Sustainability and fluid mechanics #70719

David V Boger
Laureate professor
Department of Chemical and Biomolecular Engineering
The University of Melbourne, Victoria 3010
Australia

Abstract

The minerals and energy industries worldwide are very upbeat about sustainable development. Many companies have sustainability managers. Unfortunately most of their effort in sustainable practice is directed towards the social and stakeholder interaction in the community. Very little effort is being made to apply sustainable practices to management of liquid waste tailings. Even though technology exists now to move from wet to dry disposal methods, the industry still insists on building traditional dams that defer the costs associated with dealing with waste until some time in the future when the company is often able to escape the liability. The paper summarises how knowledge in fluid mechanics (non-Newtonian fluids) can be exploited to minimise the waste associated with these important industries.

Introduction

It is surprising that so few people are aware of the triple bottom line. The three lines represent Society, the Economy and the Environment. Society depends on the economy, and the economy depends on the global ecosystem, whose ultimate health represents the ultimate bottom line. More precisely, the triple bottom line now focuses corporations, not just on the economic value that they add, but also the environmental and social value they add and/or destroy. At its narrowest it is a framework for measuring and reporting corporate performance against economic, social and environmental parameters. Sustainable development is linked to the triple bottom line in that it is about strengthening the business while reducing negative social and ecological consequences. Many major corporations now report relative to the triple bottom line.

The impact of fluid mechanics

How can fluid mechanics influence the triple bottom line? Knowledge of non-Newtonian behaviour can be exploited by many industries to drastically reduce the volume of waste currently produced and stored, and hence reduce the negative social and environmental impact of these industries. The minerals industry worldwide is an example, while the huge oil-sand mining activities in Canada is another, as is the disposal of human waste. For example, there are copper mines in the world which produce, on average, 250,000 tonnes on a dry basis of fine particle waste per day. Such waste is pumped to a disposal area at relatively low concentration when the material has Newtonian flow characteristics. This disposal area is invariably a very large dam; in fact, disposal areas approaching half the size of Singapore are present in the world. If the waste from such a mine, whether it be from minerals, coal, oil or human waste, is dewatered and the water is reused in the process, the footprint produced by the dam can be reduced dramatically. In fact, it is possible to go from wet to dry disposal. There are many incentives to do this ranging from conservation and reuse of water to reduction of the considerable risk involved in these dams. In the last twenty years there have been forty-four tailings dam failures. The probability of such a failure apparently ranges from one in seven to one in fifteen[www.wise-uranium.org/mdaf.html].

The consequence of a dam failure is dramatic and can be tragic. The photograph in Figure 1 shows the rupture in a tailings dam holding the waste from a lead-zinc mine in Spain in 1998. Five million cubic metres of water and particulates containing high levels of heavy metals poisoned two rivers and flooded crops. The company was fined 45 million euros; the miner sued the company who built the dam for 101 million euros; regional authorities sued the company for 89.8 million euros; shareholders apparently are suing the company for their losses as the company shares plummeted. Cleanup costs exceeded 250 million euros. This is a graphic example of what happens when such a tailings dam bursts; in this case, no lives have been lost.

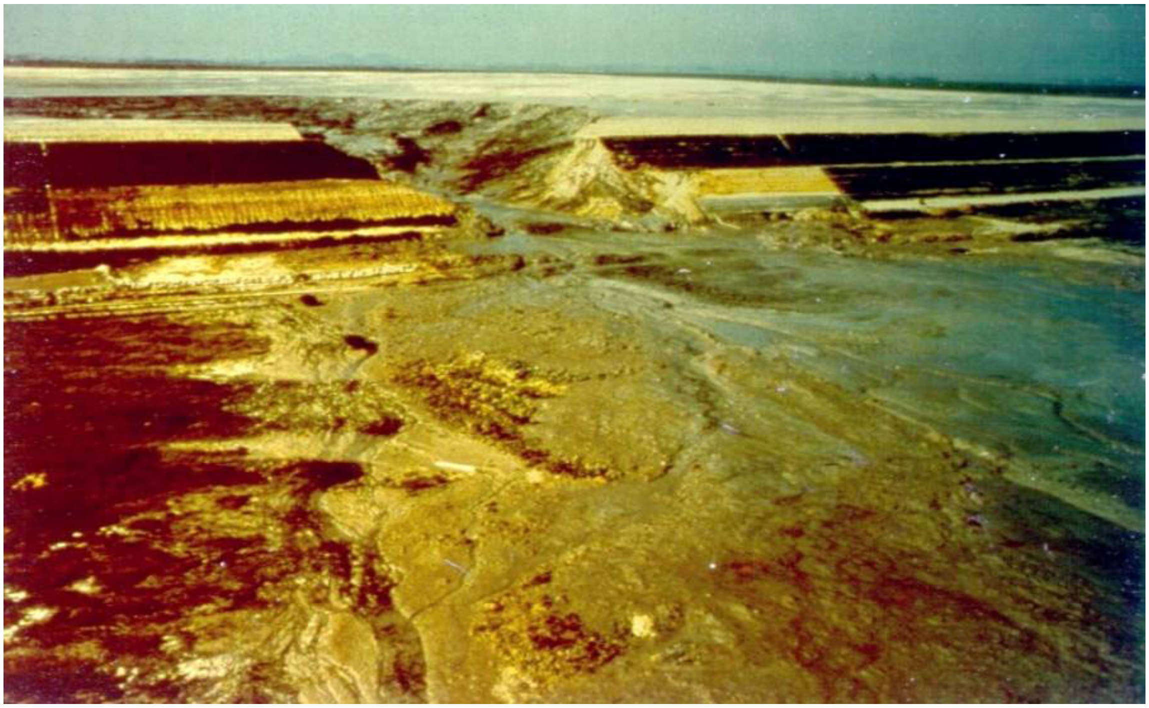

Figure 1: Failure of the Boliden lead-zinc tailings dam in 1998.

In another case, the Stava failure on 19 July 1985, 268 people lost their lives as a result of the tailings dam failure. Such failures can virtually be eliminated by moving from wet, Newtonian fluid suspension disposal to a highly concentrated, non-Newtonian fluid disposal simply by understanding and exploiting very basic shear and compression rheology. As the concentration is increased the material becomes non-Newtonian, exhibiting, generally, pseudoplastic characteristics. Further increase in the concentration sees the beginning of a yield stress, and ultimately, one generates a very high yield stress material which may be difficult, if not impossible, to pump. Materials with yield stresses up to 200 Pascals can now be pumped with centrifugal pumps, and it is technically feasible to dewater and pump at such concentrations and dry stack, as is the case in the alumina industry in Western Australia (see Figure 3). An application of very basic rheological principles, involving both compression and shear rheology, is all that is needed to reduce the risk, recover water, and reduce the footprint. Hence, consistent with the triple bottom line, exploiting the rheology will decrease the negative social impact and environmental impact of the particulate fluid waste, not only from the minerals industry, but also from the coal, oil and human waste disposal industries.

The photograph in Figure 2 shows the type of paste material which can be produced in compression thickeners and pumped, whilst the photograph in Figure 3 shows a dry disposal area, which contrasts markedly with a Newtonian, fluid dam which is often the current practice.

The presentation deals with the technical aspects of fluid mechanics which can be exploited to minimise the environmental impact in many minerals and energy industries.

Figure 2: Mineral waste produced with a compression thickener.

Figure 3: Alcoa Western Australia, bauxite waste dry stacking.