenzie appeared to choke back tears as he described the "heartbreaking" scene he witnessed in Brazil.

The International Council on Mining and Metals, or ICMM, which includes most of the world's biggest miners, said in December that it would "convene a global review of tailings storage facility standards and critical controls."

Unlike dams that store water or generate hydroelectric power, tailings dams aren't designed and built all at once. They are gradually raised by mining companies as they exploit mineral deposits. While many water dams can be drained and often removed at the end of their working lives, mining companies design their dams with a different goal in mind: to leave them behind when the ore runs out.

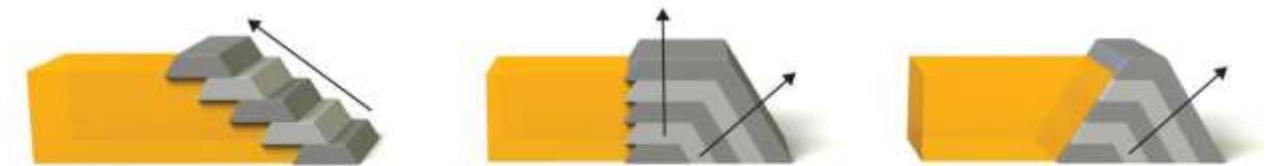
The most common, "upstream," design involves letting the tailings closest to the dam dry out. These dry tailings are then used as the foundation for new levels, raised by plowing earth or tailings into successive embankments. As it requires the least amount of

bulldozing, the upstream method is the least expensive way of building a tailings dam and was employed by Samarco.

Many engineers say upstream dams are the most likely to fail. Earthquake-prone Chile bans the design.

Types of Tailings Dams

As the volume of tailings grows, new levels of the dam—often made of sandy, dried tailings—are added to increase its capacity.



UPSTREAM DOWNSTREAM CENTERLINE

Built up and out

Built in

Built out

Solid tailings

In the centerline and downstream designs, new levels of the dam are placed atop previous levels and built outward. This results in a bulkier—and often sturdier—structure.

In the upstream design, these new embankments rest directly upon the ‘beach’ inside the reservoir. This saves money, since it requires little earthmoving.

Sources: Jon Engles, tailings.info; WISE Uranium Project

A 2009 study by longtime industry engineers that examined 42 years of accident data found the frequency of tailings spills increases when commodity prices fall, “in the manner of a hangover after a good party.” This could reflect pressures to cut costs “once mines constructed on the basis of rising commodity prices are forced to operate with the reality of lower commodity prices,” said the study by engineers Todd Martin and Michael Davies.

Mr. Martin now works at [Anglo American](#) PLC, while Mr. Davies works at Canadian mining company [Teck Resources](#) Ltd. Neither company made the engineers available for comment.

When accidents do happen, they bring not just flooding but heavy, sandy mud that destroys everything in its path. In 1985, a spill of just 200,000 cubic meters wiped out an Alpine village in Italy and killed 268 people.

By comparison, Samarco's dam held 55 million cubic meters of tailings. Rescuers noted at the time that the death toll would likely have been greater if the dam hadn't collapsed during the day, when many residents of the nearest village, Bento Rodrigues, were either away at work or at least awake.

"If I'd been two minutes slower I'd be dead," said Maria Irene de Deus, a longtime resident of the community who fled on foot after the dam burst.

Tailings Dam Risks



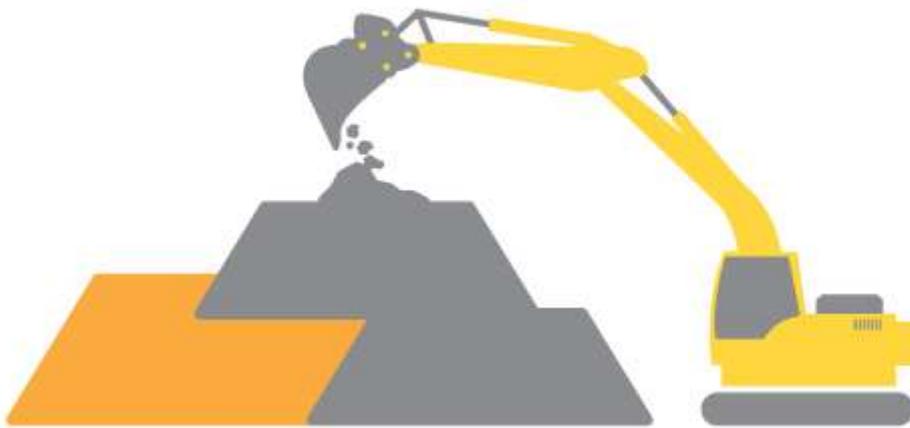
Water

Water is a tailings dam's worst enemy. If it saturates the dam walls or the tailings beneath an upstream dam, the whole structure can liquefy and slide. Wetter tailings also travel farther and faster if they escape, causing more destruction.



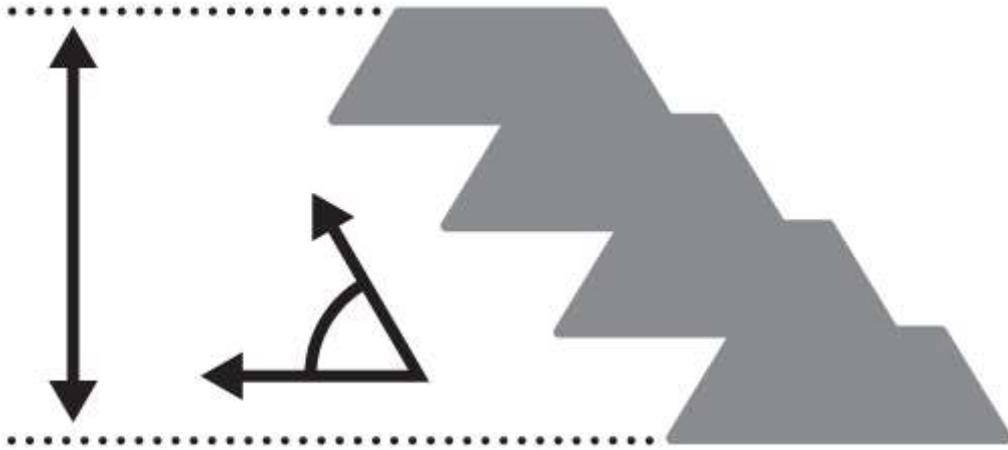
Weak Foundation

An undetected layer of clay or silt beneath a tailings dam can prove disastrous. In addition to being less sturdy than rock or sand, such materials drain poorly, allowing water to silently infiltrate the dam.



Rate of Rise

Upstream tailings dams should be raised slowly, to allow the beach time to dry and consolidate enough to support a new level of the dam. But this requires a level of discipline that can test mining companies.



Height and Angle

The taller the dam, the greater the catastrophe if it fails. The steeper the dam, the greater the risk. For an upstream dam made from tailings themselves, engineers recommend a 25% gradient – flat enough to walk up.

Mr. Davies, the engineer, said in a 2002 paper that the failure rate for tailings dams was approximately 10 times that of water-retention dams. Back then, he estimated there were “somewhat more than 3,500 tailings dams world-wide.”

No one knows for sure. ICOLD doesn’t include the structures in its 58,000-entry World Register of Dams due to internal concern that their high failure rates would tarnish the reputation of all dams, said spokesman Emmanuel Grenier.

The Wall Street Journal asked the top five publicly traded mining companies by annual revenues how many tailings facilities they manage world-wide, which is the tallest and which holds the largest volume. Just one, Anglo American, answered all three questions, noting it has 109 tailings storage facilities world-wide, 38 of which are inactive. Its tallest dam is Perez Caldera No. 2 at 110 meters, and the largest storage capacity is Las Tortolas at 448 million tons, both in Chile.

Vale gave a partial answer to the first, saying it has 143 tailings dams at its iron-ore mines in Brazil. Rio Tinto PLC gave a partial answer to the first, saying it has 35 tailings facilities in operation “and many more closed and legacy sites.” BHP Billiton identified its biggest and tallest tailings dam, Escondida in Chile, but didn’t say how exactly how many it has. [Glencore](#) PLC declined to answer any.

The lack of comprehensive information prompted David Chambers, a geophysicist at the Montana-based Center for Science in Public Participation, and Lindsay Newland Bowker, an environmental risk manager in Maine, to compile a database of all the tailings-dam accidents they could find between 1915 and 2010. Their answer: 226.

Based on the findings, they projected that 11 “very serious” tailings-dam failures—defined as having a release of at least 1 million cubic meters of tailings, traveling more than 20 kilometers or causing multiple deaths—would occur between 2011 and 2020. So far, there have been five.

“It’s one of those things you’d like to be wrong about,” says Mr. Chambers, who advocates for safer tailings storage.

Dangerous tailings dams aren’t just a developing-world problem. Canada, home to one of the world’s most advanced mining sectors, saw its largest-ever tailings accident in 2014 when [Imperial Metals](#) Corp. ’s Mount Polley dam collapsed. Some 8 million cubic meters of gold and copper byproduct poured into a pair of glacial lakes in British Columbia, temporarily cutting off local drinking-water supplies.

A stream where sockeye salmon used to spawn is currently being used as a “ditch” to drain water from the mine site while Imperial Metals rebuilds its tailings dam, says Richard Holmes, a fisheries biologist who lives a short drive away. He says most of the tailings are still in the bottom of the lakes.

The company declined to comment.



A 2014 breach at the Mount Polley Mine in Canada spilled waste into a nearby creek and two glacial lakes. *PHOTO: JONATHAN HAYWARD/CANADIAN PRESS/ASSOCIATED PRESS*

Concern about tailings from closed mines hit the national spotlight in the U.S. last August. An Environmental Protection Agency cleanup crew accidentally triggered a leak from an old gold mine in Colorado that spilled arsenic, cadmium and lead into a mountain river,

prompting the governors of three states to declare a state of emergency. The mine had been closed since 1922.

Scientists say the typical culprit for tailings accidents is too much water, which can cause earthen dams to liquefy. A review panel after the Mount Polley accident recommended that miners adopt technology to remove water from their waste before storing it.

Another way to make a dam safer is to expand it by building outward, rather than upstream atop dried tailings. Called the downstream design, this results in a bulkier structure that more closely resembles a water dam.

But either technique is more expensive than upstream dams.

“What we need to do in order to stop this high frequency of tailings-dam failures is to put safety first,” says Mr. Chambers, of the Center for Science in Public Participation, a nonprofit that focuses on mining. “And right now companies don’t do that frankly. They put economics first.”

Big mining companies deny that is the case. Top engineers say they won’t design a tailings dam if budget limitations may affect its safety. Some, such as ICOLD’s Mr. McLeod, say they avoid building upstream dams altogether.

“We believe that these facilities can be safe with the application of appropriate design and management standards,” says ICMM President Tom Butler. “My members being global companies, they’re very concerned about their reputations. They’ve got a very strong incentive to get this right.”

In the case of Brazil, officials acknowledge that regulatory oversight is sparse. Prosecutors say the National Department of Mineral Production, or DNPM, had only two dam-safety specialists responsible for monitoring more than 300 tailings facilities in Minas Gerais state before the accident. The agency was also hit by funding cuts amid Brazil’s ongoing fiscal crisis.

“We don’t have a budget or human resources,” says DNPM spokesman Paulo Santana.

By most accounts, Samarco was actively involved in nearby communities before its accident, and was seen as a responsible company. In early 2015, it agreed to spend 500,000 reais setting up a new water-supply system in Bento Rodrigues. Company officials often participated in town-hall meetings.

“Samarco always went to meetings in Bento Rodrigues saying not to worry, sleep easy,” said Gilberto Pereira da Silva, a 33-year-old father of three who was displaced along with most of the village when the dam burst. “We lived in fear but trusted Samarco.”