Mining: integrating research and local community based ecosystem restoration

JAN FEYEN[1], PATRICIO CRESPO[1,2] and ROLANDO CÉLLERI[1]

1 *Mountain Research Unit, Faculty of Engineering, University of Cuenca, Ecuador,* feyenjan@hotmail.com

2 *Institute of Resources Management, Justus Liebig-Universität Gießen, Germany*

Keywords: Mining, environmental organizations, local communities, intercultural dialogue, research-based experts, conservation, ecosystem restoration

Abstract

Although the perception of mining in general is negative, largely due to the lack of proper communication between stakeholders, the non-transparency of license agreements, the existence of unscrupulous mining practices, and the inadequacy of mining laws and control mechanisms, the authors believe that there is room for economic, social and environmental responsible mining. A plead is made for the strict application of environmental effect monitoring throughout and after the mine lifecycle and the formulation of appropriate mitigation and restoration measures, which should be part of mine planning, and improve communication and active involvement of the local communities in what the authors call "*local community based ecosystem restoration*". Actions should be better supported with scientific evidence and authority. *Condition sine qua non* to make it happen requires enhancing communication but also the working together between all stakeholders in an open and constructive mind without prejudice, respecting care for all, no matter the stakeholder groups one belong.

1. Confrontation of fundamentally different philosophies

As stated by Williams (1990) the debate over mining is poisoned by the confrontation of fundamentally different philosophies, often resulting to angry confrontations over the nature of evidence. At issue is whether mineral resources should be extracted and exploited - or revered and preserved? Opponents of mining contend extracting natural resources from the earth is a crude and destructive method of making money. Environmentalists claim that mineral mines heavily destroy the environment using chemicals like cyanide to leach gold from crushed ore, a technology that has transformed even unprofitable mines into rentable enterprises (McGoll, 1980; Fields, 2006; Kumah, 2006). Once the gold is removed, the remaining material, called waste rock or tailings, are dumped, and the regional water resources are tainted with chemicals. In short environmentalists state that mining in endangered environments cause immeasurable environmental damage (Tarras-Wahlberg et al., 2001; Mudd, 2007). They also argue that until recent little to no attention has been given to the restoration of the affected environment. Other critics state that

opening a mine would generate housing shortage, sharp intensification in traffic, increase crime, drive up the costs of local drug and alcohol rehabilitation programs, among other social impacts (Pick et al., 2003). Mining antagonists state that miners and governments place priority to resources development for the nation's well-being, but overlook the detriment effect of the operation on the environment and local communities. Large mining projects in general take place in rural areas, where it coexists with local communities historically marginalized from development processes and, what is more, it advances at the same time as many of these communities become poorer. It should not be surprising that this situation heavily contributes to the antagonistic feelings of local communities to mining companies and governments; the latter inspired by the free market and free trade philosophy support mine companies to increase foreign exchanges (Hilson, 2002; Bebbington et al., 2008).

Local communities, who depend largely upon the land for their livelihoods, consider the land they have been living for generations as their ancestral territory. The philosophy of the local people, who have been the guardians of the land and the natural resources, both above and below the land up to the sky, consider the land as their property and according to this way of thinking no one has the right to take the land and exploit its resources. According to them, multinationals and governments, want all the wealth and destroy the rivers and the environment and leave people in misery to get it (Haarstad and Floysand, 2007). Once the river polluted local communities, using the river for all facets of life, are forced to migrate to places where there is still plenty of fish in the river or look for other sources of potable water. Another cause of resistance to mining is the potential loss of sovereignty. Mining frequently disrupts life-ways of local people, undercutting their capacity to sustain themselves as a community (Downing et al., 2002).

At the other hand mining proponents state that natural resources are a God-given gift to humankind and the society has the obligation to develop those resources for the betterment of all people. According to González Zenteno (2007) is the mining potential of Latin America undeniable. This author states that over the last 20 years, the liberalization of investment regimes has turned the region into the main target of the world's mining investment, capturing between 25% and 30% of the global budget. This translated into a steady increase in the region's share of worldwide mineral and metal production, a trend which likely continues given Latin America's countries competitiveness and global consumption forecasts. It is recognized that mining is a major customer of other businesses and helps develop other parts of a community like infrastructure (road and rail) and enhances the introduction of new technologies. All over the world it has been seen that mining increases employment in the area of the mine and also the level of skills of the local people. Mining is not just digging as stated by ACIL Tasman Ltd. (2006), but adds to essential support services including maintenance, warehousing, safety and first aid, human resources and administration. Last but not least, mining makes significant government tax payments, and for Ecuador in particular, if well managed by the national and local governments, it might contribute to diversifying the country's export pallet (Burley, 2000).

In the first week of April 2008 Ecuador's constitutional assembly passed a mining mandate that cancelled a majority of the country's mining concessions, suspended remaining projects, and imposed a moratorium on the awarding of new concessions while giving the government the opportunity to rewrite the country's mining legislation (Mychalejkon, 2009). The overall objective of the new legislation, according to President Rafael Correa is not to say *"yes or no"* to mining but to make mining economical, social and environmental sound. Defenders of the mining industry stated that the mining mandate in the assembly merely passed on subjective grounds largely based on the lack of constructive involvement of the society in mining at national, regional and local level and respect for the environment. Nearly a year later, on 4 February 2009 Ecuador's new mine law saw daylight (Registro Oficial Ley Minería; http://www.cme.org.ec/portal/index.php?option=com_remository&Itemid=5&func=fileinfo&id=86), but its implementation has been delayed by the national elections of 26 April 2009.

The poor image of mining is also strongly affected by the rather negative image of small-scale and artisanal mining projects using rudimentary technologies, and not possessing the financial nor the technological capacity of taking the right measures to minimize or avoid mining's environmental effects and health impacts (Aubynn, 2009). However, the main aspect in the debate on *"yes or no"* to mining, which until today has not been sufficiently addressed is if large- and small-scale metallic mining can be made economical, social and environmental attractive. Is it really impossible to bring into consonance the differences between the protagonists and the antagonists of mining? Can mining for example through legislation, education and use of appropriate technologies not be transferred to a responsible economic activity with respect for the environment and societal involvement (Maponga and Ngorima, 2003)?

The authors in this paper discuss three fundamental pillars which might contribute to an improvement of the relationship between mining companies, the society and the environment. A research-based assessment and remediation of mine impacts in participation with environmentalists will make mining during and after the lifetime of the project more acceptable from environmental point of view. A reduction of the tension between stakeholders requires an objective- and explanatory-based, and transparent communication between stakeholders on equal basis and in a language understood by all. Finally offering to the local people the opportunity to be effectively involved in ecosystem restoration, will not only reaffirm and help improving the self-esteem of the affected communities, but also will generate employment throughout and after the lifetime of the mine.

2. Assessment and restoration of the environment

Stating that mining does not have negative impacts is an overstatement, just as it is saying that the society can live without the exploration of minerals. Those complaining about the negative aspects of mining should realize that our modern society depends strongly on minerals (Shen et al., 2005). Without the mining industry there would be no metal, plastic, or concrete for the pipes that carry water to and wastes away from our house. There would also be no metals for automobiles, meaning that we would

have to either walk or ride an animal where ever we want to go. We would have no glass for windows nor would we have the materials necessary for any of the electronic devices that we use. In essence, without mining, we would have to go back to a stone-age lifestyle. How would the level of unemployment be if we could not exploit Earth's resources? In fact everything we do has some effect on the environment around us. The challenge for mining and all other human interference, like farming for example, is to minimize impacts and for mining to reclaim the land once the mine has phased out.

Impacts of mining vary with the type of mineral and the kind of mine. The challenge is to monitor during the different mining phases the impacts and to take timely mitigation or protection measures. Impacts should be expressed with respect to the reference situation before any mining activity take place. For the characterization of the initial situation traditionally a Baseline Environmental Assessment (BEA) study is performed. In addition, the BEA aims to provide decision-makers with practical guidance for how the potential development should be managed to minimize negative impacts, as well as provide information that will be useful for the development of any future Environmental Assessment (EA) document (World Bank, 1997; Bureau of Minerals and Petroleum, 2007). Once mining activities started and even during the post-closure phase of the facility, EA studies using the data collected via a monitoring network ought to be developed. The purpose of EA's is identifying possible environmental effects and their magnitude; proposing measures to mitigate adverse effects; and predicting whether there will be significant adverse environmental effects even after the mitigation is implemented. Timely and efficient environmental assessments result in more informed decision-making that supports sustainable development.

The monitoring network should encompass the measurement of abiotic and biotic variables (Bunn and Smith, 2002). The spatial variability of those variables at the time prior to occupancy depict the spatial variability of the topographic, geomorphic, geological and pedologic terrain features and interferences, climate and the surface and groundwater hydrologic conditions, the land use, and the natural biodiversity of flora and fauna. The network not only should measure the abiotic and biotic properties prior to the onset of the mine activities, but also during mine exploitation and after mine decommissioning as to characterize the temporal variability in variables and changes caused by mine activities. The complexity of information and the spatial and temporal scales to be covered requires the installation of an advanced, dense and highly performing network of sensors and manual observations, and the establishment of guidelines for monitoring, data downloading and processing. It is evident that not every square meter of the concession area has to be monitored and it is a demand to develop a practical and appropriate "sparse" spatial design which is steered by the tension between the cost of sampling and number of sites to be sampled; the allocation of resources across space and time; and the unique mining features (Dobbie et al., 2008).

Challenges during the construction, exploitation and abandonment phases are minimizing impacts and rehabilitate, and this from the beginning onwards as to prevent long-term problems. Minimizing impacts requires the development of mitigation measures and approaches which can come in a variety of forms,

such as technologically-based, logistical and management-oriented. They have to be developed on a continuous basis throughout the lifetime of the mine project and taken into consideration in the decision-making process. If impacts are inevitable, the affected sites should be restored in their original condition. A large variety of remediation techniques and landscape restoration methods exist, including the recovery of degraded soils, the restoration of the local and regional hydrology, and the revegetation of native plant communities (Brown, 2005). Since every mine site is different existing technologies have to be tuned to local conditions. Sometimes the ecosystems on the projected mine site, as for example rain forest and páramos, might be so fragile and difficult to restore that for exploitation preference has to be given to a closed-mine pit design with minimum impact on the surface.

Environmental effect monitoring, data processing and interpretation, the design of mitigation measures and the tuning of restoration approaches require the attachment to the mining of a multidisciplinary team of research oriented experts. The inclination to research is very essential for the correct processing and interpretation of data, the formulation of appropriate mitigation and restoration measures, and the try-out of ecosystem remediation technologies; all non-traditional mining activities (Hilson and Murck, 2001; Azapic, 2004; Suppen et al., 2006). The benefits of the permanent involvement of a multidisciplinary research-based expert team are: (i) assurance that mining is done in an environmental responsible manner; (ii) local research capacity in mitigation, remediation and restoration technologies is developed; and (iii) knowledge of environmental legislation and requirements is improved, as well as the ability to monitor compliance with environmental legislation.

3. Communicating to environmentalists and local communities

The intense and brutal protest of environmentalists and local communities against mine companies can be largely attributed to the poor communication between stakeholders. Mine companies, often supported by governments, have long had a questionable reputation for social responsibility, especially in developing countries (Kapelus, 2002). According to OXFAM (2009) the roots of the problems between local communities and mine companies are: (i) locals experience to few benefits from mining revenues; (ii) mining companies in the past made serious mistakes in their relationship with local communities; and (iii) local governments lack the capacity and political will to regulate the industry, manage local-conflicts and redress grievances. Other reasons of protest are that mining companies often violate the rights and endangers the way of life of local communities (Bebbington et al., 2008). In developing countries the indigenous peoples' rights are traditionally protected and guaranteed by national law. However, as a consequence of the liberalization policies, adhered by governments, mining laws have been redesigned to promote foreign investment, overruling in many cases the local peoples' rights (Harrison et al., 2003). This led to many illicit mining activities affecting the livelihoods and lands of the poorest people in and nearby the mining sites. The frustration and the growing opposition of the local communities and organizations is also fed by politics and the failure of the local and national governments to apply the law.

In addition, by lack of knowledge and legal means, not all communities are aware of their rights, rights which are often violated by mining companies with the support of the government. According to OMCT (2009) also the investments in mineral extraction are not always fully balanced with the human rights of the communities involved, nor are in line with the right to basic necessities such as clean air, safe water and unpolluted soil. Given that the concerns of the local communities, the fear that development projects destroy the traditional economy, community structures and cultural values, are not correctly addressed by mining companies and governments, it is not surprising that communities start opposing with all means in the wake to defend their rights.

Local communities are often supported in their struggle by environmentalists, but not always for the same reasons. The main reasons why environmentalists oppose against the granting of mine concessions is the threats of their development to water resources, public health, the ecosystem, and landscape. According to Gutierrez (2009) severe social and environmental impacts are to be feared from acid drainage, water pollution, and evaporation of cyanide, used in the leaching process to separate gold and silver from rock. In regions with water scarcity, mining might also exacerbate water shortages. Among other burdens are the increase in traffic by trucks overloaded with ore and the recklessly driving attitude of the truckers. Gosar (2004) states that mining generate four categories of large-volume waste: mine waste (overburden, barren rocks), tailings, dump heap leach and mine water, which respectively contribute to a series of physical, pollution and health impacts. Among the physical impacts are the destruction of the natural ecosystem of the mining site, changes in landforms and the remaining of abandoned equipment, distortion of the natural water resources system, failure of structures and dams, and land degradation and instability. Pollution is due to drainage of chemical loaded effluents, the leaching of chemicals, and increase in air-borne dust and other emissions, such as sulphur dioxide and nitrogen oxides from smelters. Health impacts on-site might be due to the physical risks and exposure to toxic materials, heat, noise, vibration and radiation, whereas off-side health impacts are the consequence of the contamination of surface and groundwater, and the atmosphere of surrounding areas. Following Hudson et al. (1999) the main issue in metal mining is the control of acid mine drainage and of the erosion of waste rock and tailing deposits during and after closure of a mine.

There are also extremists who for dubious reasons set-up local communities and environmentalist groups against mining companies. Their interest is not always in line with the objectives driving those stakeholders, but for example their goal could be simply preventing and/or hindering the development of new mine projects that will compete with the small-scale artisanal mining projects in the neighborhood. Another reason could be that extremists are set-up by the government in an attempt to persuade the mining company paying unofficially bribes to government representatives in exchange for obtaining the mine concession and government support, or simply that they are paid by environmentalist organizations to block any new development (Peterman et al., 2007).

Whereas it is difficult to control the motivation and actions of extremists, mine companies and governments should work together with environmentalists and local communities with the ultimate objective of operating and managing metallic mines in harmony with the on-site society, national legislation and the environment. Impacts which are inevitable should be minimized or remediated as soon as possible after detection. After abandonment the mine site should be restored in its original status, and actions to achieve this should be taken early in the exploitation phase. In addition, education, communication and involvement of the local communities and representatives of environmental organizations will help reducing the confrontation between stakeholders.

As stated by Hagerman (1996) a lot of development experts assume that the answer to the problem is to provide to locals better technology, but the real focus should be on improving communication. From the perspective of their relationship with mining companies, governmental and non-governmental organizations, villagers often feel frustrated that people are constantly coming in and telling them what their problem is and what the solutions to these problems are, without really taking the time to really understand their situation. Another major problem that poisons the communication is the language used by each group of stakeholders. Government officials and representatives of the mine often use, mostly not intentionally, an academic jargon by which the representatives of the local communities are intimidated, reinforcing by them the impression that they are unable to participate. Communication will help in understanding the concerns and viewpoints of the different stakeholders. Petterson et al. (2008) concluded in their recent paper that using a communication model that closely follows geological models for pollution issues helps local people better understanding the objectives and potential impacts of mining, and how by using science and technology effects can be prevented and restored. Those authors describe four case studies from the Solomon Islands exploring communication strategies relating to land access, a live volcanic event, the setting-up of a gold mine, and raising awareness of volcanic hazards. They found that the basic elements in good communication are understanding of local peoples culture, customs, values, taboos and political-governance structures; involvement of indigenous people at every level of the communication process; identifying and including all stakeholders; a clear message, method and outcome focus; usage wherever possible of face-to-face communication and pictures as well as words; involvement of the community in practical exercises; a thorough follow-up and evaluation process; and sufficient time to allow the process to be effective.

The relation between environmentalists and mine companies can according to Hudson et al. (1999) only improve explaining to the first group of stakeholders that the scientific and technological advances in recent time increased the understanding of the physical and chemical processes that cause undesired environmental consequences and resulted to the development of efficient mitigation and remediation approaches and technologies. Currently research emphasis is also given to the complete reclamation of disturbed lands, including the development of treatments and stabilization of metal-bearing soils; prevention and treatment of contaminated water; controls on the amount and character of emissions to

the atmosphere; and minimizing waste and recycling raw materials and by-products. Recently techniques for the revegetation of native plants saw daylight and have been successfully applied in several abandoned industrial projects. As to avoid a too large impact on the cost-benefit of metallic mining, research on more cost-effective approaches preventing undesired environmental impacts is still very much needed. Scientific and technological research, focused on understanding the underlying processes important to these problems, can provide the foundation for new, cost-effective solutions. The challenge for future metal production is to develop environmentally sound mining and processing techniques.

Involving in the mining process the local research community and environmentalist organizations offers a dual advantage, namely: (i) mine activities and all possible impacts are properly monitored, and mitigation and remedial actions are scientifically well underpinned; and (ii) doing so will contribute to strengthening the research capacity of the local scientific community in environmental effect monitoring, data analysis and interpretation, and in all facets of land reclamation. Smoothing of the relationships between stakeholders requires in addition intense participatory communication between stakeholders, in which in addition to staff of the mine, researchers, environmentalists and representatives of the local communities participate.

4. Local community based biodiversity and ecosystem restoration

Whereas in several countries in the northern hemisphere the society accepts that earth's resources, such as water, coal and minerals, are state property and the government has the right to properly exploit those resources for the benefit of the society, governments also deployed legal instruments which assure that during and after the lifetime of the industrial development care is taken of the environment. The main differences with societies in the developing countries is that the northern societies are more educated, and therefore better see the needs and benefits of mining, and have more confidence that legal regulations are applied and strictly controlled. Local communities have a complete different philosophy. They believe that the land they occupy and everything related to this land is theirs. For them it is difficult to accept that the state hand out their land to transnational corporations for whatever industrial exploitation. Facilitation of international communications, networks and supportive NGOs a worldwide movement of local people exist seeking to reclaim their rights to their ancestral lands and jurisdictions. Better communication and active incorporation of local people in the development, and strengthening of the government in drawing appropriate laws and in effective implementing and controlling their application might improve the tolerance of local communities, and remove the feeling of marginalization and discrimination.

A drawback of mechanized mining is that at first glance it offers little employment for local people, given the low level of education and skills of the latter. This is partly true but of the workforce in mines still the largest fraction of people employed, up to 80 and 90%, are locals receiving upon recruitment intensive trainings (Acemoglu et al., 2001). It is correct that before the mechanization of mining operations lifetimes

of mines were much longer, whereas today the lifetime of mines can be as short as 10 to 15 years, undermining the perception that being employed by a mine is a lifetime opportunity. To better accommodate disappointments regarding employment opportunities the mine, with the support of the government, should look for additional job opportunities, which fit the educational and skill level of local people, and last longer than the lifetime of the mine. However, it cannot be the responsibility of the mining company to assure welfare payments in place of the government. What needs to be done, in addition to the recruitment of local people as mine workforce, is the search for job activities for locals which reassure their role as guardians of the land. Why not using the capacity of the local people in activities geared towards the remediation and restoration of the land during mine exploitation and after mine closure? Employment of locals in activities of ecosystem restoration enables sharing in a constructive way project benefits with the locals. After mine abandonment locals can become the managers for the local government to conserve the land and develop economic activities grounded in the landscape, flora and fauna.

Steps in ecosystem restoration in which locals can be involved encompass (Aguilar, 2001; Li, 2006; Straede and Treue, 2006; Zhang et al., 2007; Horowitz, 2008; Mendez and Maier, 2008):

(i) The identification and commercialization of ecosystem goods and services;
(ii) The conservation of species and habitats;
(iii) The development and follow-up of field plots for the regeneration of natural plants and degraded soils;
(iv) The implementation of lime and other fertilizer experiments for the restoration of the original soil pH;
(v) The setting-up of experiments testing substrate amelioration techniques and phytostablization mechanisms including precipitation of metals by bacterial and root surface, precipitation of metals by bacterial and root exudates, bacterial uptake and sequestration of metals, and root uptake of metals; and
(vi) The design and implementation of landscaping trials, including the establishment of bufferzones around areas with mine activity.

It is evident that the local communities lack the knowledge and skills to implement autonomous above cited activities, and therefore trainings appropriate to the educational level of local people have to be organized. Furthermore, to assure that the works of the local villagers are successful activities should be planned, coordinated and supervised by researchers having expertise in ecosystem restoration (Byers et al., 2006), eventually assisted by representatives of environmentalist organizations. Whereas in an initial phase funding for those activities have to come from the mine company, as time pass operations should be funded with support from the public sector and enterprises based on the subsistent use of the natural resources. The skills the local villagers acquire during the lifetime of the project will be very helpful for the

restoration of the mine sites after closure. Those skills can also be hired in by the public/private sector for the restoration of other degraded sites.

5. Metallic mining: Is there a road forward?

The public sector based on the way mining companies often operate in developing countries; frequently labels mine companies as modern conquistadores. They are convinced that mine companies with government support dig and export minerals, paying a little fraction of the revenue as tax money to the nation, enriching in the first place the mine company's shareholders. Whereas this was the case until very recent, mining companies under the increased pressure from opponents are under greater public scrutiny. Mine companies responded by developing global corporate social responsibility strategies as part of their larger global business strategies. In these strategies, a prominent place is given to their relationship with local communities and restoration of the environmental damages. Unfortunately the legal framework in developing countries that should assure that mining is done in an economic, social and environmental responsible way is insufficiently developed. In addition, governmental capacity to control if mining is done in an ethical way, as regulations prescribe, hardly exist. As a consequence of private companies business mentality and the government's insatiable thrust for funding leaves the door open for corruption; the awarding of concessions without requiring environmental impact studies, prior and throughout the lifecycle of the mine (Peterman et al., 2007).

The authors believe that notwithstanding mining causes inevitable environmental impacts, the voluminous list of scientific and technological papers recently published proves that today adequate mitigation and restoration approaches exist to avoid and/or minimize impacts, as well as to restore the mine site in its original status after mine closure. To assure that during the mine phases sufficient attention is given to the environment the authors suggest that in the BEA and EA's research-based experts are involved for monitoring, the analysis of collected data, and the formulation of appropriate mitigation and restoration measures. An important task of the research-based experts is analyzing the potential efficiency of advanced remediation and restoration techniques and adopting those techniques to the local conditions. Involving research-based experts offers the advantage that local research capacity is developed and that the research knowledge and experiences acquired during the follow-up of the mining process contributes directly and indirectly to an improvement of the legal regulatory framework and procedures guaranteeing vigorous control of mine effects.

To remove and/or reduce the preoccupation of local villagers the authors suggest that the mine company, in corporation with the local and national government, give focus to the following: increasing the frequency and improving the communication with local communities; involving the community actively in the mine development enabling them to improve their standard of living; and providing training in the activities for which local villagers could be efficiently involved. Given the cultural background of local people, who believe to have been the guardians of the land from ancestor's time, the authors suggest to

get the local villagers primarily involved in activities geared towards the conservation and the restoration of the landscape and ecosystem. It is believed that it would be considerably easier to train the villagers in those activities than to train them for the highly mechanized jobs in the modern large-scale and technological dominated operations. The advantage is that doing so will reaffirm the local villagers as guardians and preservers of their cultural heritage, a role which they can continue to play long after the mine closure. In addition, the improved knowledge they acquire herein will open the door for new market opportunities, because environmental restoration will be a never ending business.

The knowledge and technologies exist to improve mine operation. If it happens depends from the corporation between the stakeholders, and the assurances the mining company is willing to give to the concerns of the government, local communities and environmentalists, and the desire of the local research community to be involved in the environmental effect monitoring, follow-up and the formulation of mitigation and/or restoration measures. Of course implementation of the good intentions will be subject to the profit margin left after incorporating the ideas and suggestions issued by the authors in this paper. It is likely that the profit margin of large-scale operations leaves enough room for improved communication and interaction with all stakeholders, the incorporation of research-based experts, the application of the necessary mitigation and restoration measures, and involving local villagers in non-typical mine activities such as ecosystem restoration. And indeed under the pressure of the stakeholders (government, local communities, environmental organizations, NGOs) and the worldwide growing interest for socially and ethical responsible investment make that today the larger mine companies are gradually integrating most of the recommendations presented in this paper. That people are still retaliating against mining is primarily the consequence of (i) the poor communication between the stakeholders (mine companies, government, local communities, environmentalists, protagonist and antagonist of mining); (ii) the suspicious rather than the non-suspicious attitude as a consequence of the lack of understanding and/or the non-willingness to understand what the positive and negative aspects of mining are; and (iii) the not always correct claim that locals are insufficiently employed by mine companies. Improving stakeholder communication, making both the positive and negative sides more cognitively accessible, and motivating and incorporating local communities in activities of remediation and ecosystem restoration for sure will contribute to the reconciliation between the society and mining. Whereas the large and modern mine companies have the willingness to work on a better communication, train and employ local people rather than importing people from outside, and invest in vocational training of local villagers, government representatives and environmentalists, it is very likely that small-scale artisanal mine cooperatives lack the knowledge, expertise and the profit margin to make their developments environmental friendly. They most likely will continue polluting unless the governments have the courage to call an halt to the developments that are unable to guarantee meeting the legal criteria.

References

Acemoglu, D., Johnson, S. and Robinson, J.A., 2001. An African Success Story: Botswana. Working Paper 01-37, Massachusetts Institute of Technology, Department of Economics Working Paper Series.

ACIL Tasman Ltd., 2006. Cost and benefits of CSIRO robotic mining R&D. Economics Policy Strategy report to CSIRO's Lapsing Program Review. ACIL Tasman Ltd., Australia, 44pp.

Aguilar, G., 2001. Access to genetic resources and protection of traditional knowledge in the territories of indigenous peoples. Environmental Science and Policy, 4(4), 241-256.

Aubynn, A., 2009. Sustainable solution or a marriage of inconvenience? The coexistence of large-scale mining and artisanal and small-scale mining on the Abosso Goldfields concession in Western Ghana. Resources Policy, 34(1), 64-70.

Azapagic, A., 2004. Developing a framework for sustainable development indicators for the mining and minerals industry. Journal of Cleaner Production, 12(6), 639-662.

Bebbington, A., Humphreys Bebbington, D., Bury, J., Lingan, J., Munoz, J.P., Scurrah, M., 2008. Mining and Social Movements: Struggles Over Livelihood and Rural Territorial Development in the Andes. World Development, 36(12), 2888-2905.

Brown, M.T., 2005. Landscape restoration following phosphate mining: 30 years of co-evolution of science, industry and regulation. Ecological Engineering, 24(4), 309-329.

Bunn, S. and Smith, M.J., 2002. Design and implementation of an ecosystem health monitoring program for streams and rivers in Southeast Queensland, Australia: an overview. Bulletin of the North American Benthological Society (Rosenberg, D., Ed.), 17pp.

Bureau of Minerals and Petroleum, 2007. BMP guidelines – for preparing an Environmental Impact Assessment (EIA) Report for Mineral Exploitation in Greenland. 16pp. Retrieved 10 April 2009 from <http://www.bmp.gl/minerals/EIA_guidelines.pdf>

Burley, M.H.L., 2000. Impact equity and Canadian mining in Ecuador, a case study of stakeholder perspectives from communities, government and industry. MSc dissertation, School for Resource and Environmental Studies, Dalhousie University, Halifax, Nova Scotia, Canada, 306pp.

Byers, J.E., Cuddington, K., Jones, C.G., Talley, T.S., Hastings, A., Lambrinos, J.G., Crooks, J.A. and Wilson, W.G., 2006. Using ecosystem engineers to restore ecological systems. Trends in Ecology & Evolution, 21(9), 493-500.

Conzález Zenteno, P., 2007. Indigenous people and mining. Environment and Natural Resource Management Programming in Latin America and the Caribbean, IDRC. Retrieved 27 March 2009 from <http://www.portofentry.com/site/root/resources/analysis/4407.html>

Dobbie, M.J., Henderson, B.L. and Stevens, D.L., 2008. Sparse sampling: Spatial design for monitoring stream networks. Statistics Surveys, 2, 113-153.

Downing, T.E., Moles, J., McIntosh, I. and Garcia-Downing, C., 2002. Indigenous peoples and mining encounters: Strategies and tactics. IIED and WBCSD, Mining, Minerals and Sustainable Development, Report 57, 41pp.

Fields, S., 2006. The price of gold in Chile. Environmental health perspectives, 114(9), A536-A539.

Gosar, M., 2004. Environmental impacts of mining. Materials and Geoenvironment, 51(4), 2097-2107.

Gutierrez, R., 2009. Environmentalists against gold-mining fever. Coastal Post Online. Retrieved on 11 April 2009 from <http://www.coastalpost.com/09/01/23.html>

Haarstad, H. and Floysand, A., 2007. Globalization and the power of rescaled narratives: A case of opposition to mining in Tambogrande, Peru. Political Geography, 26(3), 289-308.

Hagerman, E., 1996. Communicating with Indigenous Peoples: Lessons from Guyana. Université du Québec, Montréal, Canada, MSc dissertation, 107pp.

Harrison, G.W., Rutherford, T.F. and Tarr, D.G., 2003. Trade liberalization, poverty and efficient equity. Journal of Development Economics, 71(1), 97-128.

Hilson, G., 2002. An overview of land use conflicts in mining communities. Land Use Policy, 19(1), 65-73.

Hilson, G. and Murck, B., 2001. Progress toward pollution prevention and waste minimization in the North American gold mining industry. Journal of Cleaner Production, 9(5), 405-415.

Horowitz, L.S., 2008. "It's up to the clan to protect": Cultural heritage and the micropolitical ecology of conservation in New Caledonia. The Social Science Journal, 45(2), 258-278.

Hudson, T.L., Fox, F.D. and Plumlee, G.S.,1999. Metal mining and the environment. AGI - Environment Awareness Series, 3, 68pp. Retrieved on 11 April 2009 from <http://www.agiweb.org/environment/publications/metalsfull.pdf>

Kapelus, P., 2002. Mining, corporate social responsibility and the community: The Case of Rio Tinto, Richards Bay Minerals and the Mbonambi. Journal of Business Ethics, 39(3), 275-296.

Kumah, A., 2006. Sustainability and gold mining in the developing world. Journal of Cleaner Production, 14(3), 315-323.

Li, M.S., 2006. Ecological restoration of mineland with particular reference to the metalliferous mine wasteland in China: A review of research and practice. Science of the Total Environment, 357(1), 38-53.

Maponga, O. and Ngorima, C.F., 2003. Overcoming environmental problems in the gold panning sector through legislation and education: the Zimbabwean experience. Journal of Cleaner Production, 11(2), 147-157.

McColl, G.D., 1980. The mining industry and the natural environment. Resources Policy, 6(2), 153-165.

Mudd, G.M., 2007. Global trends in gold mining: Towards quantifying environmental and resource sustainability. Resources Policy, 32(1), 42-56.

Mendez, M. O. and Maier, R. M., 2008. Phytostabilization of mine tailings in arid and semiarid environments - An emerging remediation technology. Environmental Health Perspectives, 116(3), 278-283.

Mychalejkon, C., 2008. Ecuador undergoes mining makeover. Upside Down World: Covering activism and politics in Latin America. Retrieved 10 April 2009 from <http://upsidedownworld.org/main/content/view/1249/49/>

OMCT, 2009. Fighting torture and other forms of ill-treatment by preparing reports and complaints to international bodies addressing their economic, social and cultural root causes. OMCT-Latin America. Retrieved 11 April 2009 from <www.omct.org>

OXFAM, 2009. Mining conflicts in Peru: Condition critical. 14pp. Retrieved 5 April 2009 from <http://www.oxfamamerica.org/newsandpublications/publications/briefing_papers/mining-conflicts-in-peru-condition-critical/Mining-Conflicts-in-Peru-Condition-Critical.pdf>

Petermann, A., Guzman, J.I. and Tilton, J.E., 2007. Mining and corruption. Resources Policy, 32(3), 91-103.

Petterson, M.G., Tolia, D., Cronin, S.J. and Addison, R., 2008. Communicating geoscience to indigenous people: examples from the Solomon Islands. Geological Society, London, Special Publications, 305; 141-161.

Pick, W., Naidoo, S., Ajani, F., Onwukwe, V., Hansia, R. and Bielu, O., 2003. Prevalence of alcohol and cannabis use and reported knowledge, attitudes and practice regarding its relationship with health and safety on mines in South Africa. Safety in Mines Research Advisory Committee: Wits School of Public Health, Health 712, Johannesburg, South Africa, 85pp.

Shen, L., Cheng, S., Gunson, A.J. and Wan, H., 2005. Urbanization, sustainability and the utilization of energy and mineral resources in China. Cities, 22(4), 287-302.

Straede, S. and Treue, T., 2006. Beyond buffer zone protection: A comparative study of park and buffer zone products' importance to villagers living in its buffer zone. Journal of Environmental Management, 78(3), 251-267.

Suppen, N., Carranza, M., Huerta, M. and Hernandez, M.A., 2006. Environmental management and life cycle approaches in the Mexican mining industry. Journal of Cleaner Production, 14(12), 1101-1115.

Tarras-Wahlberg, N.H., Flachier, A., Lane, S.N. and Sangfors, O., 2001. Environmental impacts and metal exposure of aquatic ecosystems in rivers contaminated by small scale gold mining: The Puyango River basin, southern Ecuador. Science of the Total Environment, 278 (1), 239-261.

Williams, M., 1990. Mining Future - Environmentalists try to stave off rush for State's minerals. Seattle Times, Sunday, December 30, 5pp. Retrieved 27 March 2009 from <http://seattletimes.nwsource.com/cgi-bin/PrintStory.pl?slug=1111986&date=19901230>

World Bank, 1997. Environmental Assessment of Mining Projects. Environmental Assessment Sourcebook. Environment Department, World Bank. 21pp. Retrieved 10 April 2009 from <http://www.worldbank.org/html/fpd/technet/decade/assess.htm>

Zhang, L., Liu, Q., Hall, N.W. and Fu, Z., 2007. An environmental accounting framework applied to green space ecosystem planning for small towns in China as a case study. Ecological Economics, 60(3), 533-542.