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Outlining Environmental Challenges in the Non-Fuel Mining Sector

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STRADE is an EU-funded research project focusing on the development of dialogue-based, innovative policy recommendations for a European strategy on future raw materials supplies. In a series of policy briefs and reports the project will offer critical analysis and recommendations on EU raw materials policy.

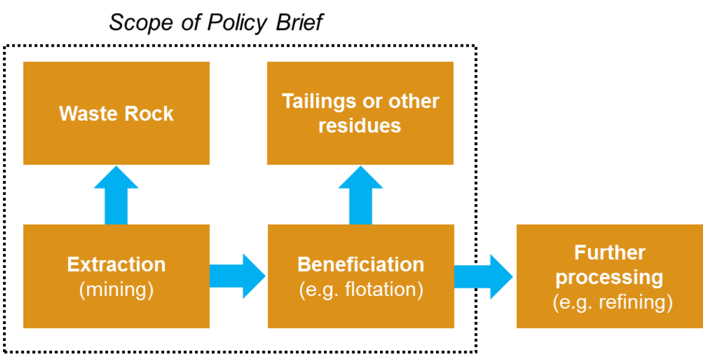
This policy brief is the fourth in a series of research articles and reports to be produced under STRADE. This brief reviews environmental impacts and ecological challenges in raw material production.

1 Introduction and Scope

Various forces raise the demand for raw materials and metals, including a continuously growing population, a steadily increasing standard-of-living especially in emerging economies, and on-going consumption in industrialized countries. Technological innovations, such as newer digital technologies, require an increasing variety of metals as well. Society's need for metals is undisputed; in the described growth scenario, primary metal extraction will – despite exceptions for some metals - cover most of the world's material demand in the next decades, even if ambitious recycling and resource efficiency measures are successfully implemented. The challenge is to ensure metal extraction that causes minimal impact to the environment. Although awareness of environmental issues surrounding the mineral extraction processes has significantly progressed over past decades, global mining and processing activities are still frequently accompanied by large environmental impacts. This policy brief summarises the most common environmental risks associated with mineral extraction and highlights the importance of international policy actions that promote responsible mining and processing practices.

This paper concentrates on the environmental impact of ore extraction and processing directly occurring at mining sites. Since other refining activities, such as smelting, are often located in larger plants thousands of kilometres away, they shall not be addressed in this policy brief.

Figure 1: Main process steps in mining



2 Environmental Issues in Mining – Overview

As an issue of increasing importance, the environmental impact of mining is being raised as a concern on various political agendas. In the currently revised EU's "Best Available Techniques Reference Document for the Management of Waste from the Extractive Industries (MWIE-BREF)" the European Commission identified key environmental issues of mining waste management facilities and defined best-practice guidance to minimize and mitigate the environmental impacts of mineral extraction (EC 2016). The UNDP states in its 2016 publication "Mapping Mining to the Sustainable Development Goals: A Preliminary Atlas" that responsible mining and managing environmental impacts is crucial for mining companies to maintain their social license to operate (UNDP 2016). In line with this, during the recent DG Growth Raw Material Diplomacy Event in Brussels in June 2016 one day was solely dedicated to environmental issues in mining.

The past efforts of industry and governments have led to significant improvements in environmental performance. However, the severe environmental impact from many active and abandoned mines still needs to be addressed. Later policy briefs will address the economic and social challenges for responsible mining practices; this paper focuses on the main environmental mining aspects.

If adequate technologies or management practices are applied, the following major environmental impacts from mining can be substantially mitigated.

- **Acid Mine Drainage (AMD):** According to the UNEP, AMD poses a serious threat to water resources and is the mining industry's top environmental problem (UNEP 2010). AMD occurs when sulphide minerals, which are part of waste rocks or mining tailings[1], are exposed to oxygen and water, leading to a chemical reaction in which sulfuric acid forms. The acid dissolves heavy metals, such as arsenic, cadmium, mercury or lead, and can contaminate groundwater and soil if no restraining systems are installed. The next section provides more details.

- **Water contamination:** Several factors can cause severe ground water contamination. In addition to acid mine drainage, as described above, mining often penetrates the earth to depths which reach the water table. This allows groundwater to flow into the mining pit, which may contaminate local groundwater. Leakages from tailing ponds if the floor and sides are not properly sealed can lead to high concentrations of toxic reagents and heavy metals in groundwater. Toxic components originate in applied chemical reagents, such as cyanide or nitrogen-compounds, as well as by-elements in ore (UNEP 2010, ELAW 2010). Contaminated groundwater may affect the clean water supply, surface water and, via irrigation, agricultural soils. Toxic effluent waters from processing that are not properly treated or retained directly contaminate surface waters and affect ecosystems and human health, e.g. via the food-chain.

- **Dam bursts and flooding:** Tailings deposits are stored in large ponds or dams known as Tailing Storage Facilities (TSF). In climates with heavy rainfall and in tectonically active regions, a TSF has a higher risk of failure. A TSF failure is the risk with the largest environmental impact. Failures can kill aquatic life and pollute surface and drinking water over large areas downstream. Similarly, surface flooding from heavy rainfall can release the toxic tailing sludge into surrounding areas. Further details on these risks are given in the next section.

- **Waste production:** Mineral extraction is the largest global waste producer, particularly from copper, zinc, bauxite and nickel mining (Manhart 2016). Depending on the specific ore grades and the degree of overburden, the ratio of waste to metal mined is large (Dold 2014). For example, to mine seven grams of gold, on average one tonne of waste material must be mined, not including the overburden (Priester and Dolega 2015).

- **Air pollution:** All mining stages can affect air quality, since fine particles and dust are often produced and dispersed by the wind. This can lead to a range of environmental impacts and adverse human health effects, particularly if the dust contains heavy metals. Dust emissions from tailings with a heavy-metal load and very fine grain sizes are the most critical issue if not properly managed. Volatile reagents such as mercury in ASM gold mining as well as VOC emissions from flotation reagents or NO_x emissions from diesel-powered engines can pollute the air.

- **Soil erosion and contamination:** Land conversion due to mining and its infrastructure destroys or contaminates soil cover in many cases, which constitutes a long term or even total loss of agricultural potential. Mining processes, such as crushing and milling, reduce soil particle sizes significantly, enhancing erosion by rainfall, runoff water or wind. This can have significant impact on the immediate and downstream ecosystems and human health. While high sediment loads in surface waters commonly lead to drastic changes in aquatic ecosystems, wind erosion often leads to mid and long distance transport of particles that might contain heavy metals or other harmful substances. Erosion can have even more devastating effects if coupled with processing chemical leak and/or AMD.

- **Water availability:** The mining industry's demand for water can exacerbate existing water competition with agriculture and consumers in regions where either water availability is low or water consumption is

[1] Tailings are the materials left over after wet processes used to separate the valuable fraction from the uneconomic fraction of an ore. The leftover slurry is referred to as tailings and consists of fine particles and chemical reagents. Sometimes, it has high concentrations of toxic substances. The tailings are usually stored in impoundments known as a Tailing Storage Facility (TSF) *(compare* Figure 1*).*

too high. Groundwater lowering for mining further aggravates water stress. Governments as well as mining industry acknowledge water usage and management as an exigent concern to address with local population (IM4DC 2014; ICMM 2015; Buxton 2012).

- **Ecosystem destruction:** Mining, particularly large-scale open pit mining, can cause all or partial destruction of ecosystems and agricultural land. Impact on ecosystems is also very high for mining sites located in protected areas with high biodiversity or high vulnerability and low resilience. The habitats of many animal species may be destroyed and migratory animals' population size and diversity can decline. The previously mentioned effects on water resources can further harm aquatic wildlife and destroy wetlands.

- **Radioactive radiation:** This can arise from radioactive elements embedded in the ore that are contained in the tailings. Human health and ecosystems might be endangered by radioactive dusts transported by wind erosion and radioactive groundwater contamination from leaking TSFs.

- **Submarine / riverine tailings disposal:** Mining sites close to bodies of water, e.g. in Indonesia, the Philippines, Papua New Guinea and Norway, often dispose of tailings directly into rivers or the sea, although most industries and stakeholders widely agree that riverine and shore marine disposal should be generally banned due to the high risk of environmental contamination (Dold 2014).

Technologies and management practices to significantly reduce the environmental impacts are available and have been successfully implemented at many mining sites. Europe's mining suppliers can particularly contribute to this development with sound technological solutions. However, these technologies are often not applied for reasons such as economic motives, lack of regulation, insufficient capacity to enforce existing regulations and the ongoing use of old technology. In small-scale mining in developing and emerging countries, low levels of education reduce local residents' ability to adapt to technological advances

3 Challenges and Hotspots

Five issues in the next sections cover selected hot spots for mineral mining: acid mine drainage, tailings dam/TSF failures, radioactivity in tailings and waste and submarine tailing disposal. The last section highlights environmental impacts from decreasing ore grades.

3.1 Acid Mine Drainage (AMD)

Acid Mine Drainage (AMD) is one of the main problems related to mining. It is particularly an issue for copper, zinc and lead mining since they are often associated with sulfidic ore. AMD at iron ore or bauxite mines rarely occurs because the metals are usually embedded in non-sulfidic ores (Manhart et al. 2015). Long-lasting pollution is the most significant issue associated with AMD; the effects of acidic waters produced from AMD can last for hundreds or thousands of years (Widerlund et al. 2014). AMD after mine closure poses especially a threat. Globally, many regions face direct legacies from the ongoing environmental damage due to AMD at former mining sites. Often, the former mining company cannot be held accountable for the negative environmental impacts. As a consequence, no rehabilitation is performed or the rehabilitation has to be financed from public or social funds. A 2008 study revealed that nine percent of the rivers in England and Wales are at risk of not meeting their *Water Frame Directive* targets as a consequence of abandoned mines. In most cases acid mine drainage continues to pollute the water. (Environment Agency 2008)

While most abandoned mine sites and tailings ponds are hidden and do not receive the immediate attention of nearby inhabitants, some can still be found close to residential areas. For instance, residues from gold mining were deposited in sparsely populated areas outside of Johannesburg, South Africa, before the 1950s (Kneen 2015). Sharp population growth led to rapid urbanization that currently extends beyond the closed mines; tailings ponds that were remote 60 years ago now neighbour residential areas. Studies show that the area is largely affected by AMD (Mining Weekly 2010).

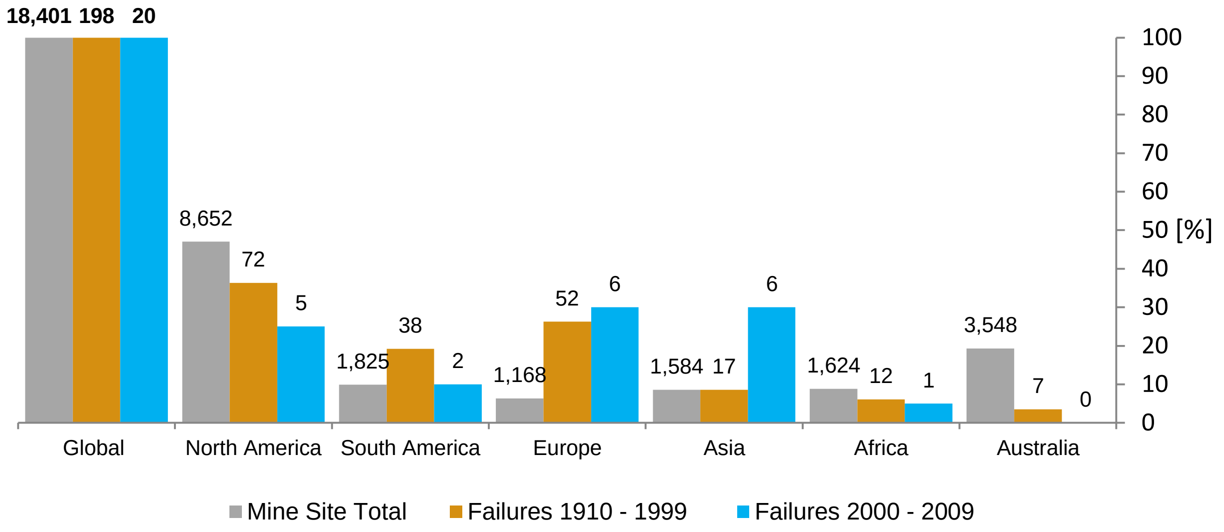
3.2 Tailings Dam Failures

Alongside the described possible environmental impacts of controlled mining operations, accidents may also lead to massive ecological problems. Tailings dam failures are one of the most devastating environmental accidents. In Brazil in November 2015, a tailings dam failure discharged more than 50 million cubic meters of sludge into the surrounding areas. The resulting mudflow interrupted the drinking water supply of at least 260 000 people, more than 600 inhabitants lost their homes and several people died. The mudflow contaminated more than 600 km of the nearby river Rio Doce (Neves et al. 2016). Water samples from the river indicate concentrations of substances such as lead, aluminium, iron, barium, copper, boron and mercury by far exceed tolerable levels. The river's toxic water composition now renders it useless for irrigation or consumption. Biodiversity and density of aquatic species has also sharply dropped; most of the endemic biodiversity as well as the gallery forests were destroyed by the waste wave. The wave reached the Atlantic Ocean and contaminated the fragile coastal region. Media reports often refer to the catastrophe as the “Brazilian Fukushima”, pointing out the devastating environmental consequences (FAZ 2015).

This catastrophe is not a secluded case. The history of mining is paved with TSF failures similar to Brazil’s. Between 2000 and 2009, twenty dam bursts were reported worldwide. Dam construction underestimated the risk factors for a failure, especially heavy rainfall events and snowmelt. Climate change may likely lead to more heavy precipitation events, resulting in more frequent accidents. Consequently, dams should be constructed with strong consideration for all possible atmospheric conditions or seismic activities (Azam and Li 2010).

Tailing dam heights widely vary, from less than ten meters to up to hundred meters. Even for 100 m dams, dam bursts do occur. The higher the dam, the more content can be released during a failure (Rico et al. 2007). Uncontrollable events such as rainfall and seismic activity are the main reasons for dam failure, although mistakes in management operation and structural weaknesses also cause accidents. New vacuum and pressure technologies developed over the last decades offer more environmentally sound possibilities for tailings storage. In dry tailings disposal, the deposited unsaturated tailings help mitigate dam burst risks. However, the technique can primarily be used for only low throughput operations; only few mining projects use the technique due to higher production costs (Davies 2011).

Figure 2: Tailings dam failure distribution (count and per cent) by region (Azam and Li 2010)



note: the individual categories amount to 100% globally

Tailing dam accidents do not only affect developing countries. Between 2000 and 2009, 5 dam failures occurred in North America and 6 in European countries. Moreover, Europe has the worst incidents-to-mines ratio (1:200). Different climate conditions may play a key role. Australia, for example, has three times more mine sites, but reports eight times fewer tailings dam failures (compare Figure 2). Many European regions are exposed to flooding from snow melt and heavy rainfall. The global inventory of all reported dam bursts over the last 100 years estimates a 1.2% failure rate (Azam and Li 2010). Incident rates could be even higher, particularly in Africa, South America or Asia as accidents at remote locations might be undetected by the public and go unreported.

3.3 Radioactivity in Tailings

Although tailing radioactivity mostly stems from uranium mining, the waste from extracting other metals associated with radioactive by-elements can also irradiate tailings sludge. Wind erosion can then transport the radioactive dust, and rainfall and oxygen may dissolve the radioactive particles and trigger mine drainage, contaminating streams, aquifers and groundwater. The radioactivity can enter the food chain and affect human health and wildlife.

Rare-earths mining and processing often coincide with radioactivity leaks from thorium (Dold 2014, Walz et al. 2016). For example, a twenty-year follow-up study by the Chinese Healthcare Research Centre indicates that workers in Baotou have higher risks of dying from lung cancer (Schüler et al. 2011).

In another example, gold production in the Witwatersrand basin in South Africa mined approximately 800 000 tonnes of uranium, three quarters of which remains in openly exposed regional tailing dumps (Winde 2013). This 600 000 tonnes of radioactive mining waste represents ten times more than the world uranium production in 2014. With a uranium concentration exceeding that of tailings from uranium mining, this incident has a strong impact on the surrounding environment (Winde 2013).

A research project commissioned by the German Environment Agency reports that waste from mining uranium, thorium, tantalum, niobium and rare-earth elements imposes a high risk of enhanced radioactive radiation from the high uranium and thorium concentrations. German and Chinese data also suggest that many other non-radioactive ores can also have critical radioactive radiation levels (Manhart et al. 2016).

3.4 Submarine tailings disposal

In contrast with tailings disposal in on-shore impoundments, a few sites dispose of their tailings into the sea or other waterbodies. Tailings' fine grain size and toxic content containing chemical reagents and heavy metals increase the risks for environmental damage, although AMD does not occur when the waste is isolated from the air. However, more studies are needed to understand the consequences of such waste disposal techniques on biodiversity and other ecological aspects.

Similarly, not all risks associated with disposal of tailings in deep sea locations are entirely known. Initial studies already indicate deep sea disposal accompanies reduced abundance of aquatic life (Hughes et al. 2015). Currently, 16 mines in 8 countries use deep sea tailings disposal techniques (Groß 2016). Indonesia, Philippines, Papua New Guinea and Norway still dispose of some of their submarine tailings close to shore. Submarine disposal for mines close to the coast is relatively cheaper than on-land disposal, leading to distorted price competition with mining sites following best-practice waste treatment standards.

3.5 Increasing Challenges from Decreasing Ore Grades

Over the past decades, the specific concentrations (grade) of ores have decreased for a range of commodities, leading to greater amounts of waste rock and tailings. Reasons for the decrease are disputed. One common explanation is that most rich ore deposits have already been exploited leaving only lower grades today (Mudd 2010). Others argue that the cost effectiveness to mine lower ore grade in already developed mine sites distort the grade ratings (West 2011). Both sides, however, agree that the trend towards lower grade ore mining will lead to larger amounts of waste, higher energy and water demand and could potentially increase environmental impacts such as AMD, tailing failures and water stress. These issues should be tackled appropriately (Dold 2014).

4 Regional differences and challenges

The following section discusses specific challenges in European mining, mining in non-EU industrialized countries and mining in developed countries. The selected examples do not claim to comprehensively summarize regional differences, which will be part of the later STRADE dialogue process. Instead, these synopses seek to raise awareness on the specific issues in different parts of the world and to acknowledge that challenges in mining are not only issues in developing countries but also important issues for industrialized countries.

4.1 Europe

The volume of ores mined in Europe has decreased over the last decades. In general, European metal mining projects are concentrated in Northern Scandinavian countries (primarily for iron ore), with a few exceptions on the Iberian Peninsula and in Central Europe (mainly for copper).

After the tailings dam failures in Aznalcóllar (Spain) and Baia Mare (Romania) in 1998 and 2000, mining's environmental impact gained attention in EU environmental policy and resulted in the *Mining Waste Directive* regulating new mines in 2006. In addition, extractive industries projects must undergo an Environmental Impact Assessment (EIA) according to the *EIA Directive* of the EU (EC 2013). However, the directives do not *ex post facto* cover mines in operation before enactment of the law. Since 2006, two dam failures have been recorded in Europe, the most recent incident was at the largest European nickel mine in Talvivaara, Finland, in 2012. As a consequence, the Finnish Network for Sustainable Mining, aiming at responsible practices, was founded. Its guidelines and auditing scheme are based on the Canadian industrial initiative 'Towards Sustainable Mining' (Yrjö-Koskinen 2016).

In recent years, large civic protests occurred in Romania and Greece. In Romania, the protests turned against the plans for mountain top removal at what would have been Europe's largest gold mine at Rosia Montana (Vesalon and Creţan 2013). Greeks protested against plans for an open pit gold-copper mine and the loss of forest areas (Trilling 2013). Public acceptance for mining projects in Scandinavian countries seems to be high in non-indigenous populations, particularly when located in remote areas. In Sweden, mining's long history allows established companies to gain a social license to operate, while newer companies often meet more resistance and distrust, particularly in areas with no prior history of mining (Tarras-Wahlberg 2014). In contrast, the 20th Saami Conference in 2013, representing the Saami council's member organisations in Scandinavia and Russia, stated that “resource extraction in the Saami territories today carries huge risks and little advantages”, indicating low acceptance in the indigenous community.

In addition to its active and new mines, Europe has a huge legacy of abandoned mines. Estimates of acid leaks from abandoned mines across Europe range between 10 000 and 100 000 instances (Wolkersdorfer et al. 2006).

4.2 Other Industrialized countries

Europe is no longer a major player in the ore mining industry. However, some industrialized countries, such as Canada, Australia or the United States, and emerging economies, such as China, Brazil and South-Africa, play a leading role in ore extraction.

In many mining regions in these countries, public awareness about mining practices cannot be as easily raised due to rather low population density and a less diverse economic situation, allowing old mining projects to be extended or new ones developed with less civic opposition. Nevertheless, the environmental impact in these regions remains the same as for areas with higher population densities.

Mining legacies play a huge role in the US, Canada, South Africa and Australia. For example, an abandoned mines inventory in Canada counted over 10 000 abandoned mines, many of which are affected by acid mine drainage (AMD) (Mackasey 2000). Australia estimates that it has 50 000 abandoned mines (Unger et al. 2012). Exemplifying a common problem, drinking water was contaminated in 2010 by AMD from the abandoned Brookstead tin mine in Tasmania (White 2013). The potential dangers of abandoned mines can further be seen in the United States’ Gold King Mine wastewater spill in 2015, where a TSF failed during rehabilitation work and released 11 million litres of contaminated water into a river (Chief et al. 2015).

Tailing dam failures can also occur at active mines. In 2014, the open pit copper and gold mine at Mount Polley in Canada gained public attention after a major dam burst. The operator of the mine was an early stage member of the ‘Towards Sustainable Mining’ initiative. After the incident, the Initiative started to revise its tailings management guidelines (Mining Association of Canada 2015).

In Australia, mineral mining is a relevant part of the economy and mineral rents account for more than 5% of the gross domestic product (World Bank 2016). One major sustainability issue is the water stress in many arid mining regions which is addressed by the National Water Initiative and regional water allocation plans. Minerals industry sees a secure water supply as critical business risk that represents a significant potential constraint on further investment and expansion (Ernst & Young 2015). In line with this, the mining industry highlights the importance of water recovery and re-use technologies and the development of the Water Accounting Framework. (MCA 2016, IM4DC 2014)

4.3 Developing and emerging countries

The specific challenges of responsible mining in developing and emerging countries is a complex issue. In this section, only two critical points will be discussed; later policy briefs will address this topic in detail.

Large scale mining (LSM) plays an import role in many developing and emerging countries. Although the environmental risks for LSM are in principal the same as for industrialised countries, insufficient regulatory implementation and low transparency in many developing and some emerging countries hinder implementing responsible mining practices. Thus, export and import countries face the common challenge of finding strategies to enhance environmental LSM performance in regions with inadequate consideration of social and environmental issues.

Another issue specific to developing countries is artisanal and small-scale mining (ASM). The metals gold, tantalum, tin and cobalt are in particular mined by ASM, with estimated shares at the global production of 15% to 30% (Manhart et al. 2015). For some countries and approximately 20 to 30 million miners globally, ASM provides an important income source. Estimates from 2009 assume that in Mongolia, two South-American and six African countries more than 10% of the population depend on ASM (Dorner et al. 2012). The environmental impact of ASM can be severe. For example, ASM mostly uses mercury instead of cyanide for gold extraction; it accounts for around 37% of global anthropogenic mercury emissions (UNIDO 2013). In 2016, the Peruvian Government declared a state of emergency in the region of Madre de Dios due to extremely high mercury concentrations from illegal gold mining. In addition, since ASM is informal, no rehabilitation measures exist, leaving behind disturbed landscapes after the exploitation of a deposit.

5 Policies and industry engagements for responsible mining

The EU responded to the mining industry’s environmental challenges by adopting the *Mining Waste Directive* in 2006 and demanding an obligatory Environmental Impact Assessment (EIA) for new mining sites and a Strategic Impact Assessment (SIA) for public plans that set frameworks for future activities with relevant environmental impacts. Addressing the environmental problems of imported raw materials, the European Raw Material Initiative sees that mining can and should contribute to sustainable development. The EU’s development policy also has an important role to play in Raw Materials Diplomacy, building win-win situations for developing countries and the EU in the area of raw materials (RMI 2013). During its dialogue process, STRADE will discuss to what extent this target can be achieved and how the impact can be improved.

Most industrialized and developed countries have similarly adopted advanced regulations to improve environmental standards in mining. EU documents on best available techniques, the World Bank EHS Guidelines for Mining and guidelines from industrial associations such as the International Council on Metals and Mining (ICMM) and the Canadian 'Towards Sustainable Mining' program (TSM) document that technologies and management schemes for significantly reducing environmental impacts are available. The EU continues to fund various research projects on environmental technologies and policy strategies towards responsible mining. A deeper analysis of this EU engagement in responsible mining practice will be addressed in upcoming STRADE policy briefs.

Many examples and case studies provide evidence that sound planning and management can significantly reduce environmental risks. Generally, many large mining companies have worked hard to improve their environmental standards at large-scale mines over the last decade. Nevertheless, according to a 2012 review by the International Institute for Environment and Development (IIED), there are still difficulties in implementing, reporting, and ensuring consequences for non-compliance to the set of global rules for best practice on sustainable development and minerals that has emerged in the last decade (Buxton 2012). IIED concludes that capacity building is a highly relevant issue for future action, particularly in governments of countries with insufficient regulatory capacities and for small- and medium-sized mining companies with little knowledge on responsible mining practices.

The ASM sector also reveals significant social challenges, since currently up to 30 million workers and their families depend on ASM as an income source. Various diverse voluntary initiatives on standards, certification schemes and due diligence schemes, as well as government initiatives to grant artisanal miners title to deposits, contribute to improvements. However, the overall impact of these activities is still very limited (Buxton 2012).

A further challenge is the uneven competition; companies that invest in clean extraction technologies and better processing carry a financial burden for compliance due to a less favourable cost structure while others benefit from non-internalized external costs. The Mountain Pass Mine in the USA illustrates this very well. The mine produced rare earth elements until 2002, when it stopped extraction due to environmental concerns and competition from low-cost Chinese production. In 2011, the mine restarted production and opened new processing facilities to supply the domestic market and to allow the country to be less dependent on Chinese production. The operator of the mine invested in advanced techniques to improve the environmental performance according to legal requirements (Schüler et al. 2011). Through a variety of measures, the environmental impact of the mine was minimized. However, the investment did not pay off due to declining rare-earth prices in 2012 and strong Chinese competition; in January 2016 the company declared bankruptcy.

From a mid-term and long-term perspective, reducing environmental risks and impacts of mining operations lies in mining companies' interests, though they may have to invest significant financial resources in the short term. In the case of accidents, the costs of cleaning, repairs and fines may far outreach this initial investment – at least when operating in countries with effective governance regimes. For example, Samarco, the operator of a Brazilian mine that caused the catastrophe at Rio Doce in 2015, has to pay over USD 6 billion in reparations (Ker 2016).

Some mining companies have also recognized that sustainable development is an essential part of operational risk management. Such risk mitigation goes beyond tailings management to also address factors like increased water and energy scarcity (Buxton 2012). In line with this, ICMM and TSM responded to pollution from tailing failures in Brazil in 2015 and in Mount Polley/Canada in 2014 with a revision of their tailing management guidelines (ICMM 2015; TSM 2015).

A deeper analysis of governmental policies and industry's action aimed at sustainable development will discussed in subsequent STRADE policy briefs and workshops.

6 Conclusion

Despite large improvements in national legal requirements and industry engagement and manifold examples of successfully implementing responsible mining practices in the last decade, mining in the 21st century can still be greatly improved. Countries lacking governance capacities, mining companies needing more resources for environmental management practices and old mining sites with poor technical levels all offer many areas to improve mining. Since these factors play a significant role across many raw-material exporting countries, a significant share of Europe's mineral imports is assumed to come from poorly managed mining sites that could cause detrimental environmental impacts.

The most relevant environmental impacts mainly occurring at poorly managed mining sites – especially groundwater contamination by acid mine drainage and tailing dam failures, soil contamination from dust and erosion, damage of ecosystems, loss of agricultural land and ecological disaster from tailing dam bursts – need to be tackled by international, EU and national policies. Such environmental protections would not only benefit the environment but also the population most severely affected by mining.

The EU responded to the environmental challenges from mining waste facilities within the EU by the *Mining Waste Directive* in 2006 and the obligatory Environmental Impact Assessment (EIA) for new mining activities. EU member states are responsible for implementing the Directives into their national laws. This legal framework along with EU-funded research projects on responsible mining provides a good basis for reducing environmental impact from mining.

Addressing the environmental problems of imported raw materials, the European Raw Material Initiative promotes 'sustainable development' without formulating precise targets and policy instruments. STRADE will take up this issue in its dialogue process.

The STRADE project investigates policy options for minimizing adverse environmental impacts and maximizing societal benefits from mining and seeks integrated policy measures which consider all aspects of sustainability: ecological, social and economic issues. Therefore, the strategies developed under STRADE will be derived through stakeholder dialogues that engage participants from governments, industry, science and CSO's. New cooperation and business models are sought to unite economic, ecologic and social requirements. In this respect, following policy briefs will provide an analysis of socio-economic impacts from mineral mining and an analysis of voluntary initiatives and EU policies in the minerals sector aiming at environmental improvements.

References

Azam, S. and Q. Li (2010): Tailings Dam Failures: A Review of the Last One Hundred Years. In: Geotechnical News: 50-53.

Buxton, A (2015): MMSD+10: Reflecting on a decade. IIE D Discussion Paper, International Institute for Environment and Development, London. Internet: http://pubs.iied.org/pdfs/16041IIED.pdf (last visited 29.08.2016).

Chief, K., Artiola, J.F., Wilkinson, S.T., Beamer, P., Maier, R.M. (2015) Understanding the Gold King Mine Spill. Internet: http://www.superfund.pharmacy.arizona.edu/sites/default/files/u43/gold_king_mine_spill.pdf (last visited 01.07.2016).

Davies, M. (2011): Filtered Dry Stacked Tailings – The Fundamentals. Proceedings Tailings and Mine Waste 2011 Vancouver, BC, November 6 to 9, 2011. Internet: http://www.infomine.com/library/publications/docs/davies2011.pdf (last visited 13.07.2016).

Dold, B: (2014): Submarine Tailings Disposal (STD)—A Review. In: Minerals 2014, 4, 642-666.

Dorner, U., Franken, G., Liedtke, M. and Sievers, H. (2012): POLINARES working paper n. 19. March 2012. Artisanal and Small-Scale Mining (ASM). Internet: http://www.polinares.eu/docs/d2-1/polinares_wp2_chapter7.pdf (aufgerufen am 19.07.2016).

Environment Agency (UK) (2008): Abandoned mines and the water environment. Science project SC030136-41. Internet: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/291482/LIT_8879_df7d5c.pdf (last visited 13.07.2016).

ELAW – Environmental Law Alliance Worldwide (2010): Guidebook for Evaluating Mining Project EIAs. Internet: http://www.elaw.org/files/mining-eia-guidebook/Chapter1.pdf (last visited 21.06.2016).

Ernst & Young (2015): Business risks facing mining and metals 2015–2016 - Moving from the back seat to the driver's seat. Internet: http://www.ey.com/Publication/vwLUAssets/EY-business-risks-in-mining-and-metals-2015-2016/$FILE/EY-business-risks-in-mining-and-metals-2015-2016.pdf (last visited 29.08.2016).

European Commission (2013): Environmental Impact Assessment of Projects. Ruling the court of justice. Internet: http://ec.europa.eu/environment/eia/pdf/eia_case_law.pdf (last visited 14.07.2016).

European Commission (2016): Best Available Techniques Reference Document for the Management of Waste from the Extractive Industries in accordance with Directive 2006/21/EC. Internet: http://susproc.jrc.ec.europa.eu/activities/waste/documents/MWEI_BREF_Draft.pdf (last visited 29.08.2016).

FAZ Frankfurter Allgemeine Zeitung (2015): Viele sprechen von einem „brasilianischen Fukushima". (translated: *Many speak of a "Brazilian Fukushima").* Internet: http://www.faz.net/aktuell/gesellschaft/umweltkatastrophe-nach-dammbruch-in-brasilien-13939330.html (last visited 13.07.2016).

Groß, O. (2016): Bloß weg damit – Industrieabfälle aus dem Bergbau landen oft im Meer. In: iz3w 454, Mai / Juni.

ICMM 2015: Annual Review 2015 – A global approach to collaboration, http://www.icmm.com/publications/annual-review-2015

IM4DC (2014): International Mining for Development Centre: Mining and sustainability: experience from Australia, Mendoza 17.4.2014: www.im4dc.org

Ker, P. (2016): New setback for BHP Billiton as Samarco deal is overturned. Internet: http://www.smh.com.au/business/mining-and-resources/new-setback-for-bhp-billiton-as-samarco-deal-is-overturned-20160701-gpw53g.html (last visited 19.07.2016).

Kneen, M.A., Ojelede, M.E. and Annegarn, H.J. (2015): Housing and population sprawl near tailings storage facilities in the Witwatersrand: 1952 to current. In: South African Journal of Science 111(11/12), Art. #2014-0186: http://dx.doi.org/10.17159/ sajs.2015/20140186 (last visited 01.07.2016)

Mackasey, W.O. (2000): Abandoned Mines In Canada Prepared For MiningWatch Canada. Internet: http://miningwatch.ca/sites/default/files/mackasey_abandoned_mines.pdf (last visited 01.07.2016).

Manhart, A., Gandenberger, c.; Bodenheimer, M., Rüttinger, L., Griestop, L (2015).: Ungewollte Verschiebungseffekt4 durch Standards und Zertifizierung – Relevanz und Lösungsansätze für den Beeich der abiotischen Rohstoffe. RohPolRess-Kurzanalyse. Internet: https://www.umweltbundesamt.de/dokument/die-debatte-um-konfliktrohstoffe-moegliche-bezuege (Last visited 19.07.2016).

Manhart, A.; Oeko-Institut, ifeu, project consult (2016): Bewertung ökologische Risiken bei der Primärgewinnung abiotischer Rohstoffe – Methodenvorschlag für einen rohstoffspezifischen Ansatz. Teilbericht des Projektes Erörterung ökologischer Grenzen der Primärrohstoffgewinnung und Entwicklung einer Methode zur Bewertung der ökologischen Rohstoffverfügbarkeit zur Weiterentwicklung des Kritikalitätskonzeptes (ÖkoRess). (translated*: Evaluation of ecological risks in the primary production of abiotic raw materials – Method suggestion for a commodity-specific approach. Intermediate report of the project for the evaluation of ecological limits in primary resource extraction and development of a method for the evaluation of ecological resource availability for further development of the criticality concept)* 25.6.2016, unpublished intermediate report for the German Environment Agency

MCA (2016): Water stewardship, http://www.minerals.org.au/policy_focus/water_stewardship/ (last visited 27.6.2016)

Mining Association of Canada (2015): Independent Task Force on Towards Sustainable Mining's Tailings Management System Tables Report and Recommendations with MAC Board. Internet: http://mining.ca/news-events/press-releases/independent-task-force-towards-sustainable-mining%E2%80%99s-tailings-management (last visited 19.07.2016).

Mining Weekly (2010): Rising acid mine water could be 'catastrophic' for Johannesburg, 21.7.2010, http://www.miningweekly.com/article/rising-acid-mine-water-threat-to-joburg-2010-07-21/rep_id:3650

Mudd, G.M. (2010): The Environmental sustainability of mining in Australia: key mega-trends and looming constraints. In: Resources Policy 35: 98–115.

Neves, A.C., Nunes, F.P., de Carvalho, F.A., Fernandes, G.W. (2016): Neglect of ecosystems services by mining, and the worst environmental disaster in Brazil. In: Natureza & Conservação 14(1): 24-27.

Priester, M. und P. Dolega. (2015): Bergbauliche Reststoffe –Teilprojektbericht ÖkoRess. *(*translated*: Residual materials in mining – Intermediary report ÖkoRess.)* Berlin. Internet: https://www.umweltbundesamt.de/dokument/oekoress-teilbericht-bergbauliche-reststoffe-dr (last visited 27.06.2016).

Rico, M. et al. (2008): Reported tailings dam failures: A review of the European incidents in the worldwide context. In: Journal of Hazardous Materials Volume 152, Issue 2: 846–852.

Saami Conference 2013. (2013): The Saami Conference, Declaration, Murmansk, 2,-4.5.2013. Internet: http://www.saamicouncil.net/fileadmin/user_upload/Documents/Julgg%C3%A1%C5%A1tusat/SR_mall-_Kuellnegk_Neark_Declaration__2013.pdf.

Schüler, D.; Buchert, M.; Ran,L.; Dittrich, S. und Merz, C. (2011): Study on Rare Earth and Their Recycling. Final Report for the Greens/EFA Group in the European Parliament and Öko-Institut. http://www.oeko.de/oekodoc/1112/2011-003-en.pdf

Tarras-Wahlberg, H.N. (2014): Social license to mine in Sweden: do companies go the extra mile to gain community acceptance? In: Mineral Economics. Volume 27, Issue 2: 143-147.

Trilling, D. (2013): All that glitters. In: New Statesman; 6/21/2013, Vol. 142 Issue 5163: 30-33.

TSM (2015): Report of the TSM Tailings Review Task Force. Recommendations to Strengthen the Mining Association of Canada’s Tailings Management Requirements and Guidance. November 2015.

UNDP (2016): Mapping Mining to the Sustainable Development Goals: A Preliminary Atlas. http://unsdsn.org/wp-content/uploads/2016/01/160115-Atlas_full.pdf (last visited 13.07.2016).

UNEP (2010): Sick Water? The Central Role of Wastewater Management is Sustainable Development. A Rapid Response Assessment. United Nations Environment Programme, UN-HABITAT, GRID-Arendal. Internet: http://www.unep.org/pdf/SickWater_screen.pdf (last visited 18.07.2016).

Unger, C., Lechner, A.M., Glenn, V., Edraki, M., Mulligan, D.R. (2012): Life-of-Mine Conference 2012 Mapping and Prioritising Rehabilitation of Abandoned Mines in Australia. Internet: http://www.cmlr.uq.edu.au/filething/get/18451/LOM%20Paper%20Unger%20et%20al%20July%202012-1.pdf (last visited 01.07.2016).

UNIDO (2013): UNIDO and Mercury. Internet: https://www.unido.org/fileadmin/user_media_upgrade/What_we_do/Topics/Resource-efficient__low-carbon_production/201312_mercury_final_web.pdf (last visited 27.06.2016)

Vesalon, L. and R.Creţan (2013): Mono-industrialism and the Struggle for Alternative Development: the Case of the Roşia Montană Gold-mining Project. In: Tijdschrift voor economische en sociale geografie Volume 104, Issue 5: 539–555.

Walz, R., M. Bodenheimer and C. Gandenberger (2016): Kritikalität und Positionalität: Was ist kritisch für wen – und weshalb? *(*translated: *Criticality and positionality: What is critical for whom and why?)* In: Exner, A., M. Held, K. Kümmerer (Hrsg.): Kritische Metalle in der Großen Transformation (translated: *Critical metals in the great transformation*): 19-38.

West, J. (2011): Decreasing Metal Ore Grades - Are They Really Being Driven by the Depletion of High-Grade Deposits? In: Journal of Industrial Ecology, Volume 15, Number 2: 165-168.

White, R. (2013): Resource Extraction Leaves Something Behind: Environmental Justice and Mining In: International Journal for Crime and Justice 2(1): 50-64.

Widerlund, A., Öhlander, B. und Ecke, F. (2014): Environmental Aspects of Mining. Mining and Sustainable Development. Internet: http://www.ltu.se/cms_fs/1.124549!/file/rapport%20Environmental%20Aspects%20of%20mining_low.pdf (aufgerufen am 15.05.2016)

Winde, F. (2013): Uranium pollution of water – a global perspective on the situation in South Africa. Internet: http://dspace.nwu.ac.za/bitstream/handle/10394/10274/Winde_F.pdf?sequence=1&isAllowed=y (last visited 01.07.2016).

Wolkersdorfer, C. und R. Bowell (2005): Contemporary Reviews of Mine Water Studies in Europe. In: Mine Water and the Environment 24.

World Bank (2016): Total Natural Resources Rent (%). Internet: http://data.worldbank.org/indicator/NY.GDP.TOTL.RT.ZS (last visited 19.07.2016).

Yrjö-Koskinen (2016): Introduction to the Finnish Network for Sustainable Mining. Internet: http://www.osce.org/pc/218376?download=true (last visited 19.07.2016)

Project Background

The Strategic Dialogue on Sustainable Raw Materials for Europe (STRADE) addresses the long-term security and sustainability of the European raw material supply from European and non-European countries.

Using a dialogue-based approach in a seven-member consortium, the project brings together governments, industry and civil society to deliver policy recommendations for an innovative European strategy on future EU mineral raw-material supplies.

The project holds environmental and social sustainability as its foundation in its approach to augmenting the security of the European Union mineral raw-material supply and enhancing competitiveness of the EU mining industry.

Over a three year period (2016-2018), STRADE shall bring together research, practical experience, legislation, best practice technologies and know-how in the following areas:

1. A European cooperation strategy with resource-rich countries
2. Internationally sustainable raw-material production & supply
3. Strengthening the European raw-materials sector

Project Identity

Project Name Strategic Dialogue on Sustainable Raw Materials for Europe (STRADE)

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