Complementarity of social and environmental indicators and risks. An example of the mining industry

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Abstract

Assessing sustainability across life cycles is a complex issue which addresses environmental, social and economic dimensions. To get to an inclusive result, these dimensions need to be evaluated in combination. It is assumed that many environmental, social and economic aspects influence or depend on each other in ways that might not be evident at first glance. This work focuses on the first two aspects and aims at exploring how environmental and social Life Cycle Assessment (e- and s-LCA) complement and sometimes overlap with each other. The research looks at different dimensions like impacts, hotspots and risks and is applied to a specific case study of the mining sectors. It is carried out in the context of the ITERAMS (Integrated Mineral Technologies for More Sustainable Raw Material Supply) H 2020 project, which examines and validates a method to isolate process waters completely from the adjacent water systems, hence aiming at saving water and water pollution.

A first screening was performed analysing representative mining processes related to three different countries (Finland, Portugal and South Africa). For the social screening, the Product Social Impact Life Cycle Assessment Database (PSILCA) was used, identifying potential social risks regarding specific indicators at first and detecting major contributing processes afterwards. For the environmental screening, ecoinvent and EXIOBASE were used as databases and different impact assessment methods were selected to obtain a comprehensive overview.

Elaboration of results from this first LCA screening shows that there is a number of aspects and risks that are relevant for their impacts on both society and environment. In particular, the screening revealed the significance of water, and related indicators, for the mining activity. From an environmental point of view, water consumption and withdrawal clearly affect resource depletion. In social terms, industrial water use might have negative impacts on the livelihood of local communities that depend on local water reserves. Beside water use, other interdependencies between social and environmental dimensions were investigated.

The work shows that several issues of the mining sector are of both environmental and social relevance. This means that social and environmental LCA can complement each other to detect hotspots and major risks. Therefore, it is useful to discuss if the two analyses should always be conducted together, if E-LCA can offer answers to social topics and vice-versa.

Keywords*: social LCA, LCA, complementarity, risks, mining sustainability*

Introduction

Assessing sustainability across life cycles is a complex issue which addresses environmental, social and economic dimensions. To get to an inclusive result, these dimensions need to be evaluated in combination. It is assumed that many environmental, social and economic aspects influence or depend on each other in ways that might not be evident at first glance. This work focuses on the first two aspects and aims at exploring how environmental and social Life Cycle Assessment (e- and s-LCA) complement and sometimes overlap with each other. The research question is applied to mining, a controversial industry with great economic potential and positive effects for local employment, but also risk of significant environmental impacts.

The common perception linked to the mining industry is negative from both social and environmental points of view. In social terms (Tuusjäarvi 2013), mining can increase the employment rate in the region, gaining acceptance if local people are hired. On the other hand, according to the Finnish programme “Sustainable Acceptable Mining” (Wessman 2014, 2016), local communities may complain as community costs (infrastructure, day care, and housing for workers) increase. Furthermore, establishing a new mine site may cause the transfer of workforce from other sectors. The negative perception of mining is often linked to a risk of degradation of the quality of the local environment and feelings of insecurity. In particular, in Nordic Countries (e.g. Finland) the rapid growth of this sector has raised the fear of negative effects on other national business sectors, for instance nature tourism.

One of the main issues from an environmental point of view is referred to risks for water ecosystems (Northey 2016), under threat from heavy metal leakage, acid mine drainage (AMD), and impacts on climate change due to energy usage and related GHG emissions (Norgate 2010). Tailings and waste-rock management is another complex topic (European Commission 2007).

Furthermore, it is interesting to define in what way environmental and social LCA complement each other regarding impacts, hotspots and risks when referring to a specific case study. Therefore, relevant aspects for environment and society were investigated within the ITERAMS (Integrated Mineral Technologies for More Sustainable Raw Material Supply) H 2020 project, which examines and validates a method to isolate process waters completely from the adjacent water systems, hence aiming at saving water and water pollution.

Approach

A first screening was performed to identify relevant social and environmental indicators, potential impacts and hotspots. Therefore, representative mining processes related to three different countries (Finland, Portugal and South Africa) were analysed using the LCA software openLCA.

For the social screening, the PSILCA database was used, a transparent database containing comprehensive generic inventory information for almost 15,000 industry sectors and commodities in 189 countries. Social impacts can be assessed by 65 indicators addressing 19 different categories. Regarding these indicators, data is provided as risks by a scale ranging from no/ very low risk to very high risk. Furthermore, risks are quantified by a so-called activity variable, in this case worker hours. This measure allows to determine the relative significance of a process – and thus the associated risks – in a product system. Table 1 includes the parameters used to assign six levels of risk to the different social indicators. Characterization factors are applied for the calculation, increasing exponentially with the risk assessment. Results are finally expressed in medium risk hours.

For the environmental screening, ecoinvent and EXIOBASE were used as databases. Furthermore, different impact assessment methods were selected to obtain a comprehensive overview, namely ILCD, ReCiPe, CML baseline, Boulay et. al (2011) and EXIOBASE.

As for the choice of databases, the social one was selected for its potential to deliver results referred to major societal stakeholders (e.g. workers, local community and society); on the other side, environmental databases can offer impact assessment from more generic to very specific environmental issues, such as different water related impacts which are of major concern for ITERAMS. The following steps were followed for the first analysis of potential social and environmental risks and impacts, and their complementarity:

- Processes that best describe the mining activities and issues addressed by ITERAMS were selected in the mentioned databases.
- For the environmental screening, generic data from databases were analysed and compared with specific data given for ITERAMS. Afterwards, results were calculated to detect major contributing processes. In addition, differences and similarities in the impacts for the three countries subject of study were considered.
- For the social screening, potential social risks were first identified by those indicators assessed by high or very high risk, as reported by mining-related processes already available in the database. Afterwards, results were calculated for the selected processes and their pre-chains to assess overall impacts and detect social hotspots. A comparison with other industries in the country helped to identify especially relevant risks.
- Together with the interpretation of results, these were also compared to each other. This way, complementarity and overlapping between social and environmental LCA aspects could be outlined. Secondary literature research helped to classify the results and put them into context, especially regarding local and geographic characteristics and relevant aspects inherent to the mining industry (e.g. water and ore extraction).

Results and interpretation

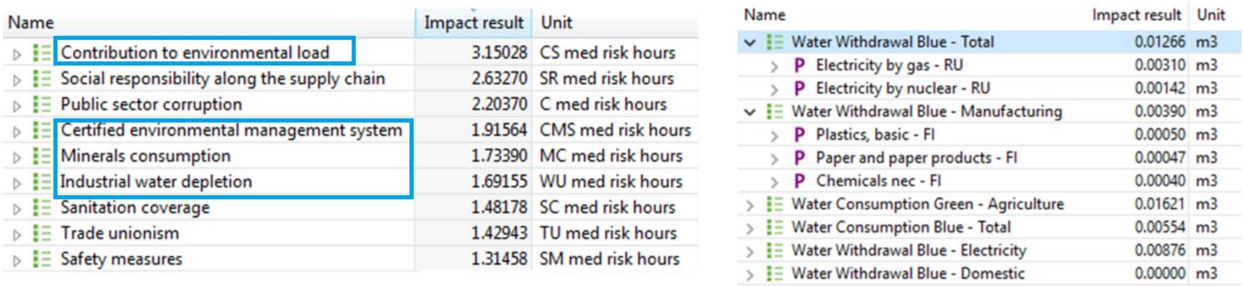
Elaboration of results from this first LCA screening shows that there is a number of indicators that are relevant for their impacts on both society and environment. Arising from investigation of results, the table below contains the impact categories which provide a complementary view on the topic. This means that PSILCA reports on some common environmental indicators with social consequences. In the same way, environmental databases show how related problems can have an impact on society.

Table 1: Main impact categories and indicators with potentially high consequences both on society and environment, addressed by social and environmental screening carried out in the context of ITERAMS.

Social screening (PSILCA)				
Category	Subcategory	Indicator	Unit	Risk assessment
Local community	Access to material resources	Level of industrial water use (related to total withdrawal or to actual renewable resources)	y, %	risk: 0≤y<10 very low; 10≤y<20 low; 20≤y<30 medium; 30≤y<40 high; 40≤y very high
		Extraction of industrial and construction minerals	y, t/cap	risk: 0≤y<2,5 very low; 2,5≤y<5 low; 5≤y<10 medium; 10≤y<15 high; 15≤y very high
		Extraction of ores	y, t/cap	risk: 0≤y<5 very low; 5≤y<10 low; 10≤y<15 medium; 15≤y<20 high; 20≤y very high
		Certified environmental management systems (CEMs)	y, # per 10,000 employes	risk: 100≤y very ; 10≤y<100; 1≤y<10 medium; 0.3≤y<1 high; y< 0,3 very high
	Safe and healthy living conditions	Pollution level of the country	y, Index value	risk: y<20 very low; 20≤y<40 low; 40≤y<60 medium; 60≤y<80 high; y>80 very high
		Contribution of sector to environmental load	y, kg, emission to air, total	risk: 0≤y<1E-7 very lowk; 1E-7≤y<1E-6 low; 1E-6≤y< 1E-5 medium; 1E-5≤y<5E-4 high; y> 5E-4 very high
		CO2 emissions total	y, kg, emission to air, total, CO2 equiv.	risk: 0≤y<1E-5 very low; 1E-5≤y<1E-4 low; 1E-4≤y< 1E-3 medium; 1E-3≤y<1E-2 high; y>1E-2 very high
Environmental screening				
Database	Assessment method	Indicator	Unit	Complementarity with social LCA
ecoinvent	ILCD	Resource depletion - water	m^3	Level of industrial water use
		Resource depletion – mineral, fossils and renewables	kg Sb eq.	Extraction of industrial and construction minerals
	ILCD, CML baseline, ReCiPe	Climate change	kg CO2 eq.	CO2 emissions total, Pollution level of the country
	ReCiPe	Water depletion	m^3	Level of industrial water use
		Metal depletion	Kg Fe eq.	Extraction of ores
EXIOBASE	EXIOBASE	Water Consumption Blue	m^3	Level of industrial water use
		Water Withdrawal Blue	m^3	Level of industrial water use

Results of the screening show the significance of water, and related indicators, for the mining activity. From an environmental point of view, water consumption and withdrawal clearly affect resource depletion. Furthermore, main driver for the mentioned impact categories is often electricity production for the three countries subject of study. On the other hand, results of the social screening reveal the significance of water use in mining by the indicator "level of industrial water use". This indicator represents "the quantity of freshwater, desalinated water and treated wastewater withdrawn for industrial purposes" related to total water withdrawal and to total actual renewable water resources (Eisfeldt 2017). Therefore, it is possible to consider the importance of industrial water use compared to other water uses, but also the pressure on the renewable water resources. Furthermore, it is assumed that high levels of water withdrawal are associated with high levels of water pollution that are linked to different risks for local communities. These risks include health problems, destruction of local economic structures, for instance agricultural practices, and an overall deterioration of quality of life. According to the dependence on local water reserves, vulnerability of local communities can increase at various levels with the use of industrial water.

Water use in the mining sector is a macroscopic aspect where social and environmental assessment complement each other. However, there are more indicators where this interdependency is relevant (UNEP/SETAC 2013). For instance, Figure 1 shows results of a social and environmental screening for two mining-related sectors in Finland as available in two databases for social and environmental assessment.



Name	Impact result	Unit
Contribution to environmental load	3.15028	CS med risk hours
Social responsibility along the supply chain	2.63270	SR med risk hours
Public sector corruption	2.20370	C med risk hours
Certified environmental management system	1.91564	CMS med risk hours
Minerals consumption	1.73390	MC med risk hours
Industrial water depletion	1.69155	WU med risk hours
Sanitation coverage	1.48178	SC med risk hours
Trade unionism	1.42943	TU med risk hours
Safety measures	1.31458	SM med risk hours

Name	Impact result	Unit
Water Withdrawal Blue - Total	0.01266	m3
P Electricity by gas - RU	0.00310	m3
P Electricity by nuclear - RU	0.00142	m3
Water Withdrawal Blue - Manufacturing	0.00390	m3
P Plastics, basic - FI	0.00050	m3
P Paper and paper products - FI	0.00047	m3
P Chemicals nec - FI	0.00040	m3
Water Consumption Green - Agriculture	0.01621	m3
Water Consumption Blue - Total	0.00554	m3
Water Withdrawal Blue - Electricity	0.00876	m3
Water Withdrawal Blue - Domestic	0.00000	m3

Figure 1: Results for different impact categories in PSILCA (left) and EXIOBASE (right) referred respectively to product system "Mining of metal ores" and "Copper ores and concentrates" in Finland.

Investigating these interdependencies, extraction of ores and fossil has an impact on resource depletion, limiting the access to material resources for local community because of commercial or industrial activities in their regions. Together with the environmental burden of destruction of material resources, this indicator is relevant as there are communities which base their life and economy on that and can then incur poverty, resettlements and local conflicts. Finally, CO_2 and other emissions can also have consequences both on the environment, expressed by the impact category "Climate change", and on the society, affecting healthy living conditions of local populations.

As for a critical reflection on data used, it is important to assure transparency and traceability. Thus, data quality has been considered when identifying risks and interpreting results. Another possible reason of uncertainty might be linked to statistical data taken from several different sources (ILO 2017) to shape the information in databases. In this case, the risk of creating gaps or poor quality data should be taken into account.

Conclusions and future developments

The work shows that several issues related to life cycle sustainability of the mining sector are of both social and environmental relevance. This means that social and environmental LCA complement and influence each other by triggering and reinforcing risks and impacts on mid-point categories. Further, a complementary analysis might also be instructive while detecting hotspots, e.g. those processes where environmental and social risks are strongly occurring, or associated with risks with high consequences for the other dimension. The latter investigation has not been carried out so far within the project. However, it seems to be an interesting point for future research.

However, it is difficult for social and environmental dimensions to overlap completely as they express different consequences and characters, although they can investigate the same problems. Therefore, it is useful to discuss if s-LCA and e-LCA should generally be conducted together, either in parallel or in a combined method. If this is not possible for any reason, it appears to be beneficial to complement e-LCA by an assessment of its social impacts because most environmental risks and emissions end up in impacts on societal stakeholders (although the emissions are triggered by human activities). The analysis results can be useful when decisions need to be taken for product design, benchmarking and planning. In the described project, they provide valuable input for the validation of the new water efficiency system.

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