TOWARDS SUSTAINABLE DEVELOPMENT IN THE COPPER MINING INDUSTRY:
NEW APPROACHES FOR STAKEHOLDER PARTICIPATION AND RESOURCE MANAGEMENT

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ABSTRACT

In the present work, a production profile of the world copper mining industry is elaborated. Facts and figures concerning ore production and waste generation associated with world-wide copper mining activities are presented. Following this, sustainable development challenges facing the copper mining industry are resumed. Major economic, social, and environmental effects associated with copper mining activities will be identified. After this, a new concept for implementing advanced sustainable development strategies in the copper mining business will be elaborated. The framework for a core set of indicators will be proposed in order to measure progress towards sustainable development. Particular emphasis will be placed on the key issue of stakeholder participation during the corporate problem-solving process. The paper will close with a short discussion and some recommendations for further action.

INTRODUCTION

Copper is of vital interest to world economy. It is used in a variety of important applications. Major use areas of this base metal in Europe include building construction (39.5 %), electrical & electronic products (37.5 %), transportation equipment (7.5 %), industrial machinery & equipment (9 %), as well as other consumers and general products (6.5 %) [ICSG-1999]. Copper is explored and mined throughout the world in more than 50 countries. Major copper ore extracting countries are Chile (29 %) and the USA (17 %). Copper ores are usually extracted from the ground, crushed, and then processed in order to obtain an enriched copper concentrate. Alternatively, copper can be leached in-situ from the ore. The minerals can be further processed into metal either by smelting and refining or by solvent-extraction and electro-winning (SX/EW). Despite the fact that copper can be recycled without loosing its chemical or physical properties, there is a growing need for primary copper. As can be seen in Figure 1, mining production of copper has significantly increased during the last decades. The continued supply of copper is essential for the global economic progress. Besides this, copper is an important contributor to GNP and foreign exchange earnings of respective “mineral” host economies especially in the southern hemisphere (e.g. Chile, Peru, and Papua New-Guinea).

Figure 1: World copper mining production [World Bureau of Metal Statistics-1999]

The presented results form an integral part of research undertaken by the sub-programme SP 2 "Extraction, Processing and Disposal" of the Collaborative Research Center 525 (CRC 525) "Resource-orientated analysis of metallic raw material flows" located at Aachen University of Technology (Germany). The long-term goal of this research program, which is funded by the Deutsche Forschungsgemeinschaft (DFG), is the identification of options for resource-sensitive supplying and processing of metallic raw materials considering technical developments and economic and ecological aims. An integrated resource management system for important metallic raw materials is to be developed and tested by the CRC 525 regarding the applicability of this framework in order to provide useful and efficient tools for decision makers. The first phase of the project (1997 - 1999) was focused on aluminium. In the second
phase (2000-2002) copper is included into the analysis of metallic raw materials. [CRC 525-2000a]

In this context, the Institute of Mining Engineering I (SP2) is assessing global copper mining activities and associated resource uses and impacts. Furthermore, available and foreseeable organisational and technological innovations are analysed with respect to their potential contribution towards sustainable development.

RESULTS

Profile of the world copper mining industry

Aiming at analysing the state-of-the-art and prospecting future trends, data on more than 600 copper mining sites have been collated, compiled and generated in the database “COPE” of the Institute of Mining Engineering I. This database gathers information on both producing sites and numerous projects in construction or feasibility status. Data sheets include, among others, site-specific information on mineable reserves, waste and ore production, mining methods, backfill and disposal technologies, land use and transport systems as well as operating and capital cost of all major copper mining activities. Table I and Figure 2 show selected figures as results generated by a database-report. For this inventory of the status quo data sets of almost 250 producing sites representative for 96% of copper mining production in 1998 have been analysed.

Table 1: Copper mining in 1998 [CRC 525-2000b]

<table>
<thead>
<tr>
<th>Copper mining in 1998</th>
<th>Mt</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Waste</td>
<td>2,487</td>
<td></td>
</tr>
<tr>
<td>Waste - Mill (O/P)</td>
<td>2,007</td>
<td>81%</td>
</tr>
<tr>
<td>Waste - Leach (O/P)</td>
<td>480</td>
<td>19%</td>
</tr>
<tr>
<td>Total Ore Production</td>
<td>2,039</td>
<td></td>
</tr>
<tr>
<td>Ore Production (O/P)</td>
<td>1,646</td>
<td>81%</td>
</tr>
<tr>
<td>Ore Production (U/G)</td>
<td>393</td>
<td>19%</td>
</tr>
<tr>
<td>Ore Production - Mill</td>
<td>1,414</td>
<td>69%</td>
</tr>
<tr>
<td>Ore Production - Leach</td>
<td>625</td>
<td>31%</td>
</tr>
<tr>
<td>Total Contained Copper</td>
<td>11.7</td>
<td></td>
</tr>
<tr>
<td>Total Contained Cu (O/P)</td>
<td>8.5</td>
<td>73%</td>
</tr>
<tr>
<td>Total Contained Cu (U/G)</td>
<td>3.2</td>
<td>27%</td>
</tr>
<tr>
<td>Cu production - Mill</td>
<td>9.7</td>
<td>83%</td>
</tr>
<tr>
<td>Cu Production - Leach</td>
<td>2.0</td>
<td>17%</td>
</tr>
</tbody>
</table>

The amount of copper produced by leaching and electro-winning has significantly increased in the last decade. Whereas in Africa, Europe, and Oceania underground mining (“U/G”) continues to play an important role, in Asia and the Americas copper ore is predominantly mined in open pits (“O/P”) (Figure 2).

Figure 2: Distribution of copper mining production

Copper mining and sustainable development

A consistent, widely accepted and practice-oriented definition of sustainable development in the context of minerals and metals has not emerged, yet. According to the Minerals and Metals Policy of the Government of Canada, as a point of entry sustainable development in the context of minerals and metals can be considered as incorporating the following elements:

- “finding, extracting, producing, adding value to, using, re-using, recycling and, when necessary, disposing of mineral and metal products in the most efficient, competitive and environmentally responsible manner possible, utilizing best practices;
- respecting the needs and values of all resource users, and considering those needs and values in government decision making;
- maintaining or enhancing the quality of life and the environment for present and future generations; and
- securing the involvement and participation of stakeholders, individuals and communities in decision-making.” [MMPC-1996]

At present, a special focus of public perception is placed on environmental and social consequences of mining, especially after the recent tailings spills in Spain and Romania. Despite this, it can be stated that metal mining companies have undergone considerable change over the past decades in order to stay competitive. Major investments and change of technology have
improved economic, social, and environmental performance at many mining sites.

Considering the scale of copper mining activities, it is not surprising that they continue to have a wide range of social, environmental, and economic impacts. The effects can be both beneficial or detrimental to the surrounding local communities. Some of the key challenges for the copper mining industry can be grouped under the following headings:

- **Globalisation**: global harmonisation of technical standards and regulatory frameworks, increase of productivity, advanced supply chain pressures.
- **Resource use**: reserve recovery, ore dilution, process recovery, energy efficiency, fresh water use, acid loss.
- **Waste and tailings management**: prevention and mitigation of releases and acid rock drainage, disposal and backfill of waste and tailings.
- **Emissions**: used air from fuel combustion, fumes, dust, noise, mine and process sewage.
- **Mine closure**: remediation of mine and waste facilities, post-mining land use, diversification of redundant workforce.
- **Social impact assessment**: distribution of benefits to the local communities, impact on well-being and lifestyle, impact on indigenous population.

These challenges need to be addressed within a corporate strategy in accordance with the vision of sustainable development.

**Corporate Strategy**

The above headings have become a critical concern for mining companies, governments and other stakeholders. Growing environmental and social concerns will profoundly shape the copper mining business in the near future. In order to cope with the new business environment, the companies will need to rely on appropriate tools for measuring, reporting, and evaluating progress. Such a set of tools and procedures should be based on existing management systems but will surely have to face the need for advanced corporate responsibility and stakeholder management.

Whereas the 70's and 80's were widely characterised by end-of-pipe strategies, in the last decade effective management systems for prevention and mitigation of impacts have emerged. A remarkable number of global players is already committed to continual environmental improvement at their mining operations throughout the world. Mining companies are preparing for integrating sustainable development into business strategies. In a few companies there has recently been a shift towards process and product stewardship practices.

The precautionary approach of the early 90's may be complemented by a participatory approach considering the long term interests and needs of the stakeholders. This approach requires both the addressing of concrete and relevant challenges as well as a consistent and transparent process through which continuous learning and revising can be pursued and demonstrated (Figure 3).

1. **End-of-Pipe**
   - “regulatory compliance”
2. **Management**
   - “precautionary approach”
3. **Stewardship**
   - “participatory approach”

![Figure 3: Corporate strategies](image)

**Framework and core set of indicators**

In a recent communication of the European Commission broad policy lines for promoting sustainable development in the EU non-energy extractive industry have been set. In this policy is stated that “important progress could be realised through the development of environmental performance indicators in order to establish a detailed assessment of the industry’s environmental performance, to monitor improvements and to differentiate sub-sectors and locations, as influenced by geological conditions and the local ecosystem.” [Commission-2000]

Complex frameworks and sets of sustainable development indicators have been developed by national governments (i.e. UK, Germany, The Netherlands, etc.) and international organisations (World Bank, UNO). These systems do not consider a number of significant mining-specific aspects and highlight a number of issues with less relevance for mining operations.

Some international copper mining companies already report on environmental and social issues [e.g.
A unique, consistent and widely accepted methodology has not emerged, yet. The vast majority of copper mining companies does not report on environmental and social issues relying on measurable and verifiable indicators.

In order to promote international harmonisation to corporate reporting the Global Reporting Initiative pursues the development of widely applicable sustainability reporting guidelines through a multi-stakeholder process of open dialogue and collaboration. These guidelines do not reflect sector-specific issues.

Aiming at assessing the performance and indicating the directions for further improvement, the implementation of a consistent, reliable and applicable indicator system is crucial. This system can be the starting point for further participatory approaches within a broader framework of an integrated resource management system.

Since sustainable development and mining covers a very wide range of complex issues, an organising framework is essential for highlighting key areas and priorities as well as links between issues and indicators. In the last decade, a number of models have been proposed for developing and organising indicators as well as illustrating links between issues. The Pressure-State-Response-Framework (PSR) was originally developed by OECD for the sectoral level and is a useful tool in the context of environmental and societal performance reviews. It is based on a concept of causality: Human activities exert "pressures" on the environment and change its quality and the quantity of natural resources ("state"). Society responds to these changes through environmental, general economic and sectoral policies ("response").

Here, three broad types of indicators are distinguished with respect to mining companies and their corresponding contribution to sustainable development:

1. Indicators of pressure (i.e. energy input, land use, air emissions, etc.): These efficiency and performance indicators describe pressures from mining processes exerted on economy, environment, and society.

2. Indicators of state (i.e. scarcity of water resources, regional unemployment rate, etc.): State indicators relate to the contribution of the mining activity to well-being of local communities and affected environment as well as to regional development and competitiveness.

3. Indicators of response (i.e. environmental and social expenditures, coverage of monitoring and measurement, etc.): Response indicators are mostly performance indicators that illustrate to what degree a company or a sector is responding to environmental and social changes and concerns. They also include indicators referring to goal-oriented actions for prevention or mitigation of impacts.

Figure 4: Proposed PSR-framework for mining companies

In the PSR-framework presented in Figure 4 distinction is made between the local scale of the mining operation, the regional scale of surrounding communities and the global market place of the copper product. Each level requires a specific core set of indicators reflecting the corresponding needs and interests of affected environment and stakeholders involved. The PSR-approach is illustrated for the heading "resource use" on the local ("pressure" and "response") and regional level ("state") in Table II.
Table II: Measuring resource use and efficiency in the context of copper mining

<table>
<thead>
<tr>
<th>Topic</th>
<th>Pressure</th>
<th>State</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal resources</td>
<td>production, copper production</td>
<td>inventory of regional proven &amp; probable reserves</td>
<td>reserve recovery, ore dilution, process recovery</td>
</tr>
<tr>
<td>Energy use</td>
<td>primary energy input</td>
<td>sectoral share of energy use in region</td>
<td>energy efficiency, share of renewable energy</td>
</tr>
<tr>
<td>Land use</td>
<td>actual land use by mining</td>
<td>regional land use characteristics, naturalness of vicinity</td>
<td>share of used area remediated to date</td>
</tr>
<tr>
<td>Water use</td>
<td>fresh water input</td>
<td>state of regional water scarcity</td>
<td>water recycling rate</td>
</tr>
<tr>
<td>Waste generation</td>
<td>non-product-output (NPO)</td>
<td>state of regional waste disposal capacity</td>
<td>share of hazardous waste, share of NPO to process or market</td>
</tr>
</tbody>
</table>

Stakeholder participation

As previously mentioned, the sustainable development challenges facing mining operations are associated with the stewardship principle. Turning this concept into practice requires substantial co-operation of mining companies and key stakeholders who share common views and concerns. This shift in decision-making should be based upon a participatory approach that includes advanced corporate responsibility and the consideration of long-term needs and interests of key stakeholders. Furthermore, it should be respected that social and economic benefits deriving from the exploitation of limited regional mineral resources cannot be consumed by the present generation alone.

The issues to be tackled can be grouped under the key settings of "process stewardship", "regional stewardship", and "product stewardship".

There are four stakeholder categories that need to be addressed by a mining company:

- direct internal stakeholders (e.g.: labour force, corporate management);
- indirect internal stakeholders (e.g.: shareholders, financial organisations);
- direct external stakeholders (e.g.: local community, local government);
- indirect external stakeholders (e.g.: international NGO, scientific community).

Four grades of stakeholder management practice can be identified:

- negligence of conflicts and concurrent interests;
- information and reporting to interested parties;
- prior consultation and feedback analysis;
- participation of key stakeholders in the decision-making process.

An exemplary organisational structure of stakeholder participation is presented in Figure 5.
supporting the decision-making process

There are various ways how stakeholder groups can be involved in the corporate decision-making process. An advanced stakeholder participation in the corporate problem-solving process is illustrated in Figure 6.

There is no doubt, however, that the participation of stakeholders in the corporate decision-making progress is still a very difficult issue to handle. The corporate strategy needs to go far beyond passive responding to social obligations. Forging enhanced partnerships should rather be based upon an active commitment towards social responsibility or, even better, social responsiveness.

Figure 6: Exemplary participation of stakeholders in the problem-solving process

DISCUSSION

Corporate social responsibility in minerals development on a path towards sustainable development is possible. But it is not happening on a broad scale yet and rarely within one mining project, across the board. Future resource management strategies addressing the issue of sustainable development will have to rely on a consistent framework and a core set of key indicators. In order to cope with the aforementioned challenges copper mining companies need appropriate management tools to evaluate and communicate the full extent of environmental and social performance of their business activities.

The identification of priority issues in terms of quality, quantity and stakeholder preferences leads to a significant reduction of indicators and improves transparency and practicability of the system. The resulting core set of indicators can be used in a number of applications.

In Figure 7 scale, scope and key tool for selected applications are illustrated.

Figure 7: Application of the core set of indicators

The sustainable development challenges facing the copper mining industry require a comprehensive, integrated and multidisciplinary approach based on shared decision-making and a reliable information base. Further research needs to be undertaken in order to promote progress towards sustainable development in mining:

- establishing guidelines for relevant and credible reporting;
- designing appropriate integrated chain management strategies;
- developing a validated core set of sustainable development indicators; and
- advancing the existing approaches for stakeholder participation.

The integrated approach of the CRC 525 is offering opportunities to address some of these challenges by supporting sustainable development-based decision-making.

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