Society and Natural Resources, 26:270–284

ISSN: 0894-1920 print/1521-0723 online
DOI: 10.1080/08941920.2012.685147

Mines and Microbes: Public Responses to Biological Treatment of Toxic Discharge

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This article examines public acceptability of ecogenomics-enhanced bioremediation (EEB), a novel technology designed to treat polluted mine drainage. Given the newness of EEB and its application to a controversial area, it is important to assess its public acceptability; however, no assessments of EEB acceptability currently exist. Drawing on the Public Acceptability of Controversial Technologies framework, we treat acceptability as the conditional willingness of social groups to consider a technology as an option. Interviews were conducted with nine community groups and three First Nations living adjacent to a pilot EEB system. Participants express generally positive attitudes toward EEB, but are worried about potential unintended consequences. With low levels of trust in authorities, groups propose public monitoring as a condition of acceptability—but are skeptical that this condition will be met. Future research could facilitate processes in which acceptability conditions can be met and examine consequent changes to public acceptability.

Keywords aquatic pollution, bioremediation, controversial technologies, ecogenomics, mining, public acceptability

Large-scale industrial practices often produce toxic by-products that pose a danger to ecosystems and human health, if left untreated. Since the passage of environmental laws in the 1970s, government and industry have been required to prevent or, where this is not possible, remediate environmental pollution. A wide range of

Received 5 July 2011; accepted 10 February 2012.

We thank participants from the community groups and First Nations who contributed their time and expertise to our study. We also acknowledge the assistance of our academic colleagues and industry partners in the project "The Development of Genomic Tools for Monitoring and Improving Passive Mitigation of Mine Drainage." Fieldwork and analysis by social science team member Dr. Conor Douglas are particularly noted. The project was funded under the Applied Genomics Innovation Program by Genome British Columbia, whose support we gratefully acknowledge. Finally, this article benefited from the comments and suggestions of three anonymous referees, particularly referee number 2.

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technologies has been developed to clean up industrial pollution, from excavation and land-filling, to the application of reagents to stabilize toxins, to chemical treatment. Environmental remediation technologies are no panacea, however. These technologies are developed with the same form of technological rationality—including a tendency to dominate and control nature—that is responsible for the production of environmental problems in the first place. For this reason, it is important for the public to scrutinize the development of new environmental technologies to the same extent that they demand attention to environmental pollution.

A relatively new remediation technology employs biological methods to treat pollutants. Referred to as bioremediation, this technology relies on the activity of microbes (microscopic organisms such as bacteria) to break down pollutants into less toxic forms. Bioremediation can be applied to a number of environmental problems, including oil spills, nuclear waste, and toxic drainage from mining operations (Juwarkar et al. 2010). On the face of it, bioremediation offers a softer, less controlling method to clean up environmental pollution. However, the technology can still be quite sophisticated, entailing the design and deployment of complicated systems such as anaerobic bioreactors. Recently, another layer of complexity arose when researchers began to apply the tools of ecogenomics—the analysis of genetic material derived from communities of microscopic organisms—with the goal of improving the functioning of bioremediation systems.

The purpose of this article is to analyze the acceptability of a pilot ecogenomics-enhanced bioremediation (EEB) project for local community groups and First Nations at a mine site in British Columbia. Drawing on the Public Acceptability of Controversial Technologies framework (PACT; Wolfe et al. 2002), we make a distinction between acceptability and acceptance. Acceptability refers to the willingness of social groups to consider a technology as potentially appropriate, whereas acceptance is a final judgment or decision about whether or not to deploy a technology. Our review of available literature on public attitudes toward bioremediation leads us to expect that local community groups and First Nations will express positive attitudes toward EEB, due to its application to a valued end (environmental cleanup) and its positive affective valence (its "natural" character). We also expect that participants will express concerns about the technology, due to their lack of familiarity with it, inability to predict its performance, and lack of trust that industry and government would guard against potential negative impacts. A central objective of the article is to examine how community groups and First Nations translate their concerns about EEB into conditions of acceptability.

In the following, we provide a brief background to our study, including an overview of bioremediation technologies for polluted mine drainage and the setting and goals of our research project. Next, we review relevant literature on public attitudes toward bioremediation, describe the PACT framework, and present our research questions. We then describe our research design and our methods of data collection and analysis. The next section summarizes our findings, including research participants' attitudes toward EEB, concerns about EEB, and acceptability conditions. Finally, we relate our findings to the literature and conclude with a suggestion for how future studies of public acceptability of remediation technology might be conducted.

The Mining and Ecogenomics Research Project

Metal mines have the potential to create serious environmental problems if drainage containing elevated levels of acid, sulfates, and heavy metals is released into the environment. The principal means of avoiding such an outcome is storage or chemical treatment (Johnson and Hallberg 2005). However, since the 1970s, researchers have experimented with alternative, biological treatment methods, which rely on the action of microbes to neutralize toxins. Constructed wetland systems create anaerobic conditions to foster the growth of beneficial microbes. When mine drainage flows through these systems, microbes alter the chemistry of toxins via natural metabolic processes, thereby rendering toxins inert as they settle into the system's sediment. While such bioremediation systems have achieved a degree of success, there have also been many failures and the industry has been reluctant to adopt them (Skousen and Ziemkiewicz 2005).

In 2008, GenomeBC (a genomics and proteomics research funding organization) funded a 3-year research project to develop ecogenomics tools to improve the functioning of bioremediation systems in the British Columbia (BC) mining industry. Ecogenomics[1] involves studying the genetic material of communities of (microscopic) organisms. Rather than culturing individual microbes in a laboratory, scientists take samples from soil, water, or living organisms and analyze the genetic material that these samples contain (Eisan 2007). As applied to bioremediation, ecogenomics investigates the growth, metabolism, and relationships among functionally important microbes, thereby providing insights into the processes and pathways involved in the microbial biodegradation of toxins associated with industrial production, agricultural insecticides, and mine drainage (Gupta and Sharma 2011).

The BC research project—a collaboration among biochemical engineers (project lead), microbiologists, social scientists, two mining companies, and a bioremediation company—focuses on two pilot bioremediation systems in BC. One pilot system (the focus of this article) is located at an operating open-pit copper/gold mine site in central British Columbia. The site includes a large tailings dam and storage reservoir (approximately 200 ha in size) that collects slurry and site runoff. Elevated levels of heavy metals such as sulfate, cadmium, copper, molybdenum, and selenium are found in the tailings pond, making the water unacceptable for release into the general environment. Recently, given the need to increase operational flexibility and planning for eventual closure, the mining company applied for a permit to discharge tailings water into a creek that feeds into the local lake system.

In collaboration with the University of British Columbia (UBC) researchers, the mining company built a small bioremediation prototype, which, if it proves effective, will be scaled up to operational size. The system features an open pond lined with rich organic materials intended to encourage the growth of beneficial microbes. The UBC researchers periodically sample the system to detect the microbes present and assess their functional relationships. Additionally, the researchers are conducting laboratory experiments on the different types of organic materials that line the system to determine which one yields the greatest microbial productivity. In addition to the objective of creating a functioning bioremediation system, one goal of the project is to create a diagnostic tool that would enable bioremediation practitioners to assess microbial structure and functioning in particular systems.

Development of a full-scale ecogenomics-enhanced bioremediation system has the potential to cause controversy among local communities and First Nations, not least because it involves discharging water into a highly valued local lake system. Public consultations on the mining company's discharge permit application revealed serious concerns that the discharge would adversely affect the environmental quality of the local watershed. Moreover, several groups expressed outrage that the company was now planning to discharge mine drainage after originally promising, in their view, that it would never do so. Accordingly, levels of concern were very high and levels of trust very low.

As the social science members of the research team, we focused on this site as a case study of public acceptability of ecogenomics-enhanced bioremediation technologies. Given the need to treat toxic mine drainage before release into the environment, we were interested in community groups' and First Nations' views about the appropriateness of this treatment technology. Additionally, given the relative novelty of bioremediation in comparison with other treatment technologies, and especially the ecogenomics component, we were interested in local groups' potential concerns about EEB. Finally, given our interest in public acceptability as an ongoing process rather than a final decision, we were interested in how local groups translate their concerns into conditions of acceptability.

Bioremediation and Public Acceptability

Public Attitudes Toward Bioremediation

No studies of public acceptability of EEB currently exist (but see de Boer 2010; Roelofsen et al. 2010). Moreover, there is only a limited literature on public attitudes toward bioremediation in general, with few published studies (see Kocher et al. 2002; Lach and Sanford 2009; Skumanich 1993; Strauss 1997; Weber et al. 2001), and a small gray literature in connection with the U.S. Department of Energy remediation activities (see DOE Citizen Panel 2002; Drell and Metting 1996; Focht and Albright 2009; Lach and Peterson 1995; Sanford 2003). In general, the published and gray literatures find that stakeholders express positive attitudes toward bioremediation. Reasons given in support of bioremediation include its relatively lower cost and its ability to sequester contaminants in the ground and avoid transportation (DOE Citizen Panel 2002; Lach and Sanford 2003; Peterson 1995), as well as the perceived "naturalness" of the technology (Peterson 1995; Weber et al. 2001).

However, expressions of public support should not be equated with blanket acceptance. As Focht and Albright (2009) found in a telephone survey, a large majority (80%) of those holding an opinion express support for bioremediation but almost half of those surveyed (40%) do not hold an opinion. The authors conclude that support is therefore soft and may decline with further information. Support for this conclusion comes from Lach and Sanford (2009), who find that increased information does not result in increased acceptability, and Kocher et al. (2002), who found mixed results, with some respondents preferring bioremediation, some traditional remediation, and many unhappy with either option.

Indeed, stakeholders express a number of specific concerns about bioremediation, including the emerging nature of the technology, its effectiveness in a range of different conditions, the potential of the technology to fail, its potential to concentrate contaminants, and the potential of contaminants to become remobilized (DOE Citizen Panel 2002; Lach and Sanford 2003; Peterson 1995). Additionally, members of the public place their acceptance of bioremediation within a social and political context, focusing on the trustworthiness of authorities, the political context of institutional controls over implementation and monitoring, and the social and environmental consequences of mistakes (Focht and Albright 2009; Lach and Sanford 2009). As Focht and Albright (2009) point out, low levels of trust in experts and authorities translates into an increased demand for public participation in remediation decision making.

While this literature is tentative, it generally accords with a long-standing literature on risk perception. In general, risk researchers have found that publics view technologies as less risky (and hence more acceptable) when they are deemed to be voluntary, immediate, controllable, known, and familiar (Bronfman et al. 2008); enjoy positive affective valence (Slovic 2010); and are applied to socially desirable ends, such as health and environmental cleanup (Environics International 2000; Gaskell et al. 2011). Importantly, publics contextualize their attitudes toward technologies within a social frame (Satterfield et al. 2004), focusing on the extent to which authorities and experts can be trusted to deal with potential impacts (Earle 2010).

From Public Acceptance to Public Acceptability of Controversial Technologies

Both the risk perception literature and the bioremediation attitudes literature tend to focus on people's final judgment of technologies: Are they good or bad; should they or should they not be deployed? However, given the pilot nature of our research project and our attempt to include stakeholders upstream in the process of EEB development, we were less concerned with people's final judgments about whether or not EEB should be deployed and more interested in their views about how EEB should be developed, if they considered it to be a potentially appropriate remediation technology. In other words, in addition to our desire to learn about community groups' and First Nations' attitudes toward and concerns about EEB, we were interested in the conditions placed on their willingness to consider it as an appropriate technology.

This focus is informed by the Public Acceptability of Controversial Technologies framework (PACT) (Wolfe et al. 2002). The PACT framework differentiates between acceptance and acceptability. Acceptance refers to a final decision to deploy a technology. In contrast, public acceptability is conceptualized as a continuous variable that ranges from outright refusal through complete willingness to negotiate about the technology in question as a viable alternative. Between these extreme positions, certain conditions may influence willingness to consider the technology. Accordingly, the objective of the research was to indentify not only participant's attitudes toward a technology, but the conditions they place on their willingness to give it serious consideration.

PACT also sensitizes the researcher to multiple dimensions involved in negotiations. As our review of relevant literature earlier in this article indicates, public concerns about technologies are attached to multiple issues. PACT offers a single framework for taking these aspects into account by organizing them into four dimensions. A Constituent Dimension assesses features associated with individuals or groups, such as their values, motivations, and strategies. A Technology Dimension captures more technical features that may condition acceptability, such as perceptions of technical parameters, potential harm, and the predictability of the technology in question. A Context Dimension refers to wider cultural and social processes that influence acceptability, such as beliefs about nature, social capital (trust, networks and power differentials), and institutional support. Finally, a Dialogue Dimension involves details about the decision-making process, such as the dialogue structure and dynamic.

Research Questions

In this study, we wanted to know: (1) What are stakeholders' and First Nations' general attitudes toward EEB as a potential remediation technology? (2) What concerns, if any, do participants express about EEB? (3) How do participants translate concerns (if any) into conditions of acceptability? On the basis of research on public attitudes toward bioremediation and the risk perception literatures, we derived four expectations regarding community groups' and First Nations' attitudes and concerns. First, we expected to find positive attitudes toward EEB in general due to its application to a valued end (environmental cleanup). Second, we expected that EEB might carry positive affective valence due to its perceived "natural" character. Third, where concerns about EEB were expressed, we expected that they would be tied to issues of trust in regulators and industry, in the context of attributions of responsibility and unequal power relations. Fourth, we expected that levels of familiarity, predictability, and controllability of EEB would influence groups' concerns about it.

While we expected that public acceptability of EEB would share features with acceptability of bioremediation in general, as both technologies involve the use of microbial processes to remediate contaminated sites, we anticipated that the ecogenomics component of EEB might prompt additional concerns not accounted for in bioremediation attitudes research. Moreover, where participants expressed concerns about EEB, we were interested to learn how they specify conditions under which they will continue to seriously consider it as an appropriate remediation technology.

Research Design

The PACT framework is designed to ascertain acceptability for public groups that are in some way engaged in dialogue with technology proponents. For this reason, we chose to focus on community groups (CG) and First Nations (FN) who had engaged with the mining company over its discharge application or were likely to have an informed opinion about the treatment technology. We identified groups who met one or more of the following criteria: (1) were notified of the discharge application by the mining company; (2) had written letters to regulators and the company in response to the discharge application; (3) attended public liaison committee meetings; or (4) were likely to have informed opinions on the treatment technology but did not meet the first three criteria.

This selection process yielded a total of 11 possible groups, nine of which agreed to participate in the study: one chamber of commerce, a resource industry association, two environmental groups, a regional sustainability trust, a naturalist group, a sporting association, a community association, and a representative of the nearby scientific research station. Key officers of the participant groups confirmed their authority to speak on behalf of their membership. The number participating from each of the nine groups ranged between 1 and 5 persons, for a total *N* of 19 individuals. By engaging with these groups, we were able to derive a picture of acceptability from constituencies likely to engage with mining companies over their choice of remediation technology, rather than attempting to provide a representation of public opinion more generally.

We drew on the PACT framework to craft a semistructured interview schedule.[2] First, values, motivations, and strategies were assessed through questions about the organization's purpose, goals, and projects, as well as attitudes toward the mining company's discharge application (Constituent Dimension). Next, given that the treatment technology is in the experimental development stage, we included a number of scenarios to draw out particular concerns. To ensure that they were plausible, scenarios were developed in consultation with the ecogenomics researchers. Scenarios included (1) the addition of organic material to the bioremediation system in order to stimulate the growth of microbes that are not normally active at that location, (2) the sourcing of organic material from nonlocal places, and (3) the introduction of microbes cultured in a laboratory into the bioremediation system. Following presentation of the scenarios, we asked questions about potential concerns. Probes focused on specific variables associated with PACT dimensions, including perceptions of potential harm and predictability of the system (Technology Dimension), views about the natural environment, levels of trust and institutional support (Context Dimension), and opinions about the quality and transparency of community engagement by the mining company (Dialogue Dimension).

A second set of interviews was conducted with First Nations who have traditional territory encompassing or bordering the research site and/or who had dealings with the mine. We chose to engage with First Nations separately due to their unique relationship to the land on the basis of unsettled questions of aboriginal rights and title. Three First Nations with traditional territory encompassing the research site had previously been engaged in consultations with the mine over the discharge application; a fourth First Nation had traditional territory bordering the research site, but had not been involved in official discussions with the mine. We were able to secure interviews with three of the four First Nation organizations. Representatives included resource managers, a treaty negotiator, elders, and a chief. While these representatives do not necessarily represent the views of every First Nation member, they provide a range of expert perspectives of individuals who work to further the interests of their First Nation. We tailored the interview schedule for First Nations, while maintaining a focus on the PACT dimensions and retaining the scenarios. For example, rather than asking about organizational values in general, we inquired into the historical and contemporary relationships between First Nations and resource companies operating in their traditional territories.

Before analysis, a summary of findings was provided to research participants for member checking. Additionally, transcripts were provided to First Nations for the opportunity to remove any sensitive information. This process yielded no substantial changes to transcripts. Interviews were coded with aid of the Atlas.ti qualitative analysis software program. We developed our codebook based on the PACT dimensions, but added variations to more accurately reflect our interview data. Specifically, we added an "epistemic" dimension to capture issues concerning types and use of knowledge; relabeled the "constituent" dimension as "normative" to make it a receptor for values and attitudes; and divided the catch-all "context" dimension into three specific receptors: "sociotechnical," "relational," and "governance" contexts.

Findings

EEB Attitudes and Values

All community participants we spoke with indicate a willingness to consider EEB as an appropriate treatment technology. Most express positive attitudes toward bioremediation in general, and were encouraged that new, proactive approaches are being developed to address the longstanding problem of mine drainage. As one participant notes, EEB "sounds like the best option out of anything anybody's come up with so far" (CG 8: 242). Some participants are more cautious about EEB, suggesting that the approach is experimental and lacks long-established, well-functioning models; they view it as an unproven technology with an inadequate track record. However, even those critical of the technology are willing to consider it as an option.

Participants' general willingness to consider EEB as a treatment technology can be explained, in part, by their deep concerns about the environmental impacts of mine drainage. Community groups hold strong values about the "pristine" nature of the nearby lake system and the many species it supports, particularly salmon. In this context, participants are in favor of any treatment that will reduce risks to the environment. As one participant puts it, "Anything we can do to improve the processes [of environmental cleanup], I'm in support of. So this bioremediation, if it works, is wonderful; it makes a lot of sense" (CG 7: 133–135).

Many indicate a clear preference for bioremediation in relation to other treatment options (particularly chemical treatment), given its perceived "natural" character. As one participant notes, "Anything that can do a better job of mimicking nature has a better chance of success. The minute that you start getting involved with too much technology, . . . you end up with [problems]" (CG 1: 101). This and similar quotations suggest that, for many community groups, natural processes would do a better job of remediating water than fallible human technologies, particularly those that rely on the addition of chemicals.

Acceptability among First Nations also registers at different places along the continuum, with some representatives demonstrating strongly positive attitudes and others more likely to place conditions on acceptability. Participants from two First Nations are generally in favoir of the bioremediation option, citing, in support of their view, the technology's ability to avoid chemical inputs and its innovative character. Another First Nation is more cautious, with representatives emphasizing that bioremediation is an unproven technology with a poor track record and that it should be considered in the context of existing concerns about mines operating in First Nations' traditional territories.

Concerns About EEB as a Technology

While many community participants express generally positive attitudes toward bioremediation as a treatment option, theirs is a nuanced, not naive, view of the technology. Acceptability (willingness to consider a technology) does not automatically translate into acceptance (support of deployment); rather, it lies along a continuum and is influenced by a number of concerns, which are translated into conditions of acceptability. The same can be said of First Nations, who share a number of concerns with community groups while raising issues unique to their cultural and political circumstances.

One frequently mentioned issue is the cultivation or introduction of microbes in systems that are open to the environment. The pilot system utilizes a "water cap": In effect, while fenced, it is an open pond accessible to wildlife, waterfowl, and other birds. Participants worry that microbes could escape from the system and disrupt or displace native microbes. In particular, participants are fearful that cultivated microbes could act as alien or invasive species, upsetting ecological "balance," and potentially "knock[ing] something else out that's really critical in the natural environment" (CG 9: 166).

Concerns about the open nature of the system are also expressed in other ways. Participants note that while the microbes may be able to sequester toxic metals, these do not disappear but remain in the sediment, from where they could work their way into natural systems and become available to food webs. As one First Nations participant questions, "What happens to those micro-organisms after they eat all of that [metal]? Are the salmon and fish going to eat those micro-organisms too? And [will they] have enough levels [of metal] in them [to] impact us later?" (FN 2: 145). Moreover, First Nations participants point out that if ecogenomics-enhanced bioremediation is successful at removing and sequestering toxic metals, such systems will proliferate. Over time, they argue, small amounts of toxins will inevitably be released from these systems. They worry about potential cumulative impacts of these "new" contaminants in combination with existing sources of pollution in the watershed.

A key set of concerns stemmed from a lack of familiarity with the system and an inability to predict its consequences. Specifically, participants identified potential unanticipated consequences over time, pointing not to risks that are already known and deemed unacceptable, but to potential future scenarios that are unanticipated by those responsible for developing the technology. People we spoke with drew attention to the complexity of the systems connected to the bioremediation project, pointing out the inherent difficulty of predicting impacts. One technically astute individual noted that multiple variables are at play in treatment systems, including seasonality and the behavior of particular metals in relation to system parameters such as pH and oxidation. Unless we know how all these elements interact, she noted, the treatment system may perversely increase pollution by some metals, while reducing that by other metals.[3]

Other respondents suggest that bioremediation systems might destabilize the external, ecological complexity within which they operate. The cultivation or addition of microbes in open systems poses unpredictable risks, they argue, since, "it's very easy for things to get away and we don't really understand how the ecological cycles all fit together and what the impacts are" (CG 9: 47). Finally, respondents alluded to the wider economic complexities within which bioremediation practices takes place. For example, one participant notes that the mine's need to discharge tailings water—and hence its need to treat the water—arose through a dip in the global market for copper prices, which caused the tailing pond to fill to capacity after operations shut down. As the contributor emphasizes, "The way they actually build a dam is with the tailings. So, if they're not operating [there are no tailings] and they can't raise the dam. There are all these things coming into play, and it's difficult" (CG 9: 120).

Community groups recognize that some types of uncertainty are reducible in principle if the requisite knowledge can be produced (although many expressed skepticism that the necessary knowledge would in fact be produced). However, participants also point out ways in which uncertainty may be irreducible, without prompting by us. Several speakers pointed to the inevitability of change over time, and consequently that the assumptions on which a given treatment technology is based may be contingent. For example, one individual has "a great reluctance to believe that [EEB] would work in the long term [because] ecosystems are always evolving" (CG 6: 63). As another participant pointed out, not only do ecosystems shift and evolve over time, but issues such as climate change affect our ability to predict future conditions. And even if future trends could be predicted, there are always accidents.

Identification of what Perrow (1984) calls normal accidents—what more than one participant refers to as the "oops factor"—is one of the strongest themes arising from our interviews. No matter what assurances may be in place, say participants, accidents are bound to happen, and "when the oops factor happens, it can be pretty devastating" (CG 9: 212).[4] Given the "natural" character of bioremediation, and subsequently low likelihood of human error, most concern attached to the consequences of "natural" accidents such as floods, storms, droughts, and earthquakes, which could destroy the bioremediation system and release sequestered metals and microbes into water systems. However, the "oops factor" can also take place in relation to a failure to foresee flaws and liabilities of the system itself and the way that it operates. This is compounded by the biological complexity of the bioremediation system and the fact that small accidents, leaks, and so on may go unnoticed until the system collapses.

Conditions for EEB Acceptability: Responsible and Trustworthy Monitoring

While concerns about EEB manifested as a range of skepticism about the technology's ability to perform as promised, these concerns did not prompt outright rejection or refusal to consider EEB as a potentially useful technology. However, concerns did prompt community groups and First Nations to place conditions on their willingness to consider EEB. In connection with their strong concerns that unanticipated consequences will go undetected, participants almost unanimously called for ongoing, meaningful monitoring of the technology. As one person expressed, "They can't just go away and leave something and expect it to work. You have to audit it carefully and frequently" (CG 9: 181). In the words of a First Nations participant who notes First Nations' long-term relationship with the land, "I'd like to see the continuous monitoring even up for 100 years, because we have to [look after future generations]" (FN 2: 150). Indeed, monitoring was the only commonly shared condition expressed,[5] although the condition is nuanced and can be broken down in relation to other concerns about the social and institutional context within which environmental monitoring takes place in BC.

First, monitoring was mentioned in the context of responsibility. Some are concerned that EEB will be designed into "walk-away" systems for postclosure sites, leaving the risk that when something goes wrong—"as it inevitably will"—the mining company will no longer be there to deal with it. As one community member put it, "If it's proven that the bioremediation works and they can walk away from it, I would certainly want to know what was going to be happening as far as monitoring is concerned. And who will be responsible should the shit hit the fan" (CG 6: 64). According to many informants, the mining industry has the political-economic power to evade responsibility for unintended consequences. Some participants claim that mining companies use the promise of socioeconomic benefits to deflect attention from potential costs. By the time the costs arise, the companies have either left or are so well established that it becomes virtually impossible to shut them down.[6] According to our sources, this dependence relationship often manifests in a lack of criticism, due to the fact that most local residents have a family member or friend on the payroll at the mine.

Many respondents pointed out that the government also avoids responsibility for environmental monitoring. We were told that, due to a series of economic cutbacks, the provincial government no longer has the capacity or resources to regulate and enforce mining operations. For example, water quality tests were previously conducted and analyzed by personnel at the provincial Ministry of the Environment; now, companies conduct the tests themselves and report the results. In the words of one First Nations member, "In this day and age of downsizing and offloading responsibilities, monitoring is going to be left to the companies, potentially without enough oversight by regulatory bodies to protect the public welfare" (FN 3: 113). Some suspect that today's center-right provincial and federal governments' decisions to cut back and/or contract out certain government services are made for ideological reasons. They are concerned that this move elevates the interests of industry above the public interest. For example, we heard claims that government departments actively suppress information and analysis that might be detrimental to mine development. One former public servant suggests that employees of the Ministry of the Environment are "pressured politically to let a lot of things go" (CG 9, 116–118).

Second, the focus on monitoring was mentioned in relation to the issue of trust. According to one participant, "I don't trust the government, I don't trust big business, I don't trust any of them. And who's going to be looking after it? The government doesn't. And [the mining company] wants to [. . .] look after itself" (CG 5: 44–47). In particular, the government's devolution of power to mining companies is seen as a dangerous move, given the little trust people have in industry. As one community member put it, "This government is moving towards letting the industry police itself. And you can't do that. You can't put the fox in charge of the henhouse" (CG 10: 395). Another participant puts it more strongly, saying, "I just have absolutely no faith in the words that I hear coming out of the mouths of any mining executive. I'm sorry, but too many promises are broken, [there is] too much, 'Oh, well, yeah, that kind of happened and we didn't foresee that.'" (CG 6: 102). This lack of trust in mining companies is perhaps even more salient for First Nations, who place the activities of companies in the context of a colonial legacy of dispossession and encroachment on traditional territories. A First Nations member raises the issue in the following story:

> [One mining company] says they have fish in their tailings pond, right? And they're proud of that fact, that fish are living in there, swimming around and, you know, healthy enough to eat. Well, would they eat it? You know, are they really being honest about it? I don't think so. There's no way in hell I'd eat a fish that came out of there. I'd cook it for one of those guys [laughs]. There's no damned way I'd want to eat it. (FN 2: 266)

In this context, both community groups and First Nations call for independent, third-party monitoring. One community member suggests that the mine can do its own "quality control" as long as an independent laboratory is contracted to verify the mine's tests and to do "quality assurance on their quality control" (CG 7: 119). Others require greater distance between the mining company and ongoing monitoring. According to one group,

> I think what would be needed is third party monitoring. Not the government, not the mines. The mine supplies the money, it goes into a pot. The government and experts figure out what is needed. And the third party does the tests, does the studies, and everybody gets the information at the same time. That's what's required. (CG 9: 155–156)

But the question arises: Who should the third party be? Consultants are generally dismissed as "beholden to mining industry" (CG 9: 158), as they need to please their employers in order to be awarded future contracts. One group suggested that universities should be responsible for monitoring. Several others felt that the best solution would be to get members of the public involved. Ideas ranged from integrating stakeholders into a committee responsible for overseeing the deployment of EEB to direct public participation in collecting data. One community group member suggested that all stakeholders should "work together" to address potential problems before they arise (CG 3: 201–208). Another group suggested that "there should be an opportunity for as-non-biased-as-you-can get kinds of people having their input into this, from a variety of interests" (CG 8: 245). An even further reaching suggestion was to involve members of the public directly in ongoing research and monitoring. In the words of one participant, these people would serve the role of "citizen scientists":

> People who have years, if not decades, of experience in an area. They may not have degrees or letters after their name or whatnot, but they feel like their input is based on empirical evidence and observations on the ground as valuable. (CG 4: 89)

Along similar lines, one First Nations group is currently putting together an "environmental monitoring crew" that will have "an ability to have involvement in monitoring of the things and seeing the data when it's analysed" (FN 3: 125). Such a crew would help First Nations to "see for themselves" that EEB works as promised.

The importance of the monitoring condition to the overall acceptability of EEB is indicated by the fact that it was put forward by so many interviewees. However, we did not get the sense that community groups and First Nations would reject the technology in the absence of this condition. Rather, the monitoring proposal was put forward more in the spirit of a key recommendation that could respond to community concerns and thereby facilitate the development a more socially-robust technology. However, there was some skepticism that such a condition could in fact be met. As one group recounted, the government has several protocols to involve the public in other areas (wildlife management), but when it comes to decision making, "The hell with the protocols, they go out the window, and they make up their own mind" (CG 10: 438–439). Moreover, as one group noted, it may be difficult to motivate people to participate, since "the apathy to this kind of stuff is huge, it's massive. It's . . . you try to get people out that want to say something or have an interest even to know, is just like pulling teeth" (CG 8: 248). Perhaps for this reason, groups also looked for technological contingencies should EEB meet with some unanticipated developments. Taking a "more is better" approach, several individuals suggesting that the technology should be integrated with other forms of remediation, including chemical treatment.

Conclusion

EEB holds the potential to improve the treatment of mine drainage and to do so without the use of chemicals. However, both bioremediation and ecogenomics are new and little-known technologies. The application of ecogenomics to bioremediation is even more rare. For this reason, we assessed public acceptability of EEB as a potential technology well upstream in the process of development.

Many of our participants express generally positive attitudes toward EEB, on the basis of values about the "pristine" nature of the local lake system and on the basis of positive feelings about the perceived natural character of EEB. These findings confirm previous findings in bioremediation and risk perception research that technologies developed for perceived useful ends (here, environmental cleanup) and those with positive affective valence (here, due to bioremediations' "natural" character) will be regarded as relatively desirable in comparison with other technologies.

However, positive attitudes should not be taken as final acceptance of a technology. Acceptability should not be confused with acceptance. Participants indicated only their willingness to consider EEB as a potentially appropriate remediation technology and qualified this with a number of concerns. Chief among those concerns are unfamiliarity with technical features of design and operation (e.g., can microbes escape?), inability to predict outcomes in relation to a number of changeable parameters (e.g., the "oops factor"), and lack of trust in industry and regulators to deal with unanticipated consequences that participants feel are sure to arise. These concerns also align with the expectations we derived from the bioremediation and risk perception literatures regarding familiarity, predictability, and trust. Additionally, the ecogenomics component highlights special treatment of microbes within these systems, perhaps explaining participants' specific concerns about the potential impacts of microbes on natural systems, which does not arise to the same extent in other research.

This study points to the usefulness of treating public acceptability of new technologies as a nuanced and contingent ongoing negotiation. Often, the goal of project proponents is to get the public "on board" and win their final acceptance. (This was true in our project, where industry partners initially expressed a belief that the social science role should be one of "selling" the technology to the public.) However, potentially impacted groups take a more sophisticated view than either accepting or rejecting a technology outright. For them, a final decision is not the goal; in fact, our participants consider final decisions to be problematic insofar as they fail to account for change, uncertainty, and unexpected consequences, and insofar as they result in a failure to accept responsibility for the technology over time. Rather, participants wish to treat EEB as an ongoing experiment, withholding final acceptance while granting provisional acceptability on the understanding that it may be revoked if conditions are not met.

The difficult task will be to ensure that the publics' acceptability conditions are met in practice. Community groups and First Nations in our study expressed skepticism that they could have any influence over the development of the technology, highlighting the power discrepancies they felt in relation to industry and government. As researchers, we made an effort to share our findings with project partners as well as with our participants. We recognize, however, that this is insufficient on its own to facilitate ongoing public involvement in the development of EEB. To address this issue, we suggest that future research of public acceptability of novel technologies should have three foci: (1) assess public acceptability conditions, (2) facilitate processes that ensure that those conditions can be met, and (3) examine changes in levels of acceptability over time as conditions are (or are not) met.

Notes

1. Also referred to as ecological genomics, metagenomics, environmental genomics, and community genomics.
2. Although all participating groups and bands had some degree of knowledge of the mining company's operations and its discharge application, we did not assume a working knowledge of discharge treatment technologies. To cover these technical areas, we produced an information pamphlet describing bioremediation, ecogenomics, and our research project.

Pamphlets were distributed to research participants in advance of research meetings; we reviewed and answered questions on this material at the start of each meeting.

3. Indeed, the pilot system at the study site is encountering complex interactions of this sort that the mining company finds difficult to understand. During a site visit, we learned that while the system may be reducing some metals, it is having little success with sulfate and selenium, which are somehow linked together. It may be the case that some processes within the system are reducing sulfate while others are producing it, resulting in a steady state. But this is speculation awaiting a definitive diagnosis.
4. Many drew on a recent large-scale oil spill in the Gulf of Mexico as a prime example of the kind of accidents they were describing.
5. The fact that more conditions were not expressed may be due to participants' limited knowledge of EEB. Given an opportunity to learn more about this complex technology, other conditions may arise.
6. In this case, public mistrust of the mining company involved in the bioremediation project relates to the perception that the company broke its original promise never to discharge effluent into the environment.

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