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Environmentally sustainable mining: The case of tailings storage facilities

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ABSTRACT

This paper addresses the question of whether mining can be done in a way that contains and remediates environmental impacts and thereby safeguards the livelihoods of local populations. It focuses on tailings storage facilities (TSF) as the source of most mining-related disasters. It compares outcomes at three mines – two which ended in disaster and one notable success – to try to get at what factors are critical in producing these outcomes. Although the design and construction of TSFs is technically challenging,the paper concludes that the basic causes of TSF failure are political, not technical. A second purpose of this paper is to suggest that a social scientific analysis of engineered projects needs to pay attention to the engineering.

1. Introduction

Mining is unavoidably environmentally disruptive. Huge quantities of earth and rock are moved, some of it processed to recover valuable minerals, the rest discarded as waste. The materials that are left over after processing, known as tailings, are estimated to be produced at a rate of anywhere from five to fourteen billion tons per year. They may include sulfide minerals that can induce the formation of acid drainage, other processing chemicals, and process water. Tailings can be disposed of in a variety of ways. In the worst of the cases, they are dumped into adjacent waterbodies, whether rivers, lakes or the sea. They may be backfilled into pits left over from underground mining. Much of the time however, tailings are stored behind dams constructed of mine wastes (Edraki et al., 2014; Adiansyah et al., 2015).

Environmental disruption related to mining is inevitable. Environmental disaster, on the other hand, should not be, the more so as environmental disasters often trigger social disasters. The most critical arena for reducing the likelihood of mining-related environmental disasters lies in the handling of tailings.

Tailings dam failures account for about three-fourths of major mining-related environmental disasters (MMSD, 2002a). A tailings storage facility (TSF) can occupy several square kilometers of land with dams that can reach in the tens of meters. Tailings dams are not like water retention dams. They are built in stages as mining and waste production progresses and they are built usually of mine wastes rather than concrete. Water management is the critical problem. An adequate amount of freeboard must be maintained, calibrated on maximum likely storm activity. If water is adjacent to the dam itself, erosional or seepage processes may lead to breaching. The foundational geology is also a critical issue bearing on the stability of the embankments. TSFs in seismically active or unusually high rainfall areas are especially vulnerable (Vick, 1990; McLeod and Murray, 2003).

The technical challenges of storing mine wastes are significant. Nevertheless, I will argue here that the principal causes of TSF failures are political rather than technical. Much is known within the mine engineering community about how to manage tailings in an environmentally sustainable way (Vick, 1990). This generally involves different techniques for removing the water. These techniques are costly, however. Some companies may adopt them voluntarily. It seems reasonable to suppose, however, that until the companies generally are held to higher standards of best practice in managing tailings, we will continue to see catastrophic TSF failures.

Best practice bears on two issues in particular for the purposes of this paper. The first concerns when and how environmental considerations – in particular, the design of TSFs – are built into the mine development process. The second concerns the actual techniques involved.

I will show that when mining companies are held to the highest standards, they can and do meet them. Whether or not they are held to those standards depends in significant measure on the regulatory environment. How exigent are the regulations, how

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comprehensive are they, and how well are they enforced? The answers to these questions, I will suggest, have in part to do with the influence of the industry in particular jurisdictions compared with other land-intensive uses, especially as this bears on regulatory capacity and competence. Second, the social composition of the surrounding population also matters. Local populations with political and financial resources will have a much greater chance of escaping environmental disasters than those without such resources.

In this paper, I will explore the histories of three mines. Two of them suffered major TSF dam collapses with widespread and ongoing environmental damage: the Ok Tedi mine in Papua New Guinea (PNG), and the Mount Polley mine in British Columbia. The third mine – the McLaughlin mine in Northern California – is a rare success story in which all of the environmental dislocations necessarily associated with mining were confined on site and, to a significant degree, remediated after active mining ceased. The TSF has retained its integrity. I have explored the Ok Tedi and McLaughlin mine histories elsewhere and will summarize them briefly here (Schoenberger, 2015). The third case is more recent, dating to August 2014. I will focus on the construction and maintenance of tailings dams.

What I want to work through in this paper is why the failures failed and why the McLaughlin mine succeeded at mining in an environmentally sound and responsible way. Because the environmental damages of mining are closely linked to social harms (through impacts on livelihoods, exposure to environmental toxins and the like), it is particularly worthwhile getting at the causes of both success and failure in an effort to determine whether mining can increasingly be done in a way that contains and remediates environmental harms.

A second purpose of this paper is to suggest that a social scientific analysis of engineered projects needs to pay attention to the engineering. Because of the complex interplay among the environmental, the social and the engineered, we risk missing important information if we treat the engineered as a kind of black box. The reverse is probably also true. A quick search through recent journal publications on the topic of tailings storage facilities shows that they are all in technical journals unlikely to reach a social science or policy audience.

An important and promising exception to this is the 2011 paper by Franks et al. in the journal Resources Policy. It provides an assessment of the advantages and disadvantages of a range of waste disposal methods and proposes a set of principles that could be used to guide industry practice (Franks et al., 2011). I think we need to press further in three ways.

First, it is clear that best practice under these principles will be more expensive than many of the approaches that are in use today. The industry as a whole has expressed its commitment to more socially and environmentally responsible methods and, all other things equal, many operations can afford the additional costs and may well implement them voluntarily (ICMM, 2008). But marginal operations may be hard-pressed or simply unwilling to adopt them. Declining ore grades and declining commodity prices separately and together are no doubt putting considerable pressure on mining companies at the margin (Mudd, 2007). So we need to consider the degree to which voluntary adherence to the principles proposed by Franks et al. can be relied upon.

Second, I will try to show that the way the design of TSFs is integrated into the overall development plan of the mine matters. In brief, it needs to be an integral part of the process of designing the mine itself rather than being viewed as a separate problem.

Third, there is a question of who is able to comment authoritatively on the design and operation of TSFs. The industry as a whole is increasingly committed to meaningful participation by local communities which is all to the good. Here, though, I want to argue in favor of binding independent peer review of both the design and operation of TSFs in additional to local stakeholder participation.

Section 2 of this paper describes the research method. Subsequent sections (3 through 5) describe and analyze the performance of the three mines in question. Section 4 considers the problems of TSFs more generally, focusing on what is considered best practice by the engineering community and what conditions might foster the wider implementation of this knowledge in the design, construction, maintenance and closure of TSFs. Section 5 offers some concluding thoughts. An epilogue brings some aspects of the story up to date.

2. Research method

This research is qualitative and, in a sense, forensic. It is based on a review of published and unpublished documents related to the specific cases and to the engineering of TSFs in general. These documents include technical post mortems of the two failed TSFs. Other information was gathered from correspondence with and conference presentations of practicing engineers with many decades of experience in the construction and maintenance of TSFs. Information was also gathered from company websites, government websites and newspaper accounts.

I have only been able to make one site visit. This was to the McLaughlin mine where I was guided by the former environmental manager and the current manager of the TSF. One very experienced field engineer was kind enough to review this manuscript for technical accuracy. Some of my correspondents have preferred to remain anonymous and I am obliged to respect that request.

Case studies do not allow for statistical validation or generalization. They can, however, shed light on highly complex situations and possibly provide the grounds for developing testable hypotheses (Schoenberger, 1991).

3. Tailings storage facilities: lessons from three mines

3.1. Ok Tedi

The Ok Tedi is an open pit copper and gold mine in Papua New Guinea (PNG) developed from the early1980s by a consortium headed by the Australian firm, BHP Billiton. It cost about US$1.4 billion to develop the mine which sits near the headwaters of the Ok Tedi River in the highlands of Western PNG. The Ok Tedi's waters flow into the Fly River, and thence into the Bay of Papua (see Map 1). The Fly is notable for its extraordinary biological diversity (Townsend and Townsend, 2004).

According to the terms of a 1976 PNG law, the mine developers were required to prepare an Environmental Impact Statement (EIS). However, the company was only required to spend a maximum of US$220,000 on this study whose scope was, accordingly, quite limited. A second, government-commissioned EIS was more thorough, funded at US$1 million (Hyndman, 1988; Townsend and Townsend, 2004).

The critical element here for our purposes is that the second EIS was delivered in 1982, a year after construction had started. No alternatives to the Consortium's original design were considered (Townsend and Townsend, 2004). BHP Billiton had, however, promised the government of PNG that 100% of the tailings would be contained (MMSD, 2002b). Since the operation generated about 30 million tons of ore and 55 million tons of waste each year, management of the tailings and the waste rock were critical issues (MMSD, 2002b).