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# Mine Waste Disposal in the Ocean

## An Introduction

BY GREGG J. BRUNSKILL

*This introduction launches a series of articles on mine waste disposal in the ocean. Two articles follow in this issue and more articles will be printed in coming issues.*

Could we, should we, knowingly pollute the world ocean? It's easy to think that the ocean is awfully big, and maybe no one will notice. Unfortunately, it's too late to debate this ethical issue—we've already done it (Thiel, 2003; report on 2011 "State of the Ocean" workshop at http://www.stateoftheocean.org/ipso-2011-workshop-summary.cfm).

Tetraethyl-Pb added to transport fuels changed the concentrations and isotopic ratios of Pb in the entire surface ocean and the polar ice caps (Nriagu and Pacyna, 1988; Patterson and Settle, 1990; Kitman, 2000). DDT, dioxins, PCBs, and other deleterious anthropogenic contaminants have reached the deep sea and polar ice sheets (Dachs et al., 1999; Geisz et al., 2008). Anthropogenic fossil fuel combustion-derived carbonic acid is now titrating the carbonate alkalinity of the world ocean (Sabine et al., 2004).

The mining industry has a long (5,000-year) history of polluting local soils and water, and we can detect contaminant Pb, Hg, and other elements from mining operations in earlier millennia (Hutchinson, 1970; Abbot and Wolfe, 2003; Lee et al., 2008; Elbaz-Poulichet et al., 2011). Now, the modern mining industry is seriously proposing that it is better to dump mine wastes into the coastal and deep sea rather than to contain them in engineered tailings ponds on the land near the mine hole or refinery (Ellis and Robertson, 1999; Ellis, 2008). Marine waste disposal is certainly cheaper and quicker. Because most of this intentional pollution expanded greatly during our post-World War II generation, I suspect our descendants will look back at our culture with disappointment. We are the children of the Anthropocene (Zalasiewicz et al., 2011), and we should figure out a way to do better for future generations (Ehernfeld, 2009; Vidas, 2011).

Human technology moves more dirt and rocks around than natural river erosion transport to the sea. Global mine waste rock and tailings annual production are estimated to be somewhere between 5 and 50 × $10^{15}$ g $yr^{-1}$ (Douglas and Lawson, 2000; Schwarzenbach et al., 2010). That figure is about 210–2,100 million rock-loaded rail/truck containers per year—a rock-loaded train length in excess of 1.5 million km, or the weight of 7.4 billion Boeing 747 aircraft. Much of this waste is temporarily stored on land in pits, but gravity will eventually take this metal-rich waste downslope to the sea. Annual river transport of sediment to the sea is estimated by Li (2000) and Syvitski and Kettner (2011) as 12–15 × $10^{15}$ g $yr^{-1}$. If any large fraction of this exponentially increasing mine waste/tailings were to be delivered to the world's continental shelves, they would approximately double natural sedimentation rates.

According to Rauch and Pacyna (2009), the mining industry has increased by 50% the mobilization of natural Ag, Al, Cr, Cu, Fe, Ni, Pb, and Zn cycles in the biosphere. It would appear that this problem is not small or local. Evidence is accumulating that, in addition to dust, trace elements are supplied to the open ocean via horizontal transport from metal-rich continental shelves and slopes (Elrod et al., 2008; Cullen et al., 2009; Slemons et al., 2010; Misumi et al., 2011). Increases in the supply of coastal shelf and slope iron

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to the open ocean might be beneficial for productivity, but augmented supply rates of Hg, Pb, Cr, Cd, and As might be deleterious for marine biota or human harvest of seafood. Would you like a little more mercury and arsenic in your tuna salad? As with global greenhouse gas impacts on our ocean (Falkowski et al., 2000), metals and other contaminants from mine wastes dumped into the sea are likely to be globally dispersed in dissolved and particulate form by world oceanic currents and the relentless tides.

Rather than extracting metals only from new mining efforts, it would seem more energy and metal efficient to mine the municipal waste dump sites in cities, and to manufacture metallic goods so that valuable minerals can be easily recycled for centuries to come (Müller et al., 2006; Braungart and McDonough, 2009; Brunner, 2011; Graedel and Cao, 2010; Graedel et al., 2011; Liu et al., 2011; Reuter, 2011; Schnoor, 2011; Zhang et al., 2012). It also seems likely that old land-based mine waste piles will become valuable sites for recovery of new minerals needed for the post-fossil-fuel, decarbonized era (Gerst and Graedel, 2008; Pickard, 2008). It is often claimed that these mine and refinery wastes are environmentally harmless. If so, the wastes should be put to work as road base, concrete, and bricks, and, for ultramafic minerals, used for atmospheric and plant $CO_2$ sequestration (Pronost et al., 2011). Perhaps the deleterious human health and ecosystem impacts would be better controlled in the midst of millions of humans in large cities?

The ethics of scientific involvement in evaluating environmental impact of mining and other developments follow pathways of conflict. The social and economic engines of progress demand more and more coal, oil, steel, aluminium, copper, nickel, gold, silver, and rare earth elements to build more and more computers, iPods, airplanes, and military weapons. Government geological survey agencies provide surveys and exploration to find hot spots of mineral resources. Mining companies are happy to provide the minerals necessary for consumers, if their profits are large. The miners are supplying the demand for mineral resources from the wealthy, developed USA, Europe, China, and India, but the minerals increasingly come from lesser-developed countries with ineffective regulatory and environmental standards. This often results in exploitation of the poor to provide wealth for the industrialized countries (Ali, 2009; Mouhot, 2011). Academic scientists, consulting companies, and engineers are paid by the mining companies to conduct environmental impact studies (EISs) designed to show that mining developments will meet the legal and environmental standards of the host countries (Radder, 2010). If we are fortunate, an EIS is done (and made public) before a development begins, and it attempts to predict the impact of the mining activities on regional economic development, ecosystems, and local people (McGarity, 2004; Mirowski, 2011).

Environmental impact statements for industrial development (mining) projects are usually evaluated by the host country government agencies responsible for economic development, occupational health and safety, cash flow, mining and mineral policy, and, sometimes, environmental impacts related to the local people and ecosystems. In most cases, inadequate information is provided by the EIS, the evaluating agencies rarely have the expertise to do their jobs, and often the local people are not consulted until after the development permits are granted. Eventually and quietly, permits for mining and tailings contamination of the region are issued, in expectation of national income from taxes. The mining companies and pro-development governments emphasize the provision of jobs, training, and improved local facilities, and quietly indicate that the local people have to give away some of their land and sea tenure rights, and environmental quality (Shellenberger and Nordhaus, 2007; McGarity and Wagner, 2008). Before and

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after mining developments, environmental costs and ecosystem losses are rarely measured and subtracted from the profits of the mining companies.

Local people who are affected by the mining may hire lawyers and their own environmental consultants to review the situation, often with involvement of independent scientists with local expertise and local seafood-dependant villages. Quite frequently, there are two camps of local people: those who may benefit from the mining development, and those who will be deleteriously affected by the development. In the midst of this social, economic, and regional development conflict, now appear two groups of scientists, often presenting conflicting evidence on the impact of the mining development on coastal and deep seas. The consultants paid by the mining companies usually bias their reports in support of development, whereas the independent scientists and nongovernmental organizations usually bias in favor of natural ecosystem protection and local community rights (Wagner and Steinzor, 2006; Oreskes and Conway, 2010). In many cases, international, national, and local law and court systems are inadequate to deal with this problem (Ruggie 2008, 2011). In less-developed countries that host mining developments, the minerals and profits go to London, New York, Toronto, and Beijing, not to the local people, who are left with decades or centuries of environmental problems. And therein lies the problem.

A series of occasional papers, starting in this issue of *Oceanography*, will provide some examples of mine wastes deposited in coastal and deep seas as well as associated legal, ecological, toxicological, and engineering problems (Edinger, 2012, in this issue; Koski, 2012, in this issue). Most past mine waste pollution problems have occurred in shallow coastal seas, but in the past decade, miners have begun to propose and build submarine pipelines to dispose of mine and refinery wastes in deeper water below the coastal mixed layer (100–1,000 m depth). It is a big challenge for marine chemists and ecotoxicologists to predict the impact of refinery tailings in submarine canyons and on continental slopes. Mine waste disposal engineers like to refer to the practice as "deep sea tailings placement," or DSTP (Ellis, 2008); however, this is not really the deep sea but rather the outer shelf or continental slope. The word "placement" is also inappropriate—it implies that the mine waste will rest on the seafloor in a discrete pile and not be transported along the coast by currents and tides in particulate and dissolved form. It is clear that the time for scrutiny of proposals for mine waste disposal into the sea is well before the permit is issued. Once the waste is in the sea, there is no chance of recovery of valuable metals in the waste nor of ecological remediation over the following century.

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