Sustainability in Industrial Small Scale Mining (ISM)

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The project: Is Industrial Small Scale Mining a sustainable alternative?  
- Motivation

- Raw materials always have been acknowledged as crucial for any kind of development (paradigm):
  - Catch-up development (50s and 60s)
  - Eco-development (70s and 80s)
  - Sustainable development (80s to present)
  [- Globalisation (late 90s to present) ?]

- Still, non-renewable raw materials never have been included in these development paradigms, because:
  - non-renewable raw materials are not renewable
  - non-renewable raw materials are not substitutable (to 100%)
  - non-renewable raw materials are provided only by nature
  - non-renewable raw materials’ extraction means permanent impact on ecological systems

No strategy for the raw materials sector, only a problematization!
The project: Is Industrial Small Scale Mining a sustainable alternative?  
- Important existing Initiatives and Players

Raw Materials Industry:

MMSD: The Mining, Minerals and Sustainable Development Project (since 1999)
EAA: European Aluminium Association (since 1998)
CSI: Cement Sustainability Initiative (since 1999)
GRI/ICMM: Global Reporting Initiative/International Council Mining Metals (since 2003)

Politics:

Supranational: EU  National: Canada
World Bank…  USA
Australia ...

Product Stewardship: Green Lead™; MCEP: Mining Certification Evaluation Project, Kimberley Process
Eco-Concepts: Zero waste, MIPS, Ecological Rucksack, Factor 4, Factor 10, Factor X, Dematerialization...

Focus only on Large Scale Mining or Artisanal Small Scale Mining!
"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

It contains within it two key concepts: the concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs."

What about the Sustainability of Industrial Small Scale Mining (ISM)?

What is Industrial Small Scale Mining?

What is the actual or potential contribution of ISM to Sustainable Development?

Is ISM a viable and sustainable alternative to LSM and ASM?

Tasks:

- Definition of Industrial Small Scale Mining
- Assessment and Analysis of existing ISM operations
- Assessment and Analysis of reserves suitable for ISM
- Development of “the” sustainable ISM operations
- Development of Sustainability Indicators for ISM
- Development of a Sustainability Assessment System for ISM

Initial Research on Gold mining
Mostly Small Scale Mining is used conterminuously with “Artisanal and Small-Scale Mining” (ASM)

There is no acknowledged definition for ASM

In „small scale mining“ operations commonly less than 50 persons per operation are employed, in some uncommon cases also some thousand (e.g. the “Garimpeiros” in Brazil).

“Operations without

  • license or official control
  • occupational safety
  • environmental standards.”  \cite{Hentschel, Wetzenstein}

Poorly mechanized and not using modern production technologies and methods

Source: www.scielo.br, 2007
**Medium-Scale Mining (MSM)** is rarely used in literature. It describes “private” mining operations that are licensed by or at least declared to official authorities (e.g., in India). In Chile, mining operations with a ROM (run of mine production) of up to 2,000 t per day are defined as “Medium-Scale Mining” operations.

**Large-Scale Mining (LSM)** is used as self-explaining term.

Initial working hypothesis/definition for ISM:

Industrial Small Scale Mining refers to high technology or highly mechanized/automated extraction of small, high-grade deposits that due to their small size – in combination with geological, depth and other constraints – are not economically exploitable with large-scale mining operations.
SME definition by EC (DG Enterprise, 2007)

<table>
<thead>
<tr>
<th>Enterprise category</th>
<th>Head-count</th>
<th>Turnover or</th>
<th>Balance sheet total</th>
</tr>
</thead>
<tbody>
<tr>
<td>medium-sized</td>
<td>&lt; 250</td>
<td>≤ € 50 million</td>
<td>≤ € 43 million</td>
</tr>
<tr>
<td>small</td>
<td>&lt; 50</td>
<td>≤ € 10 million</td>
<td>≤ € 10 million</td>
</tr>
<tr>
<td>micro</td>
<td>&lt; 10</td>
<td>≤ € 2 million</td>
<td>≤ 2 million</td>
</tr>
</tbody>
</table>

Current project-result for ISM:

In-depth assessment of small and medium-sized gold mining companies showed that a maximum number of 200 employees for ISM operations is a characteristic figure.
Definition of ISM: Criteria

- Equipment Productivity (EP) defined as quotient of daily production and installed power, measured in t/kW
- Available Equipment (AE) defined as installed power per worker (WF), measured in kW/WF
- Absolute installed Power (P), measured in kW
- Run-of-Mine (ROM), measured in t/d oder t/a
- Feed, measured in t/d oder t/a
- Existing legal license [Yes/No-Criterion]
- Investment Volume (without beneficiation), measured in Euro
- Exploration and reserves calculation
WP = AE * EP

WP = Work Productivity, t/WF
EP = Equipment Productivity, in t/kW
AE = Available Equipment, in kW/WF

Work productivity correlates at least in principle with the available equipment. Example: German lignite operations

<table>
<thead>
<tr>
<th>Year</th>
<th>1888</th>
<th>2001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed Power of equipment used</td>
<td>3 kW per worker</td>
<td>300 kW per worker</td>
</tr>
<tr>
<td>Work productivity</td>
<td>3-4 t per manshift</td>
<td>200-300 t per manshift</td>
</tr>
</tbody>
</table>
## Definition of ISM operations on Gold

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Delimitation ISM to ASM</th>
<th>Delimitation ISM to LSM</th>
<th>Necessary/Sufficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration and reserves calculation</td>
<td>Yes</td>
<td>Not applicable</td>
<td>Necessary</td>
</tr>
<tr>
<td>Legal License [yes/no]</td>
<td>Yes</td>
<td>Not applicable</td>
<td>Necessary</td>
</tr>
<tr>
<td>Needed degree of performance in the following criteria</td>
<td>At least one of the following criteria accomplished</td>
<td>At least two of the following criteria accomplished</td>
<td></td>
</tr>
<tr>
<td>Absolute installed Power</td>
<td>≥ 1.000 kW</td>
<td>≤ 7.000 kW</td>
<td>Sufficient</td>
</tr>
<tr>
<td>Available Equipment (AE)</td>
<td>≥ 20 kW/WF</td>
<td>≤ 65 kW/WF</td>
<td>Sufficient</td>
</tr>
<tr>
<td>Equipment Productivity (EP)</td>
<td>Not applicable</td>
<td>≤ 0,65 t/kW</td>
<td>Sufficient</td>
</tr>
<tr>
<td>ROM or FEED</td>
<td>Not applicable</td>
<td>≤ 2.000 t/d or 600.000 t/a</td>
<td>Sufficient</td>
</tr>
<tr>
<td>No. of Workers (WF)</td>
<td>Not applicable</td>
<td>≤ 200</td>
<td>Sufficient</td>
</tr>
<tr>
<td>Investment Volume (without beneficiation)</td>
<td>Not applicable</td>
<td>UG: ≤ 25 Mio. € O/P: ≤ 4,6 Mio. €</td>
<td>Sufficient</td>
</tr>
</tbody>
</table>
Developing a sustainable ISM operation

Based on a large number of case studies 27 ISM operation models were developed, comprehending ROM figures from 200 t/d to 14.000 t/d.

Criteria for the selection of appropriate mining method:

- Easy to mechanise
- Low initial investment
- Short payback period
- Low operational costs
- Selective mining
- Flexible in mining operation
- Individual mining processes can be separated
- Suitable for low production rates
- Suitable for broad range of production rates
- High productivity
- Suitable for backfill to reduce risk of subsidences…
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Developing a sustainable ISM operation

Example: Block Caving
not suitable for low production rate
non-selective mining
high initial investment

Not suitable for ISM:

- overhand stoping: difficult mechanisation
- underhand stoping: difficult mechanisation
- longwall mining: investment, flexibility
- block caving: investment, selectivity, not for low production rate

Preferable for ISM:

- Vertical Crater Retreat Mining: scalability, efficiency
- Cut & Fill: selectivity
- Narrow-Vein-Mining: per se
- Room/Stopes & Pillar (adapted for backfill): immediate cash flow
Developing a sustainable ISM operation: process chain analysis

- Number of units
- Power per unit [kW]
- Employees per unit
- Investment per unit [€]
- Operational cost per unit [€/h]
- Equipment Productivity [t/kW]
- Hazards for employees
- Hazards for environment
- Water consumption
- and other (case specific)
Assessment and Analysis of reserves suitable for ISM operations

Active mines: Grade vs Reserves

![Graph showing the relationship between grade (g/t) and reserves (t).]
Assessment and Analysis of reserves suitable for ISM operations

Active mines & known deposits: Grade vs Reserves

- Exploration
- Active Mines

Rendering of the data in a scatter plot format.
Development of Sustainability Indicators for ISM operations

Environmental indicators
- Land use
- Water use
- Percentage of recycled water
- Energy use
- Emission into air – Green House Gases
- Emission into air – Non-Green House Gases
- Emission into water – weighted
- Voluntary investments into environmental projects
- Reclamation and rehabilitation provision

Social indicators
- Employment
- Wages
- Annual vacation
- Working hours
- Voluntary benefits for employees
- Injuries
- Occupational health, safety and environment
- Resettled inhabitants
- Child labour
- Voluntary expenditures for social projects

Economical indicators
- Production
- Economic performance
- Rate of return
- Investment into assets
- Investment into R&D and exploration
- Taxes
- Transport Distance (Extraction to Processing)
- Annual level of damages to public infrastructure caused by mining
- Percentage of infrastructure damages remunerated by the mining company
- Provision for future infrastructure damages and for rehabilitation
Questions, Comments, Contact

German Research Foundation of Economics and Labour
http://www.dfg.de

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Further information at the Institute of Mining Engineering I under
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