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Journal:	*Environmental Science & Technology*
Manuscript ID:	es-2010-01430e.R2
Manuscript Type:	Feature
Date Submitted by the Author:	n/a

Complete List of Authors:	Amezaga, Jaime; Newcastle University, School of Civil Engineering and Geosciences Roetting, Tobias; Technical University of Catalonia, Geotechnical Engineering and Geosciences Paul, Younger; Newcastle University Nairn, Robert; University of Oklahoma, Civil Eng. and Env. Science Jo Noles, Anthony; Ascciacion Civil Labor, Lima Oyarzún, Ricardo; Universidad de La Serena, Ingenieria de Minas Quintanilla, Jorge; Universidad Mayor de San Andres

A Rich Vein? Mining and the Pursuit of Sustainability.

*Jaime M. Amezaga**

Tobias S. Rötting

Paul L. Younger

Newcastle Institute for Research on Sustainability, Newcastle University, UK

Robert W. Nairn

CREW, University of Oklahoma, USA

Anthony-Jo Noles

Asociación Civil Labor, Peru

Ricardo Oyarzún

Universidad de La Serena, Chile

Jorge Quintanilla

Universidad Mayor de San Andrés, La Paz, Bolivia

Leaking tailings dams at an artisanal mine, Lake Poopó Basin, Bolivia (Tobias Rötting)

Strictly speaking, sustainable development requires that human activities are undertaken in such a manner that they do not eliminate options for future generations. Clearly, once a given mineral deposit has been mined to exhaustion, future generations do not have the option of mining it again; hence mining fails to qualify as sustainable development *sensu stricto* (*1*). Consequently, mining can only ever, at best, aspire to compatibility with sustainable development *sensu lato*, which can be defined as exploitation of a non-renewable resource (such as a mineral deposit) such that it gives rise to long-term benefits (environmental and/or social and/or economic) that equal or exceed the values which obtained prior to exploitation (*2*). At the crudest level, the "economic sustainability" of a given mining operation can be estimated by comparing extraction rates to estimates of total reserves. However, this coarse approach implicitly assumes that the only important episode in the life of a mine site is that period during which active mining takes place. This is fallacious even on economic grounds, since the wealth generated by mining can circulate in markets for decades or centuries afterwards. The post-extractive phase of the mine life cycle is, if anything, even more important when it comes to evaluating environmental sustainability, for which we need to examine the balance of benefits and dis-benefits over the (finite) extractive phase and the (essentially infinite) post-closure phase.

Environmental benefits and dis-benefits of active mining are potentially very broad, affecting any or all of air, soil, water and biota (*1*). In the mine's post-closure phase, by far the most important environmental issues relate to water. Air and soil pollution are often readily dissolved by re-vegetation and landscaping (*2*). Even mine sites which have otherwise been restored to high standards can subsequently develop pervasive and persistent problems in relation to water quality and quantity. Such problems tend to be most stark in arid catchments, such as the depicted site in Bolivia.

In this article we trace the evolution of thinking on sustainability in the mining sector from 1970 to 2010, drawing particularly upon our shared experiences of action research and developments in policy and practice in the U.S., Europe, and South America. Our findings demonstrate that the development of mining within the framework of sustainable development has arisen from the interplay of state regulation with industry-led innovation, paying particular attention to post-closure environmental issues, tempered by open dialogue with other communities of interest (e.g. agriculture; rural, and urban development).

Emergence of the Sustainability Agenda in Mining

Mining has long been a *bête noir* for environmental and social activists (*1*). In the early years, the industry did little to merit a more favourable appraisal. Gradual change began only in the 1980s with the emergence of stricter environmental regulations within a handful of national jurisdictions. Initially, the mining sector resented these regulations as external impositions. At the global level, the Rio de Janeiro Earth Summit in 1992 provoked a decade of reflection in the mining sector, as major companies gradually recognised that genuine engagement with environmental and social issues was a pre-requisite for gaining and retaining the "social licence to operate" which is necessary for the long-term pursuit of profit in democratic states. This thinking first entered the public domain in 1998 with the Global Mining Initiative (GMI), which was launched in preparation for the 2002 Johannesburg World Summit. The period 2001-2002 were heady days for the 'sustainable mining' agenda, with the World Business Council for Sustainable Development completing a major, worldwide stakeholder consultation process on "Mining, Minerals and Sustainable Development" (MMSD) (*2*), which added to the momentum of the GMI to prompt establishment of the International Council of Mining and Metals (ICMM). The ICMM brings together 19 major mining and metals-finishing companies, together with 30 national and regional industrial associations for various mined commodities.

The next landmark was reached in 2004 with the World Bank's publication of their Extractive Industries Review, which had been undertaken in response to criticisms of World Bank operations posited by environmental and human rights campaigners. While acknowledging that the extractive industries can contribute to sustainable development (*sensu lato*), the World Bank recognised that it had to intensify its efforts to reduce poverty, promote good governance, and foster transparency and stakeholder engagement in countries hosting Bank-supported mining activities (*3*). Minimum global standards set by the World Bank (*4*) were rapidly adopted as minimum requirements for mining projects financed under the Equator Principles (the benchmark for managing environmental and social impacts of major investments).

Since 2001 the ICMM Sustainable Development Framework (ICMM SDF) has been systematically developed (*5*). The ICMM SDF establishes ten principles to which all member companies promise adherence. It also commits member companies to independently-vetted public reporting in accordance with the Global Reporting Initiative. While 'performance' and the reporting thereof are two different things (*6*), and while the ICMM principles can be interpreted differently by different companies (*7*), our general impression is that there has been a marked improvement in both performance and public disclosure by ICCM member companies over recent years.

Adherence of major mining companies to voluntary codes of practice such as the ICMM SDF has led to a certain homogenisation of environmental performance by major mining companies irrespective of the strength of national jurisdictions. The great challenge will be achieving adherence by artisanal and small- to medium-scale mining companies to similar standards.

Clearly, a thorough examination of the evolution of policy and practice in relation to all dimensions of sustainability (social, economic and environmental) is beyond the scope of any one paper. Even covering all aspects of environmental sustainability would require prohibitively lengthy coverage. Hence, in order to illustrate the dynamics of the evolution of thought and action in relation to sustainability, we here choose as the most telling example the case of water management, as this is widely acknowledged to be the single greatest vector of environmental nuisance during both the extractive and post-closure phases of the mine life-cycle.

Water and Sustainable Mining

Despite the predominance of water in mining-related conflicts (*8)*, the seminal MMSD debates paid it scant attention. Restricting its discussion to a brief consideration of acid drainage, the MMSD report (*2 p233*) claimed that "water consumption in minerals production, while an important impact, ends when operation ends and thus *does not represent a long term liability*" (our emphasis). This is starkly at odds with worldwide experience and the international literature (*8*): mining can impact water quality for millennia after mine closure (*9*); ground water levels can be permanently affected by networks of drainage galleries and adits; groundwater can be lost to evaporation from pit lakes. For these reasons, it is important to evaluate the 'water footprint' of mining operations during both the extractive and post-closure phases of the mine life-cycle (*10*). To date, however, the instinct in the industry has been to focus almost wholly on the extractive phase. This has led to a poverty of understanding, and an under-valuation of water. Until the mid 1990s, water was largely regarded as at best a necessary evil (i.e. something used in the productive process) and more commonly as a nuisance or even a mortal threat (in the form of unanticipated inrushes to underground workings). It is only in the last 15 years that mining companies have begun to countenance consideration of water as an "environmental good", which has to be shared with other users, while ensuring the maintenance of healthy ecosystems. This new understanding implies strong shifts in the way companies conceptualise water management. Sustainable water management post-closure is best achieved by hydrologically-defensive planning, starting before the exploration phase. Having taken all reasonable steps to minimise negative long-term water legacies, holistic Environmental Impact Assessment of water use is necessary, and this will only be effective if it is undertaken within a framework of integrated river basin management (*8, 11*). Long-term plans need to anticipate changes in mine ownership, which are endemic in the industry: inadequate transfer of information during acquisitions can lead to loss of control of key infrastructure. This has, for instance, been the principal cause of most catastrophic failures of tailings dams in the past (*12*).

Ironically, the less water there is, the more controversial its management becomes. Analysis of overall water consumption in mining shows that it is strongly correlated to the grade of the initial ore. The declining average ore grade in most metals provides a major challenge for the future economic sustainability of mining, particularly in arid regions (*13*). Competition for water resources has already become the principal source of conflict where mines operate in arid areas (*11*). To date, the responses to these problems have varied widely from place to place, and to some degree also between the coal and hard rock (i.e. metal and industrial mineral) sectors, which have differing operational requirements for water. By considering the cases of the U.S., Europe and the *Cono Sur* of Latin America, we can tease out some of the nuances in these responses as they have emerged under conditions of varying aridity and contrasting social deprivation.

U.S.

Mining has been undertaken in what is now the U.S. since the earliest days of European settlement. Tens of thousands of kilometers of rivers are heavily polluted by drainage from abandoned coal and hard rock mines. More than one million acres of abandoned coal mine lands had been left in poor quality by the 1970s. In the western states, hundreds of thousands of abandoned hard rock mines have been recorded, with significant environmental degradation (mainly surface and/or groundwater pollution) at some 33,000 locations (*14*). Increasing recognition of the severity of these post-closure impacts from the early 1970s has spurred the development of federal regulatory laws. Early environmental legislation was general in scope, and was gradually found to be unsuitable for addressing some particular challenges of the mining sector. In 1977 the first (and only to date) mining-specific environmental law was enacted, the Surface Mining Control and Reclamation Act (SMCRA), although this applies only to coal mines. The SMCRA considerably improved mine abandonment practices and raised a levy on active mines to address the legacy of improperly abandoned mines in coalfield areas; to date this has funded around $5 billion worth of clean-up (*15*). Controversy still surrounds "mountain-top removal and valley fill" coal mining operations (*16*). No law comparable to the SMCRA has ever been enacted for hard rock mines. Nevertheless, various federal and state laws now require active hard rock mines to develop robust closure plans. However, in the absence of SMCRA-like provisions on legacy issues, some 156 older abandoned hard rock mine sites continue to generate significant pollution (mainly of surface waters), the remediation of which would require some $24 billion (*17*). The US experience abundantly illustrates the overwhelming importance of post-closure environmental quality in determining the overall compliance of mining activities with sustainability criteria.

Europe

Mining has been undertaken in Europe for more than 3,500 years, with at least some activity taking place at some time in every country in the continent. European mining declined steeply in the 20th century, as coal ceased to be the main source of energy and as European metal mining became less competitive in global markets. Industrial mineral extraction is the only growth sector in European mining today. Successful lobbying by the mining industry succeeded in exempting the sector from much of the environmental legislation enacted over the past half-century of increasing European integration. For instance, mining was exempted from the integrated pollution control measures which require all other industries to take steps at the end of production to avoid any pollution risk and return the former industrial site to a satisfactory condition. That mining, of all industries, should be excluded from this requirement is simply indefensible in environmental terms, not least because even a small mining operation can disrupt natural hydrological conditions to a far greater extent than surface-based industries (*8, 9, 10*). Given this, it is not surprising that a string of environmental incidents were to finally expose the utter inadequacy of generic European legislation when dealing with the particular issues raised by mining (*18*). Two major tailings dam failures, at Aznalcóllar (Spain, 1998) and Baia Mare (Romania, 2000) (*19*), prompted the EU to establish a Task Force, which recommended a string of legislative changes (*19*). The ensuing legislation focuses almost entirely on waste handling in active mining operations. Industry lobbying weakened many of the most significant provisions originally envisaged for the Directive, such as requiring a secondary containment bund around large tailings dams. The October 2010 outburst of red mud from a tailings impoundment at Ajka in Hungary graphically illustrates how ill-advised this omission was. More broadly, the Directive did not remove the exemption of mining sites from pollution prevention legislation, and also failed to address ongoing water pollution from abandoned mine sites, which remains by far the most pressing mining environmental issue in Europe today (*18,20, 21*).

Arid zones of Latin America

In the new Millennium, disputes over mine water pollution have become increasingly acute in parts of Latin America, particularly where poor communities still rely on untreated water from local springs and rivers. Such issues are particularly problematic in naturally water-scarce areas, such as the extensive arid areas of Bolivia, Chile and Peru.

Bolivia

The history of Bolivia is dominated by mining, which commenced before the Spanish conquest in the 16th century, but greatly intensified thereafter. All of the major cities of Andean Bolivia owe their origins to mining developments, most notoriously Potosí, which to this day has some of the world's most dangerous mining operations. The human population and ecosystems in this region still endure the environmental legacy of these activities, in the form of vast spreads of contaminated land and persistent pollution of air, soil and water (e.g. *22, 23*).

Bolivian legislation on mining, water and the environment is of recent pedigree, essentially commencing in earnest only in 1992 with the enactment of an environment act from which all subsequent regulations have been derived. Reform of mining law in 1997 introduced a requirement that future mining be conducted in accordance with the principles of sustainable development, with particular emphasis on environmental sustainability. Although the legal framework in Bolivia is now strong, enforcement remains weak. In this vacuum of responsibility, many international mining companies operating in Bolivia voluntary adhere to very high environmental standards, essentially corresponding to those enforced in North America and Europe. Nevertheless, given the aridity of much of the mining belt of western Bolivia, strict adherence to regulations devised in more humid, higher latitude countries can give rise to unintended negative outcomes. A classic example is the consumption of vast amounts of scarce water resources in evaporation ponds, in pursuit of the otherwise laudable goal of 'zero discharge' site management, which is popular in the gold (Au) mining sector. The idea of zero discharge mining is that, if no water leaves the site, neither will any pollutants. However, in areas as arid as the Bolivian Altiplano, the consumptive use of water resources to attain 'zero discharge' is far less desirable than treatment and re-use of these water resources.

Since 2005, the Bolivian government has justifiably prioritised rapid economic development to reduce severe poverty; in this political climate, environmental sustainability is not really a top priority. This has led to burgeoning of unregulated small- and medium-sized 'artisanal' mines, which often have environmental impacts out of all proportion to their size. Rapid abandonment of artisanal mines has followed recent declines in international metal prices. Not only are few precautions taken during closure; falls in metal prices are also reflected in declines in the Bolivian gross domestic product, reducing even further the scant resources available for environmental protection.

Chile

Copper (Cu) mining in Chile currently accounts for about 55% of national exports and around 37% of total world production. The majority of Cu deposits occur in the arid to extremely arid north, where water scarcity hinders mine expansion. Before the return to democracy in 1990, there were few environmental regulations in Chile. Water legislation enacted under the Pinochet government (1973-

1989) was focused on privatisation of water services, which was pursued to a more extreme neo-liberal model in Chile than in any other country. Water resources were assigned entirely to private ownership, and a free market was established for the trading of water rights. Notwithstanding 1994 legislation which requires mining developments (and other industries) to undertake environmental impact assessments, in reality the public administration has such limited jurisdiction that sustainable management of water resources is highly difficult in Chile today (*24*). Severe conflicts over access to water resources, particularly between the agricultural and mining sectors, have led to social unrest in some parts of Chile, prompting calls – as yet unfulfilled – for legislative change. As in Bolivia, many international companies have voluntarily adopted stricter environmental norms than are demanded of them by the state, often using certified environmental management systems (*25*). Nevertheless, given its extreme neo-liberalism, environmental sustainability cannot truly be claimed to be a priority for the state or private investors in Chile yet.

Peru

Peru is a world-leading silver (Ag) producer, and a major producer of Cu and zinc (Zn). Since 1960, Peru has gradually developed a comprehensive legislative framework for mining, water and the environment. Peruvian regulations oscillated between economic liberalism and state ownership until 1993, when a new constitution declared all natural resources to be the patrimony of the nation, private use of which could be pursued under licence. Further legislation introduced minimum water quality criteria which must be observed by all mining operations, and also established the basis for 'sustainable' use of non-renewable resources, which in this case is defined (rather narrowly) as efficient exploitation of the resource in a manner which prevents or mitigates the negative impact of the extraction on the surrounding resources and the environment. Prior to the creation of the Ministry of the Environment in 2008, responsibility for enforcement of these environmental protection measures was split between several government ministries, Similarly, the 2009 Law of Water Resources establishes a National

Water Authority, and a system of integrated river basin management. Peru now has the most comprehensive regulatory system for mining and the environment in South America.

Nevertheless, about a third of all current social conflicts in Peru are associated with mining, and these are predominantly water-related (*26*). In many cases, these social conflicts have deep historical roots, with memories of previous political dispensations continuing to cloud present-day decision-making. More recent mining developments illustrate the efficacy of the modern regulatory system in Peru. For instance, the Cerro Verde Cu mine in Arequipa province, southern Peru, has expanded its production capacity significantly in the last few years. This has required a substantial increase in water use. Being aware of the concerns of the local population and other water users, the mining company has implemented a proactive environmental management strategy, co-financing a dam which not only provides water for the mine, but also generates hydroelectric power for the local population, and distributes excess water to other users in the basin of the Rio Chili.

In 2007, the Peruvian nongovernmental organisation (NGO) Labor and the EU-funded CAMINAR project (Catchment Management and Mining Impacts in Arid and Semi-Arid South America) established a technical advisory group for the Rio Chili catchment under the auspices of the Regional Government. Multi-stakeholder dialogue convened by thus group has established that current mining operations are not contaminating the river; sewage from Arequipa City is the main source of water pollution (*27*). The Rio Chili dialogue group is mirrored at the national level by a 'Mining Dialogue Group', which brings together mining companies, governmental agencies, NGOs and citizens' groups in an atmosphere of growing reciprocity and trust.

Conclusions: aligning mining with sustainable development (*sensu lato*)

Attaining compatibility between mining and sustainable development *sensu lato* is contingent upon the resolution of some key challenges, which can be conceived as arising from the incommensurability of values (*28*). For instance, on what basis can we directly compare a socioeconomic benefit with the intrinsic value of natural terrain in its pre-mining condition? Socioeconomic benefits of mining extend far beyond the values of wages, dividends, and taxes. Some ancient mining has left a legacy of World Heritage Sites, which add socioeconomic value to the land. More mundanely, as recycling of metals gradually replaces primary production by mining (*29*), further value is added repeatedly to initial worth derived from mining long ago. This is but one example of the ways in which wealth generated by former mining activities continues to circulate in the world economy. If we are to compare these socio-economic benefits with the intrinsic value of natural terrain in its pre-mining condition we will require robust estimates of the "non-use value" of mineralised ground. Any piece of ground can be considered an environmental asset insofar as it provides the foundations upon which natural soils, watercourses and ecosystems develop. Mining has the potential to entirely remove this asset value, in whole or in part, temporarily or permanently. With suitable design, underground mining can be undertaken in such a manner that pre-existing surface conditions are barely altered. However, this is relatively expensive, and is also more hazardous for miners. Hence, since the mid-20th century, more than three quarters of world mineral production has been by surface mining, which inevitably entails elimination of the previous land surface. In some cases, back-filling and reclamation of surface mine sites can return the land surface to an environmental status which is as good as (or even better than) its previous condition (*30*). This is particularly the case where the land surface was previously degraded by other human activities. Where water quality is not a limiting factor, abandoned surface mine voids can even be developed as reservoirs for public water supply, as has occurred recently at Belo Horizonte in Brazil (*31*). However, where valuable mineral deposits underlie fragile natural ecosystems, restoration to "as good or better" status may well be impossible over any reasonable time-scale. In such cases, it might well prove impossible to demonstrate compatibility of mining even with sustainable development *sensu 'latissimo'*.

And just how '*latissimo*' would our definition of sustainable development need to be for the socio-economic benefits of mining to justify large-scale and long-term pollution of natural waters for centuries or even millennia after mine closure? Thankfully, in those cases where effective treatment of abandoned mine waters can be achieved, it is usually the case that the necessary costs are dwarfed by the wealth yielded by the mine during its extractive phase (*8*). However, this may be of little comfort where someone other than the original polluter (or their heirs) ends up paying for remediation (*20*). Furthermore, there are numerous cases in which comprehensive treatment of abandoned mine waters is simply not achievable for any conceivable level of investment. For instance, intensive investigations of an intensively mined catchment in Cornwall (UK) revealed that treatment of the entire flow in the river would still fail to achieve regulatory standards, due to the pervasive presence of vast sources of re-contamination downstream (*32*). At a smaller scale, many small, artisanal mines have yielded little wealth, yet have disproportionate environmental impacts which can persist indefinitely after mine closure (*22*); this is particularly so where mercury (Hg) is released into rivers from small-scale Au winning operations (*33*).

So what can be done to improve the chances of aligning mining with sustainable development (*sensu lato*) in future? From our experience of modern mining operations on three continents, we would argue that three conditions must be fulfilled:

1. Development and enforcement of regulations which, when necessary, can robustly defend environmental non-use benefits of mineral deposits in comparison with projected social and economic benefits which could arise from their exploitation. It is crucial that these regulations adequately deal with the long-term, post-closure phase of the mine life cycle.
2. Adoption of voluntary practices by mining companies which exceed the minimum requirements demanded by the relevant legal jurisdiction. Foremost among these practices are "defensive" mine planning procedures, which embody the principle that "prevention is better than cure". Detailed discussion of what this might entail in relation to water management has already been initiated (*34*); there is a need to consider how this approach might be expanded to encompass other environmental compartments and socioeconomic scenarios.

3. Genuine inter-sectoral dialogue, to resolve long-running conflicts and pro-actively foster mining which embraces sustainable development *sensu lato*. The Peruvian national Mining Dialogue Group provides a good model for this.

The degree to which these three conditions are realised varies from one jurisdiction to the next. In relation to the countries considered in this paper, for instance, we would argue that the U.S. has the best overall performance, and is pre-eminent in relation to condition 1. Europe still has some way to go on all three counts, albeit active mining operations are now managed far more responsibly than was the case as recently as the 1990s. Peru has recently made impressive progress in relation to 3. Elsewhere, it is precisely the expansion of activity under 3 that is likely to act as the catalyst for further developments on 1 and 2. Nevertheless, even at the present stage of development, there is no shortage of individual mining operations which faithfully reflect conditions 2 and 3, even if 1 remains a 'work in progress' in terms of government policy. Overall, we believe it is fair to say that the pursuit of sustainable development (*sensu lato*) is finally coming of age.

Jaime Amezaga is Senior Lecturer in Environmental Policy and Sustainability in the School of Civil Engineering and Geosciences at Newcastle University (UK), where Paul Younger is a full Professor and Director of the Newcastle Institute for Research on Sustainability. Tobias Rötting, who was at Newcastle University when this paper was written, is now a Researcher in the Department of Geotechnical Engineering and Geosciences, UPC-BarcelonaTech, Spain, Robert Nairn is Director, Center for Restoration of Ecosystems and Watersheds and Associate Professor, School of Civil Engineering and Environmental Science, University of Oklahoma, USA. Anthony-Jo Noles is Coordinator of the Lima Office of the Asociación Civil Labor. Ricardo Oyarzún is member of Departamento Ingeniería de Minas, Universidad de La Serena and Centro de Estudios Avanzados en Zonas Aridas (CEAZA-ULS, Chile). Jorge Quintanilla is Emeritus Professor of Universidad Mayor de

San Andrés, La Paz, Bolivia. Please address correspondence regarding this paper to J.M.Amezaga@ncl.ac.uk.

Acknowledgements

The production of this article has been partly supported by the CAMINAR Project INCO-CT2006-032539, co-financed by the Sixth Framework Programme of the European Commission. The views expressed herein do not necessarily represent the official opinion of the European Commission.

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(Robert W. Nairn)