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REPORTS ON SELECTED THEMES IN NATURAL RESOURCES DEVELOPMENT IN AFRICA: ARTISANAL AND SMALL-SCALE MINING AND TECHNOLOGY CHALLENGES IN AFRICA

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Abstract

The case studies reviewed in this paper indicate that there have been notable attempts to develop and deploy appropriate technology for small-scale mining in several parts in Africa. These technologies have contributed on a micro scale to improving productivity and reducing localized impacts to the environment. However, results at a macro level are less encouraging. The sector is still plagued with many problems. Several reasons could be advanced for this poor performance. They include poor understanding of the nature of the problem; the ad-hoc nature of some of the programmes launched to develop the sector; lack of funding and local infrastructure to support research, development and innovation of appropriate technology; and inadequate framework for technology diffusion and assimilation. More important however, is the fact that these attempts were isolated and very technical-oriented in nature. Other important societal and techno-economic variables were very often ignored.

While recognizing the importance of technology to improving productivity in small-scale mining, this paper suggests alternative policies to rendering the sector more sustainable. They hinge on adopting a people-focused multi-disciplinary and holistic view of artisanal and small-scale mining, centred in the recognition that it is essentially a finite and poverty-driven activity.

Keywords: Small-scale Mining; Technology; Environment; Impact; Poverty; Productivity; Sustainable; Livelihoods; Appropriate; Alternative.

Introduction

1. Despite attempts by many African countries to assist artisanal and small-scale miners and to formalize and foster growth of the artisanal and small-scale mining (ASM)[1] sub-sector, it continues to be an activity beset with problems of sustainability. These stem from an overall inadequate legal and regulatory framework and low productivity, exacerbated by the application of rudimentary and inappropriate technology, which in turn impact on capacities to generate income. Other problems include isolation from the mainstream of economic development (D'Souza, 2002), which prevents ASM from becoming a recognized sector of the economy, deleterious environmental effects[2], health (including HIV/AIDS), occupational hazards and ubiquitous socio-cultural disturbances (increased lawlessness and smuggling, heightened land use conflicts[3], widespread prostitution and alcoholism, child labour, etc.). Notwithstanding, the sub-sector attracts many people particularly in rural areas. International Labour Organisation (ILO, 1999) estimates show that out of a total of almost 13 million worldwide engaged in small-scale mining (SSM), Africa has 3 to 3.7 million people directly involved in the activity. They can be classified in four groups (Weber-Fahr, M. et al, 2001)[4], namely permanent artisanal and small-scale miners, seasonal artisanal and small-scale miners, poverty-driven artisanal and small-scale miners, and gold-rush artisanal and small-scale miners.

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[1] In this paper the terms "artisanal and small-scale mining"(ASM) and "small-scale mining"(SSM) are used with the same meaning. Similarly, the terms "miners", "artisanal and small-scale miners" and "small-scale miners" have been used interchangeably.

[2] These include land degradation and soil erosion, river siltation, destruction of riverbeds and margins particularly in alluvial mining, acid mine drainage, deforestation, unprotected mine holes, trenches and other excavations and mercury and cyanide pollution. Of these, the use of mercury for gold amalgamation is considered one of the greatest environmental and health problems caused by small-scale mining. For example, according to the Mining Environmental Management News (May 22,2003), the Evandro Chagas Research Institute in Brazil, a tropical disease centre, has found high levels of mercury contamination among newborn babies at three hospitals in the city of Itaituba, in the Amazon. About 60% of all the 1,666 babies born during 2002 in the three hospitals of the city had 80 ppm of mercury in the blood, 50 ppm above the acceptable level stipulated by the World Health Organisation. The contamination is said to have been caused by gold mining in and around the rivers of the region during the 1980s. In those years, the Itaituba area was a major gold producer. Though most mining has now ceased, the problems persist. Estimates from the Brazilian agency responsible for mineral production indicate that around 600 t of mercury was deposited in the Tapajós River, one of the biggest tributaries of the Amazon River, over a 10-year period. Most of the mercury found its way into the food chain through fish.

[3] In the IDRC home page (http://www.idrc.ca/books/899/003into.htm), see introduction to the book "Cultivating Peace: Conflict and collaboration in natural resource management " (edited by Daniel Buckles), for general discussions on conflicts over the use of natural resources.

[4] According to M. Weber-Fahr et al (Weber-Fahr et al, 2001), " permanent artisanal and small-scale miners are involved in the activity year round for most of their productive careers and they often have substantially higher incomes than they would in other activities. Similarly, seasonal artisanal and small-scale mining can be a regular, often life-long source of income, performed in the context of seasonal work. By generating above-subsistence incomes, savings from mining can be an important source of funds for developing other businesses. On the other hand, poverty-driven mining is practiced by a largely itinerant, poorly educated populace with little employment alternatives, in most cases as a result of recent loss of employment in other sectors. In this case, miners remain trapped in a low revenue earning cycle. Lastly, gold-rush type mining is often a short-term concentration of small-scale and artisanal miners, which leave their regions or traditional occupations lured by promises, which very often are not realized, of a far more lucrative activity than anything else they might be engaged in. In this category of miners, because of lack of a long-term perspective, only very few succeed."

2. In many cases, small-scale miners are attracted by the possibility of generating quick wealth in the absence of alternative income-generating activities. They usually mine high-value and low-volume minerals such as gold and precious stones, which command good prices and are easier to sell, even though lack of access to markets and related information make most miners vulnerable to exploitation by middlemen.

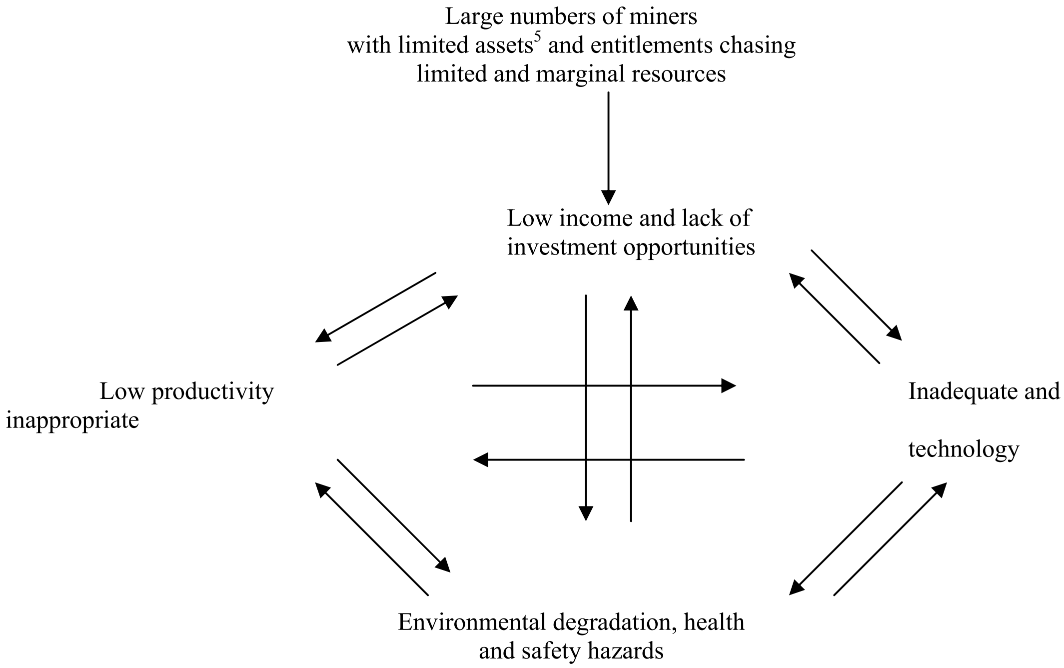
3. This paper presents a brief review of the dictates and profile of ASM and examines several programmes designed to facilitate access to technology by small-scale miners. It also identifies several technologies developed to improve the productivity of ASM operations and to reduce their impact on the environment. The emphasis is on technologies that are robust (which withstand the rigours of local environment), flexible, simple, cheap and accessible, and that have demonstrated practical results. Finally, it attempts to derive lessons, to identify some success factors, and to recommend policies and strategies for better development and dissemination of appropriate SSM technologies and to foster advances in this sub-sector in general. The case studies presented in this paper (boxes 1 to 10) are adapted from the "Compendium on Best Practices in Small-scale mining in Africa", (ECA, 2002).

Caught in a Poverty Trap

4. Increasing numbers of people have turned to SSM to seek alternative livelihoods. In many cases, this was impelled by growing economic crises, the effects of structural adjustment, particularly in sub-Saharan Africa, which increased unemployment, mine redundancies in large mine companies due to crumbling mineral prices, and decreasing rural livelihood choices, chiefly in areas affected by natural (mainly droughts and floods) and man-made disasters.

5. The United Nations Development Programme (UNDP, 1999) argues that in a given area, the increase in the numbers of artisanal and small-scale miners, with inadequate human and social capital, on limited and marginal resources, lowers productivity and income per head, which as a result affects the technology choices that miners can make. Working from a low capital and asset base, most SSM activities are of a rudimentary nature, with little mechanization (Shovels, hoes, picks and wheelbarrows are the tools commonly used). Where there is mechanization, equipment and techniques are inefficient and hazardous to the environment and to the miners. In consequence, productivity, ore recovery and yields continue to be low and income remains at subsistence level. This hinders re-capitalization and upgrading of mining operations and keeps small-scale miners in a vicious cycle of poverty (See Figure 1).

Figure 1: Artisanal Mining Poverty Trap



Adapted from UNDP (UNDP, 1999)

6. It has been further noted (UNDP, 1999) that the cycle is aggravated by legal and regulatory failures, including failure of governments to recognize and formalize the sub-sector. Because miners do not have security of tenure or access to high-quality and mineable resources, they cannot generate adequate income or use their mineral rights as security for funding or to enter into joint ventures with other more capable partners. To this, one can add poor access to financial resources caused by the reluctance of banks and other financial agencies to provide loans and other financial assistance to the unregulated ASM sub-sector. The problem has been worsened by the HIV/AIDS pandemic.

7. Increasing pressure on available resources resulting from conflicting interests has limited the capacity of governments to intervene. In a lot of cases, where they have intervened, they have not recognized the finite nature and poverty level of SSM and have focused, instead on promoting, without success, technical-oriented and isolated approaches to addressing the challenges affecting the sub-sector.

[5] These assets are of a natural (e.g. land or access to and rights to land) and social (e.g. human and social capital) nature.

Developing Environment Friendly Technologies

8. The severe nature of environmental impacts caused by artisanal and small-scale mining, requires that technology choices be made following a thorough and informed assessment process such as the environmental technology assessment (EnTA). The United Nations Environmental Programme (UNEP) ***Technical Workbook on Environmental Management Tools for Decision Analysis***[6] defines EnTA as an integrated and holistic analytical tool designed to ensure that decision-making processes at the conceptual and strategic levels related to technology selection, adoption, implementation and use are sustainable. In a phased and flexible manner, these assessments should help examine the reasons for the proposed or related technologies; identify guiding policies and other standards; analyse and describe technology options or alternatives; investigate or evaluate technology effectiveness; identify decision makers and decision making processes; identify impacts or changes; carry out impact or risk evaluation; generate policies; and establish an implementation and follow-up framework.

9. Unfortunately, evidence shows that EnTAs have seldom been carried out in ASM technology programmes. In particular, in designing and implementing such programmes, little involvement, consultation and participation of small-scale miners have been observed. Yet, this is a prerequisite for improving the acceptance of new technologies by the intended target group. Notwithstanding, some efforts have been deployed in many countries to develop environment friendly technologies. The cases illustrated below of mercury retorts (see box 1), shaking tables (see box 2) and sluice boxes (see box 3) are telling.

[6] http://www.unep.or.jp/ietc/Publications/TechPublications/TechPub-14/1-EnTA2.asp 5 June 2003

Box 1: ThermEx retort – Ghana and Tanzania

Small-scale miners continue to use mercury for the recovery of gold without taking any protective measures despite danger to human health and the environment. The attraction of mercury is based on the fact that it is readily available, cheap and efficient in recovering fine-grained gold.

The ThermEx retort is probably the first commercially available glass retort ever produced. It is compact, with dimensions compared to 2 cigarette packets, and weighs approximately 1kg. The retort has been successfully tested in Tanzania and Ghana where it is now widely marketed. The recommended selling price is $US520.The ThermEx manufacturers contend that in addition to the environmental impact resulting from heating the amalgam in open air, miners lose up to 12% of the gold during the amalgam burning process. Such losses are said to occur through:

(a) Spattering during the burning process;
(b) Incrustation of the amalgam into other metallic surfaces like pans and shovels commonly used during the burning process;
(c) Gold losses resulting from manipulating small beads; and
(d) Losses from gold dragging by mercury vapour.

The ThemEx glass retort allows miners to observe the entire process of separation of mercury and gold from the amalgam. Other advantages include:

(a) The retort warm-up time is shorter compared to metallic retorts (7-12 minutes);
(b) Contrary to metallic retorts where the gold becomes darker or browner due to its reaction with iron, in the glass retort there is no colour change; and
(c) There are less gold losses than in metallic retorts where gold infiltrates into iron surfaces.

Box 2: The British Geological Survey (BGS) shaking table

Shaking tables are simple devices consisting of a flat deck with parallel riffles that are effective for processing of materials in the size range of 3mm (millimetres) to 50µm (microns) and are capable of recovering 90 wt.% of the gold present in that size range (Appleton and Williams, 1998). Gravity separation is achieved through the action of shaking the table longitudinally, which allows heavy minerals to migrate along the riffles to the end of the deck, leaving light minerals to be washed over the riffles.
The BGS shaking table (Appleton and Williams, 1998) was designed and tested using ores obtained from the Philippines SSM areas. The table is based on a simple design of a riffled-deck using widely available materials and a manual-driven mechanism. It consists of a frame and supporting base made out of hardwood with a formica deck surface slightly roughened with wet and dry abrasive paper. The drive mechanism consists of bicycle gear, wheels and chains, with an appropriate gearing ratio to step up the manual drive input. Reciprocal motion required for shaking the table is achieved through the use of an eccentric cam, which is attached to the shaking table via a universal ball joint. The rotation of the handle at a speed of 1 revolution/second produces longitudinal motion of about 300 strokes per minute, which is suitable for separation of fine particles. The 'end-knock' effect is then produced by the sudden release of a stronger rubber band that is stretched by the eccentric cam. This simple design is completed with sloping of the deck controlled through appropriate wedging of the deck sub-base, wash water supplied through plastic piping and by using suitably partitioned plastic drainpipes to collect tailings and concentrate. Field trials have proved that the simple shaking table, if set up properly, can recover fine-grained gold. This was demonstrated through recovery of fine-grained gold from miners' tailings where the grain size was only around 30µm. Miners who operated the table were impressed by its performance, which is important for technology dissemination. Based on the outcome of the field trials, a more comprehensive approach that combines three processes, namely, washing to remove fines and slimes; washing on a sluice box; and treatment on a shaking table, was recommended.

Box 3: Sluice boxes – Insiza riverbed mining project – Zimbabwe

A sluice box is one of the oldest gold-processing types of equipment, and is described by Agricola (1556) in his famous book, "De Re Metallica". Recoveries of up to 98% of gold coarser than 100µm has been attributed to some well-designed and operated sluice boxes, (Appleton and Williams, 1998). This has been demonstrated in a project financed by the German Technology Cooperation Agency (GTZ), operated by the Department of Mining Engineering of the University of Zimbabwe and implemented by the Insiza Rural District Council in Zimbabwe. Improvements in the sluice box design generated fairly high productivity of around 4 tons per miner/shift and recoveries of around 70%. The efficiency of sluice boxes has also been tested by a combination of laboratory and field experimentation carried out by the British Geological Survey (BGS) through work done in the Philippines (Appleton and Williams, 1998), Guyana and Zimbabwe (Styles, 2002) on small-scale gold mining. The field tests conducted on several ores with varying gold grain size distributions in Guyana indicated that the perceived problem of major losses of very fine-grained gold had no factual basis. Based on the Guyanese field test recommendations, it was concluded that sluice boxes are capable of achieving 80% gold recovery. The results of the BGS work in the Philippines were also interesting. The following recommendations for improving gold recovery using sluice boxes are based on those results:

(a) Wet screening to remove material coarser than 500µm (which should be passed over a sluice box to recover gold coarser that 500µm);
(b) Material finer than 500µm to be passed over a second sluice, to recover gold coarser than 200µm; and
(c) Tailings from stage (b) to be wet screened to remove material coarser than 200µm (ideally free of gold) and then passed over a shaking table (to recover gold to 50µm).

Further recommendations included:

(d) The time interval between cleaning-out operations should be short to enhance recovery of fine gold, which would otherwise be lost due to solids packed around the riffles;
(e) The inclination angle of the box should be increased by particle size. Experience elsewhere has shown that angles of 7^o - 12^o and 12^{o-}- 14^o are suitable for materials finer and coarser than 1mm respectively;
(f) The feed and wash water rates should be high enough to enable efficient separation of coarse-grained gold without excessive loss of fine-grained gold;
(g) Gold ore with a significant proportion of clay-bound and weakly cemented material should be washed ("scrubbed") and screened prior to sluicing in order to liberate gold trapped in clay;
(h) Ore should be screened prior to sluicing and the resulting coarse and fine streams should be diverted down different sluices (see (e)) in order to improve overall gold recovery; and
(i) The use of alternative riffles would enable a higher recovery of gold. Expanded metal riffles are

Improving Technology Assimilation

10. Illiteracy levels in SSM communities are very high. This affects the capacity to assimilate sophisticated technologies and to derive from them sound and efficient results. The problem can be minimized if appropriate training and extension services are provided to such communities. To improve efficiency and effectiveness, and to achieve greater impact and dissemination, it is recommended that ***training of trainers (ToT)*** be conducted. In addition, the use of simple and practical language, audio-visual methods and illustrations (see box 4) is desirable.

Box 4: ITDG promotion of mercury-saving retorts

Following successful development and field-testing of the retort in Zimbabwe, the Intermediate Technology Development Group (ITDG) prepared a concise leaflet containing practical information for miners and decision makers (Twigg, 1996). The leaflets contained details on the dangers of mercury, the need for a closed retort, the materials and parts required to make one, procedure for making and using one and first aid treatment for mercury poisoning. The fabrication process of the retorts was explained in steps that could easily be followed by miners and contained six illustrations:

- The whole unit in operation;
- The individual parts;
- Diagram explaining stage one of the fabrication of the retort;
- Photograph of the components assembled;
- Photograph of the components before assembly; and
- A sketch showing how to collect mercury after use.

The leaflet was produced in English, Portuguese, Spanish, Kiswahili and Bahasa. An A3 coloured poster aimed at supplementing the leaflets was produced with one side containing warnings about the dangers of mercury and the reverse side showing practical information. The poster has so far been printed in English, Spanish and Portuguese. The leaflets and posters have been distributed to miners in different countries through mining departments, NGOs and private agencies.

Facilitating Access to Technology

11. A major problem restraining access to technology by small-scale miners is lack of finance and appropriate information about where and how to procure equipment. In addition, there are few companies specialized in SSM equipment. In this regard, innovative tax policies and the dissemination of information about business opportunities in the ASM sub-sector could encourage the establishment of these companies. Access to technology can also be facilitated by the establishment of communal centres, such as the Shamva Mining Centre in Zimbabwe (see box 5) where centralized equipment and services are provided to small-scale miners at discounted prices or through payment in kind (Usually part of the processed ore). It should be noted however that most of these centres were established with donor support. As in the case of Shamva, which ran into big problems after its main supporting agency, GTZ, withdrew from the project, over-dependence and reliance on donors can be counter-productive; In most cases donors development agendas and involvement are short-term, while developing a sustainable SSM sub-sector is a long-term venture.

Box 5: The Shamva mining centre: A good practice in facilitating access to technology

The Shamva Mining Centre (SMV) was set up with the objective of assisting small-scale gold miners in the Shamva/Bushu mining areas in Zimbabwe to acquire and use appropriate technologies and skills in the mining and processing of gold, (Svotwa and Bugnosen, 1993). The centre is also intended to encourage establishment of viable, safe and environmentally sound mining operations that contribute towards sustainable rural development. It was set up through technical assistance from the Intermediate Technology Development Group, UK, in collaboration with the Small-Scale Miners Association of Zimbabwe (SSMAZ) and the Zimbabwe Ministry of Mines. However, the uniqueness of the service at the time also attracted donors willing to finance the centre, including GTZ, Gate, European Union (EU), the UK's Department for International Development (DFID), Comic Relief and others.

On the technology front, the centre offers ore-processing (custom milling) services, provides hired drilling and blasting services and sale of explosives, arranges transport to ferry ore from the mines to the centre and provides technical extension services. In the initial phase (1989-1990), the installed milling and ore-processing facilities included a 4 t/day 3 stamp mill, a low-cost shaking table, an amalgamation barrel, settling pond and a retorting facility. By 1990, the demand for the services exceeded the capacity of the centre. Phase two of the project was then initiated by installing a ball mill with the capacity to process 1 ton of ore per hour. A VAT leaching plant with a capacity of 100 tons per month was also installed.

The centre employs drillers and their assistants to provide drilling and blasting services to miners. The extension services are usually limited to the Shamva/Bushu area and include services on safe working habits, choice of mining methods, simple sampling methods, underground support systems and boosting production. In its first 5 years of operation, the centre was well utilized by the miners in the area and processed 8,519 tons of ore yielding 40kg of gold

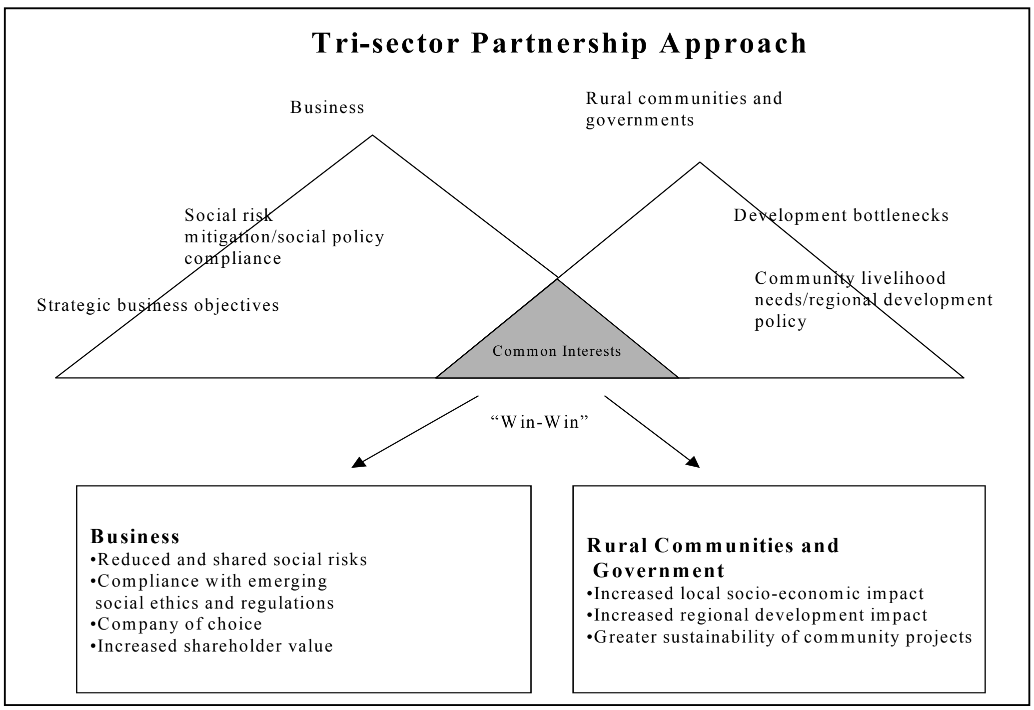
In order to ensure the commercial sustainability of SMC, a company was set up to run the project. A manager and secretary were appointed under the guidance of a 7-member Board of Directors consisting of representatives from SSMAZ (4), finance and legal experts (2) and ITDG (1). In 1999, the management of the centre was transferred to SSMAZ. The centre is still running, but on a much-reduced scale due to a number of problems including lack of managerial experience and the economic problems that the country is facing at the moment.

Cooperation Rather Than Confrontation

12. Land and mineral rights disputes and other types of conflicts between large and small-scale miners are prevalent in many mineral economies in Africa. They arise from lack of trust and confidence, poor communication and dialogue between the two groups of mining operators as well as poor corporate community relations. Other reasons include unfair allocation of resources to small-scale miners; legitimate and illegitimate resource claims by the two groups (IFC, 1999); contradictions between different tenure systems (statutory and customary) which exacerbate small-scale miners' fears of relocation; perception of or real threats to livelihoods of small-scale miners; failure of governments to intervene when problems occur; unmet expectations on benefits from mining; and unfulfilled promises by large-scale mining companies. Notwithstanding this, there is potential for building synergies and promoting pro-active tri-sector collaboration involving business, rural communities and government, which deliver value to both large companies, rural communities and

governments (see figure 2). In the case of technology, this is premised on the fact that large-scale operators have better access and can therefore widen technology options of scale-miners to mutual advantage (see box 6), as well as by facilitating capacity building and skills transfer through training. Other assistance that large scale-operators can give to small-scale miners (ILO, 1999) include sharing geological and other technical information; releasing mineral resources that can not be mined profitably by large-scale mining; facilitating access to affordable assaying and mineral processing services; providing workshop facilities; procuring and storing explosives; buying and treating tailings; providing emergency assistance and mine rescue; and socially very important and trust-building, improving social infrastructure in and around small-scale areas including schools, hospitals, water supply, transport and road network.

Fig 2: The Tri-sector Partnership Model



Adapted from Business Partners for Development: Natural Resources Cluster (1999), (http:www.bpd-natural resources.org/media/pdf/working/onewpaper.pdf, 15 April 2003).

Box 6: Meremeta gold buying scheme-Tanzania

Meremeta is a 50/50 joint venture company formed in 1998 between the Government of Tanzania and Triennex, a South African company. The main objective of the company is to provide assistance to small-scale miners and market their gold. The operation includes:

(a) Provision of equipment such as pumps, compressors and drilling equipment;
(b) Installation of custom grinding equipment, which miners use for grinding and processing ore; and
(c) Buying gold directly from the miners at a 20% reduced price to cover the cost of grinding and with no questions asked about the source.

Given the lack of access to finance and equipment that affect small-scale miners, the scheme was popular and expanded to nearby districts although at a much slower rate than anticipated. The scheme also attracted other local entrepreneurs who brought in their own locally made grinding mills, which run on tractor and lorry engines. These entrepreneurs pose stiff competition to Meremeta despite the fact that they apply a fixed charge

Research and Development (R&D): The Missing Link

13. It has been noted (ECA, 2000) that the import-substitution development model based on large-scale capital intensive industrialisation followed by many African countries after their independence, contributed to the creation of disjointed links between local scientific and technological institutions and the productive sector. Industrialisation was heavily dependent on foreign skills, technology, management and capital. Creation of local capacity and inputs industries was not promoted.

14. Yet, in Africa, there is need to improve technological capacities, create and diffuse innovations. The continent needs technologies that are more productive, flexible, affordable, reliable, acceptable, simpler and cheaper that can foster the development of local competitive small to medium-scale enterprises (SMEs). These and other emerging technologies need to be identified so that they can be efficiently and cost-effectively re-engineered and adapted to the African context. To improve technology acquisition and development and to enhance local capacity to internalize and adapt modern techniques to local environments, there is also need to enhance the capacity of local learning and training institutions. Very few African countries have the necessary human and financial resources to be able to accomplish this daunting task. In South Africa, MINTEK, a research and development centre of excellence has been in the forefront of developing pro-poor technologies. These include, among others, the iGoli process for gold processing (see box 7).

15. More modest R&D projects have been carried out in other parts of Africa, involving collaboration between research centres in the South and their counterparts from the developed world. These include the *Mercury-free recovery of gold project* (see box 8) being undertaken by the University of Dar-es-Salaam, Tanzania (UDSM, 2002) and Imperial College, London (Pratt, 2002); the *Improved Gold Recovery Project* involving the British Geological Survey and the Intermediate Technology Development Group (ITDG) in Zimbabwe (Styles, 2002)**;** and the *Mercury-free gold recovery* being implemented by the Tarkwa School of Mines, (University of Science and Technology-Kumai) in Ghana (Sackey, 2002).

Box 7: Small-scale mining and processing Technologies – MINTEK

MINTEK of South Africa is developing a number of processes and equipment for application in the SSM sector. Some of the technologies include the following:

(a) The iGoli mercury-free gold-extraction process**:** The iGoli process is a gold- recovery technique that has been developed at MINTEK to eliminate the use of mercury by small-scale miners. The process, which was launched in March 2001, makes use of simple household chemicals such as pool acid (HCl) and bleach (NaOCl) to dissolve the gold. This is followed by filtration and gold precipitation with sodium meta-bisulphate. In order to reduce the possibility of accidents with acids, MINTEK developed a training programme for miners. At least one miner from a given small-scale mining community would be trained by MINTEK at their laboratories so that he/she can train other miners back in the community. The training course includes practical test work, a visit to a small operating mine, engineering design drawings for the manufacture of strakes and a simple booklet giving details of the process. According to MINTEK, this new chlorine leaching technology has already been tested with small-scale miners in Tanzania where recovery of gold of up to 99.9% purity was achieved.

(b) Electricity-free processing equipment**:** Equipment is being developed for small-scale miners who have no access to power. One such equipment is ***Strakes***, already in use with the MINTEK iGoli process. In order to recover fine gold, strakes need to be vibrated. More research work is underway to develop ways of vibrating the strakes without using electricity.

(c) Efficient comminution techniques**:** The application of conventional ball mills in the grinding of ore leads to loss of gold behind the liners. Old-fashioned stamp mills, which were designed to crush and grind, do not suffer from such a problem. As such, research is being conducted to look at the application of centrifugal forces to increase recovery or develop a more simplified comminution system.

Box 8: Mercury-free recovery of gold project

The project in Tanzania aims at developing non-polluting gold-recovery techniques that can replace amalgamation. The method is based on the ***Coal Gold Agglomeration*** (CGA) process developed by British Petroleum (BP) in the 1980s, as an outcome of studies on the formation of spherical coal-oil agglomerates as a means of recovering coal fines. The process was then successfully developed further as an alternative to the traditional cyanidation process used in large-scale plants.

The project is still in its initial stage. Test work conducted at the University of Dar-es-Salaam in Tanzania has established parameters linked with agglomeration size distribution and the requirements for the initial rate of agglomeration. By using locally produced coal and light gas (diesel) on one hand and then coal and kerosene on the other, different process parameters of agglomeration, were established. Tests on gold recovery were carried out using a synthetic mixture (Graphite-ESCAID agglomerate) and recoveries of up to 99.8% (reproducible) were achieved. In tests using coal-diesel agglomerates (20% agglomerates to ore ratio), recoveries of between 99.1 - 99.8% (100% reproducible) were achieved. In order to study the process parameters further, more tests on gold recovery using coal-diesel agglomerates with both synthetic and natural ore will be conducted. This will lead to development of a pilot plant designed according to the established optimum parameters.

16. A very important challenge in the R&D agenda for ASM is to undertake research that results in simple and cheap products, which can be manufactured locally. Boxes 9 and 10 below typify the case.

Box 9: Blower manual-driven fan – Mugusu Mine – Tanzania

Miners at Mugusu in the Lake Victoria Goldfields area mine gold from underground excavations as deep as 100m. Although the mining area is located on the high Geita Hills and water inflow is not a problem, the depth of working makes ventilation one of their worries. Miners have designed a manually driven blower fan that has six to eight blades of thin pieces of metal sheet welded on a 16”-19” long shaft. The driving mechanism uses a bicycle wheel and a rubber drive belt, which connects the wheel to the shaft of the fan. A 25mm diameter PVC pipe is then connected from the fan down to the working face. This provides enough air to a single face although it takes a long time to remove fumes after blasting. A more improved version is used in Colombia, where the drive uses a bicycle frame and drive mechanism. A gasoline engine can also be adapted to drive the blower fan.

Box 10: Crushing – impact crusher – Filabusi Gold Project – Zimbabwe

Most small-scale miners now employ crushers as the first stage in size reduction. For crushing of hard rock, a small hard rock impact crusher with 800 or 1000mm rotor beater bar circle x 500 or 600mm width has found wide applications. The Filabusi gold project design incorporates a small hard rock impact crusher with the size of 850mm diameter rotor x 670mm width powered by a 25kW drive. The crusher, which has a capacity to produce 20 –30 tons per hour, is the smallest in the range of impact crushers. The advantage of impact crushers is that they produce cubical or spherical shaped grains unlike the platy or elongated pieces produced by jaw crushers. They are also cheaper, simpler to maintain and can be manufactured locally, as done in Zimbabwe

Policy Implications: Addressing the Challenges

17. Proponents of the sustainable livelihood approach (UNDP, 1999) argue that the issue at the core of small-scale mining is not only technical, i.e. improving productivity, but also and more important, providing alternative livelihoods (based on agriculture) to small-scale mining communities. Opponents of this approach advocate that even where rural communities have stable livelihoods, many of their members are still lured by the prospects of making quick fortunes from mining. They further state that for some communities, mining is a way of life that is deeply rooted and forms part of their history and socio-cultural fabric. In this regard, those value systems and perspectives should be brought to bear on the solutions proposed for the sub-sector, which should be geared towards finding technology options that impact on productivity. On the other hand, a significant number of practioners believe that unless policy options are changed and adequate administrative, technical and financial support is provided, the problems affecting the SSM sub-sector will never be redressed.

18. The terms of debate are not mutually exclusive. The technologies discussed have contributed to improving the productivity of SSM operations and reducing their impact on the environment. Yet, very few small-scale miners use these technologies probably because of their inability to purchase them on an individual basis. This may suggest that establishing pools such as the Shamva mining centre may facilitate access to technology. On the other hand, efforts to reduce the unit cost of the equipment should help to render them more

accessible to small-scale miners. This could be easier achieved if the equipment would be produced locally, using locally available materials where possible. Work by indigenous research centres capable of adapting and innovating existing technologies could catalyse this process.

19. More important though, since some of the SSM development problems may be linked to the limited assets and entitlements of SSM communities, a pluralist, holistic and multi-pronged approach is required to make small-scale mining a viable activity. This approach should be based not only on the provision of affordable and accessible technology options to small-scale miners, but also in formalizing the sector and developing alternative livelihoods to ASM (diversifying income sources and broadening non-mining incomes). The latter should result respectively in fewer miners per unit area, creation of alternative skills and, ultimately, in more income for the remaining miners.

20. The above vision was adopted in Yaounde[7], Cameroon in 2002. The Yaounde Vision recognizes ASM as a poverty-driven activity and recommends that ASM should be integrated in the Poverty Reduction Strategy Papers (PRSPs) of African governments. It further urges that the mining policies and laws of the member States should be reviewed with a view to incorporating a poverty reduction dimension in ASM strategies.

21. But how effective will these measures be? There is no sufficient evidence yet to inform the discussion, for very few countries, if any, have implemented the above vision in its integrity. Notwithstanding, a combination of measures described above, including the provision of specialized training to miners and adoption of simple strategies for dissemination of technology will certainly yield better results and impact than current practices. Beyond this and equally relevant is the training of small-scale miners in analytical skills, sound business and production management culture, capabilities and practices (UNCTAD, 2002). This will facilitate the transformation of small-scale mining from a transitory and shock-or-coping-responsive activity into a serious business. To further enlighten the debate on artisanal and small-scale mining, behaviour studies are also needed to better profile small-scale miners and understand the factors (whether in permanent mining, seasonal mining, poverty-driven mining, or gold-rush mining) motivating them to engage in this activity.

22. Noting the structural weaknesses of ASM, is the idea of a bottom-up development a mere fallacy and an en-vogue concept? Given the survival nature of ASM, can small-scale miners be empowered to be the masters of their development and the catalysts of the change process? Considering the divergent interests of the main stakeholders and their often vicious relationships, have the merits of tri-sector partnerships been blown out of proportion? Are African governments interested in developing a SSM sub-sector or is their development model skewed in favour of large-scale mining? Finding answers to these questions should also feed the future research agenda on artisanal and small-scale mining in Africa.

[7] The Yaounde Vision was adopted during a joint ECA/UNDESA Seminar on "Artisanal and Small-scale Mining in Africa: Identifying Best Practices and Building Sustainable Livelihoods of Communities", held in Yaounde, Cameroon from 18 to 22 November, 2002

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