Natural Resources
FORUM

Natural Resources Forum 26 (2002) 3–13

Small-scale mining and its socio-economic impact in developing countries

Gavin Hilson

Abstract

This article examines both the positive and negative socio-economic impacts of small-scale mining in developing countries, and outlines some key measures for improving sustainability in the sector. It is important to clarify that, in spite of experiencing its share of environmental- and health-related problems that adversely impact human quality-of-life, small-scale mining plays a pivotal role in alleviating poverty in the developing world, and contributes significantly to national revenues and foreign exchange earnings. Though these important socio-economic contributions make small-scale mining an indispensable economic activity, there is an obvious need for improved sustainability in the industry, more specifically, for operations to resolve pressing problems, many of which have wide-ranging impacts. However, because most small-scale mines are low-tech and employ poorly trained uneducated people, it is difficult for the sector to improve on its own. Thus, governments and regional international bodies must play an expanded role in bridging critical information, technologic and economic gaps. It is concluded that governments and regional organizations could accomplish much in the way of improved sustainability in the small-scale mining industry by: (1) legalizing small-scale mining and implementing sector-specific legislation; (2) contributing to community development and providing increased economic support; and (3) providing training and educational assistance, and playing an expanded role in the dissemination and transfer of important technologies.

Keywords: Small-scale mines; Socio-economic impact; Sustainability; Mining

1. Introduction

Small-scale mining has brought both major problems and immeasurable socio-economic benefits to a number of developing countries. In recent years, however, the bulk of research has been devoted to analyzing the negative aspects of the industry. As documented in a now burgeoning literature, a number of environmental, health and safety problems persist, each of which adversely impacts human quality-of-life, mainly because most operations are low-tech and employ uneducated and poverty-stricken workers. Sufficient effort has been made to make the world aware of these problems, which include, *inter alia*, excessive pollution, chemical contamination, inadequate mine safety design, and disease, but in the process, the socio-economic importance of the industry is increasingly being overlooked.

The purpose of this article, therefore, is to put into perspective the socio-economic significance of small-scale mining in developing countries, and to outline some key measures that could help resolve many of its current problems and improve the sustainability of operations. It is important to clarify that for decades, the extraction and processing of minerals on a small scale has provided millions of people from a great number of developing nations with economic security, and in the process, has helped to alleviate poverty where other industries could not. Small-scale mining has also produced sufficient revenue and foreign exchange earnings for the governments of these countries, and continues to produce close to one-sixth of global mineral output. These contributions alone make small-scale mining an indispensable activity in Africa, Latin America and Asia.

The first of four main sections that follow, provides an overview of small-scale mining, including a discussion of key definitional problems, the minerals that are mined on a small scale, and locations where small-scale mining is most common. Next, the article seeks to clarify the socio-economic importance of small-scale mining in developing countries, by drawing heavily from the published literature. Some of the major problems in the industry are then briefly examined to illustrate the challenges faced by governments

The author is a member of the Environmental Policy & Management Group (EPMG), Imperial College Centre for Environmental Technology (ICCET), Royal School of Mines, London. E-mail: g.hilson@ic.ac.uk

Table 1. Definitions of small-scale mining in selected countries

Country	Definition
Brazil	Individual or collective extractive work, using rudimentary methods, manual devices or simple portable machineries — for immediate exploitation of a mineral deposit which, by its nature, dimension, location and economic use, can be worked, independent of previous exploration work, according to criteria set by the National Department of Mineral Production.
Burkina Faso	Activities conducted on ore bodies or deposits by natural or legal persons using traditional techniques or low mechanization levels.
Chile	Mining operation by a person who works at a mine property or process plant by himself and with or without the family support, a maximum of five salaried workers, or by legal society with no more than six partners.
Ethiopia	Small scale mining means mining operations to be designated as such by the Minister of which the annual run-of-the mine ore does not exceed a certain limit, which differs from one mineral product to another and on the nature of mineral occurrence.
Ghana	Small-scale mining refers to operations of individual Ghanaians or organized groups of Ghanaians (4–8 individuals), or cooperative of 10 or more individuals, which are entirely financed by Ghanaian resources at certain limit, and carried out on full time basis using simple equipment and tools.
Mexico	Mines whose annual production values do not exceed US$3.0 million, provided that their daily production capacity is less than 200 tons per day (for metal mines) and 300 tons per day (for non-metal mines).
Suriname	The exploitation of mineral deposits which, due to their mode of occurrence and their size, can be mined economically by simple means and techniques.

Source: Bugnosen, 1998.

and policy-makers in promoting a more sustainable small-scale mining sector. The article concludes by outlining some key steps that could lead to improved sustainability. For the purposes of the discussion, sustainable (small-scale) mining is recognized as activity in the sector that is continuously making improvements in social, economic and environmental areas.

2. Global overview of small-scale mining

2.1. Small-scale mining defined

A number of attempts have been made to define 'small-scale mining' in an international context, according to criteria such as mine output, labour productivity, organization of the enterprise, and levels of technology. Peiter *et al*. (2000), for example, provide a broad definition of small-scale mines, suggesting that they are generally those mining operations that are both labour intensive and low-tech. Jennings (1997), goes one step further, arguing that small-scale mines, whilst low tech, can be placed into one of two broad categories: 1) high-value mineral extraction, in particular gold, silver, and precious stones; and 2) quarry mining or simply the removal of industrial minerals and construction materials on a small scale. More precise definitions have also been adopted by, for instance, Amavilah (1998), who defines a formal small-scale mining firm in terms of number of employees, size, earnings, labour productivity and production capacity. In fact, some countries have even formulated their own definitions (see Table 1) for the purposes of including small-scale mining in national policies.

However, as Solomon (1997) explains, none of these definitions has received universal recognition because:

1. Terms such as 'artisanal' (a label typically used for illegal mining) and 'small-scale' are used loosely in different contexts by different people.
2. The trade-off between capital employed and labour is generally not taken into account.
3. The relationship between production and value varies from sector to sector (e.g. high tonnage/ low value for commodities such as sand vs. low tonnage/ high value for diamonds, etc.).
4. The most easily recognizable distinction — the degree of formality — is not necessarily related to size.

For the purposes of this article, small-scale mining per se can be distinguished as mining activity involving the application of low, intermediate technology and universal prospecting methods, and requiring low initial investments and high employment per-unit output. More specifically, each operation exhibits, *inter alia*, the following:

- An involvement with the extraction or processing of precious metals/gemstones on alluvial deposits or orebodies situated at or near the surface;
- Intense labour activity with fewer than 15 workers per operation;
- Remote and isolated location — situated well out of the reach of urban centres;
- Rudimentary techniques and low technological awareness;
- Low degree of mechanization and a chronic shortage of capital; and
- Low levels of environmental, health and safety awareness.

Further, from a technological perspective, the activity encompasses a broad range of operations, from informal micro-scale mining that utilizes almost exclusively manual techniques to extract high value minerals from alluvial deposits and outcrops, to small organizations of semi-skilled entrepreneurs who employ mechanization strategies and semi-advanced mineral processing techniques.

In sum, for the purposes of the discussion that follows, a mine operating on a small scale is a producer, often spor-

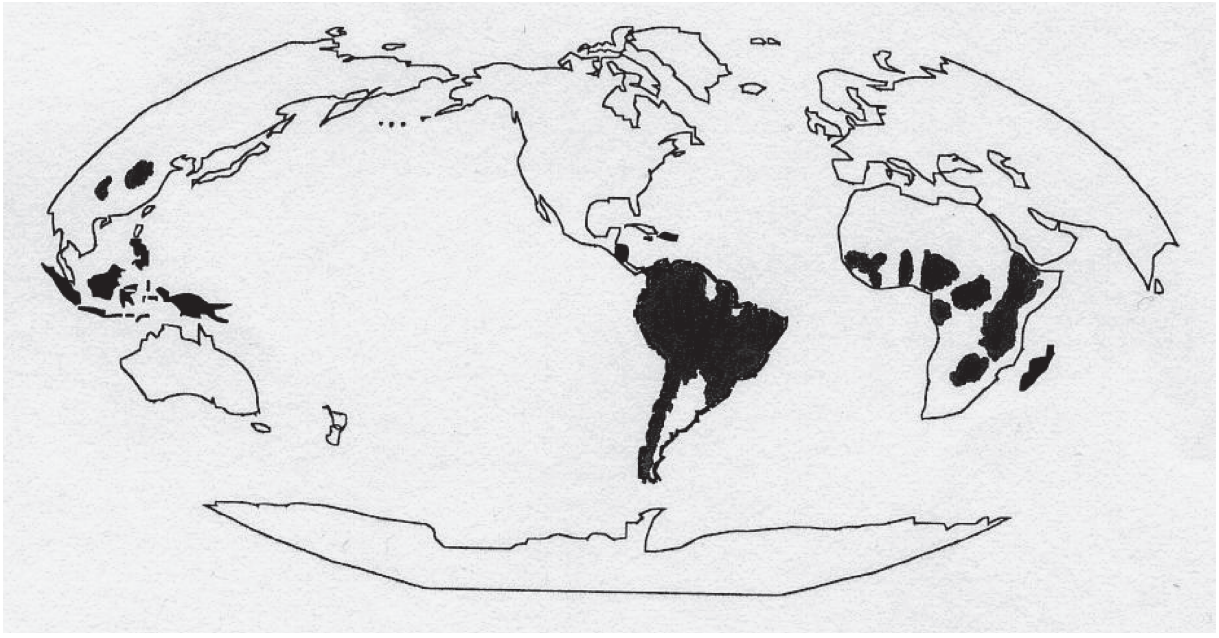

Figure 1. Locations of important small-scale mining districts around the world
Source: Modified from Priester and Hentschel, 1993.

adically, of limited amounts of minerals from deposits with few known ore reserves and of character not readily amenable to large-scale mining (adapted from Carman, 1987).

2.2. What minerals are mined on a small scale and where?

By nature, small-scale mining can only exist where mineralization occurs near the surface or, in the case of precious metals, within unconsolidated rocks, most commonly those contained in river-bed alluvions, eluvions and colluvions, and altered upper portions of quartz veins. Small-scale mines, which are found scattered throughout Asia, Africa, and Latin America (see Figure 1), are as diverse as the minerals they produce. They engage in the extraction of more than 40 minerals, including precious, semi-precious, heavy and industrial minerals, and construction materials (Traore, 1997). It is important to note that precious metals and gemstones are by far the most economically important minerals mined on a small scale, because of their high value per unit weight. Other minerals and materials, such as clays, tin, tungsten, bismuth, limestone, sulphur, lithium, salt and uranium, are also commonly mined on a small scale, but for much lower returns. Many of the base metals, such as copper, iron ore, lead, zinc, manganese, and nickel, however, normally do not lend themselves to small-scale extraction because of the need for economies of scale in producing them (ILO, 1999).

It is estimated that small-scale mines account for between 15 and 20% of global non-fuel mineral production (Jennings, 1993), and in many regions worldwide, activity has increased considerably in recent years. In Africa, for example, during the 1970s and 1980s, a combination of decreased demand for minerals, drastic falls in mineral prices, plummeting mineral investment, and widespread drought, triggered an attempt in a number of countries to diversify mineral production and reduce dependence on a single mineral for export. Widespread small-scale mining activity was encouraged, as it required minimal technological and economic investment for start-up. In the case of South America, output from small-scale mining has also increased in recent decades. This is best illustrated by Brazil, where annual gold production from small-scale mines operated by informal miners called *garimpeiros*, rose from 5 tons in 1970 to 78 tons in 1990 (see also the article by Marcello Veiga and Jennifer Hinton in this issue, pp. 15–26). Today, some 90% of gold comes from nearly 2000 small sites operated by these non-organized prospectors (UN, 1996; Lacerda and Salomons, 1998). A great number of other countries in Latin America, Africa and Asia also have flourishing small-scale mining sectors.

3. Socio-economic importance of small-scale mining

It is safe to say that small-scale mining was first recognized as an industry in 1972, following publication of the United Nations report, *Small Scale Mining in Developing Countries* (UN, 1972). This report put into perspective for the first time the economic importance of small-scale mining by analyzing the state of global operations at the time and historical production trends. As Davidson (1993) explains, five major international meetings have since taken place in: Jurica, Mexico (1978); Taxco, Mexico (1981); Helsinki, Finland (1983); London, UK (1987); and Ankara, Turkey (1988), as well as two important regional seminars in

Mombasa, Kenya (1980) and Calcutta, India (1991), all of which were devoted to analyzing the prospects and problems of small-scale mining. These meetings primarily emphasized the environmental and health impacts of small-scale mining, issues that have overshadowed the important socio-economic contributions of the sector. In mid-February 1993, however, at a weeklong international seminar on "Guidelines for Development of Small- and Medium-scale Mining" held in Harare, Zimbabwe, the socio-economic importance of the industry was finally etched in stone when participants agreed that small-scale mining operations, collectively, make important contributions to national economies, and provide economic stability to thousands of indigenous people residing in rural areas. The seminar reached a consensus on the following: (1) the potential business benefits of small-scale mining outweighed its negative aspects; (2) small-scale mining was a motor driving entrepreneurship; and (3) equipment needed by small-scale miners could in fact be manufactured in developing countries (see Labonne, 1994). The socio-economic importance of small-scale mining is described more in detail in this section of the article.

Table 2. Small-scale mining operations and employment totals in selected developing countries

Country	Number of mines	Estimated employment
Argentina	670	5,800
Bolivia	1000	70,000
Brazil	10,000	1,000,000
Burkina Faso	35–60	60,000
China	250,000	3,000,000
Colombia	9600	100,000–200,000
Ghana	400–700	30,000
Guyana	3500	10,000–20,000
Haiti	50	4,500
India	10,000<	500,000
Indonesia	77,000	465,000
Mexico	2000	20,000–40,000
Pakistan	2400	90,000–370,000
Peru	1550	20,000
Philippines	700	200,000
South Africa	5500	15,000–20,000
Tanzania	4000	450,000–600,000
Viet Nam	500–600	35,000–40,000
Zambia	200	30,000
Zimbabwe	2000–5000	50,000–350,000

Sources: UN, 1996; ILO, 1999; Ávila, 2000.

3.1. Rural employment: small-scale mining and poverty alleviation

Small-scale mining plays a pivotal role in alleviating poverty in many rural regions of the developing world, primarily because it is viable in remote areas with minimal infrastructure where other industries could not function. Operations are low-tech, and because most do not require technical staff, the industry employs the least educated and the poor. Today, an estimated 30 million people depend on the incomes generated, directly and indirectly, by small-scale mining (ILO, 1999). An exact figure of the workforce is nearly impossible to ascertain, however, because of rampant illegal mining activity, much of which is unaccounted for. Many (e.g. Borla, 1996; Bugnosen *et al*., 1999) are in general agreement that small-scale mining employs some six million men and women worldwide, although a recent report, *Social and Labour Issues in Small-scale Mines* (ILO, 1999), suggests that between 11.5 and 13 million are employed in the industry.

Perhaps the biggest stimulus to participation in small-scale mining activity is the lure of quick enrichment and the financial and social independence that comes with it (Astorga and Duran, 1994). Wages are comparatively higher than employment in construction or agriculture, making work in this sector financially appealing. Further, small-scale mining provides employment for many retrenched workers from large-scale mines, which in turn has increased income levels, raised living standards, and minimized rural-urban drift (Al-Hassan, 1997). The provision of employment has also helped lower crime and suicide rates.

In Zaire, over 500,000 people work at small-scale diamond, gold and tin mines (Jennings, 1994), and in Ghana, an estimated 24,000 rural jobs have been created as a result of small-scale gold mining alone (Amegbey *et al*., 1997). Similarly, certain countries in Asia and South America have a disproportionately high percentage of their labour force engaged in small-scale mining activities. In China, approximately three million people are employed at small-scale coal mines (ILO, 1999), and in the Philippines, at Mount Diwalwal on the Island of Mindanao alone, as many as 100,000 small-scale miners are engaged in gold extraction and processing activities (Hollaway, 1997). The importance of small-scale mining in Latin America from an employment perspective is best exemplified by Brazil, where, within the Amazonian region alone, a human contingent of 500,000 relies on small-scale gold mining for economic survival (Meech *et al*., 1998). In neighbouring Bolivia, at least 20,000 people are employed in small-scale tin mining. Table 2 provides more specific employment estimates for small-scale mining in selected developing countries.

3.2. Women and small-scale mining

Small-scale mining provides numerous opportunities for women in developing countries. It is estimated that women could account for as much as one third of the sector, including informal activities (between 3.5 and 4 million), with possibilities of another 1.5 to 2 million being involved indirectly. Though the extent of female participation in small-scale mining activities varies from country to country, in several instances, women play a more prominent role than men in the industry. For example, it is estimated

that women represent 75% of small-scale mining workers in Guinea; 50% in Madagascar, Mali and Zimbabwe; and 40% in Bolivia. In Ghana, 75% of the traders of mined salt are women, and female participation in gold panning and extraction techniques is widespread (UN, 1996). In fact, as Labonne (1996) explains, women work in almost all aspects of the operation, especially panning, carrying, washing, and sorting of ore, and have done so for generations.

It has been difficult, however, for female small-scale miners to obtain development assistance. Women typically face both socio-economic and technical constraints, as well as an overall inability to access bank credit. Traore (1994), for example, notes that African women involved in small-scale mining experience such difficulties because of insufficient knowledge of mining techniques and lower education levels than males, which handicaps their learning and hinders opportunities for assistance. Additionally, cultural values often interfere with women attempting to obtain credit and loans. More specifically, men are typically perceived as being the head of households and their consent is therefore needed to obtain financing. Further, because women are often considered inferior, men working under female supervision at mines frequently disobey orders.

However, in spite of these cultural barriers, female participation has been steadily increasing in recent years, primarily (ILO, 1999) because of:

- The introduction of cultural educational programmes;
- An acute unavailability of alternative employment;
- Profound impacts of drought on farming activities; and
- The pursuit of a greater economic independence.

Initiatives can be taken by NGOs and the public and private sectors to facilitate an improved operating environment for women. As Davidson (1993) points out, governments can incorporate gender issues into national political agendas, and implement strategies that would make possible the greater participation of women at all levels. In fact, certain countries, most notably Ghana and Zimbabwe, have actually formulated gender-neutral legislation to ensure that on paper, both women and men have equal access to mining titles (Labonne, 1996). There is also a need to provide training for women, and proper educational material concerning safety, handling and environmental issues at mines. Further, given the fact that women are responsible for children, proper childcare, schooling, first aid, and food services could be provided to working women. These changes may not necessarily dissolve the cultural barriers that have existed for centuries, but would certainly have a positive impact in an industrial area in need of major support.

3.3. Revenue and production from small-scale mining

The economic importance of small-scale mining to regional governments cannot be overstated. Operations not only provide employment to thousands of indigenous people, but mineral output also contributes substantially to national mineral markets. As indicated above, small-scale miners are engaged in the extraction of more than 40 minerals, including precious, semi-precious, heavy and industrial minerals, and construction materials (Traore, 1997), and total production is estimated to account for 15–20% of global non-fuel mineral production (Jennings, 1993). For governments in developing countries, most of which face debt and economic difficulties, this mineral output could contribute substantially to foreign exchange earnings.

What makes small-scale mining an indispensable economic activity is the fact that in many instances, it is financially viable where mineral deposits are only marginal for large-scale mining companies (Kumar and Amaratunga, 1994), the principal industry, and often the hub of the economy in a great number of developing countries. Smaller deposits require less time to develop and therefore have a faster payback on investment compared to large-scale operations. The sector, therefore, is responsible for the extraction and processing of minerals that otherwise would not be mined, and in the process, can contribute significantly to foreign exchange earnings through exports, and to the creation of secondary employment opportunities.

Several authors have provided regional estimates of both production and sectoral earnings. In sub-Saharan Africa, for example, gold and gemstones worth approximately US$1 billion are extracted on a small scale each year (Noetstaller, 1995), which has largely been a result of regional formalization of small-scale mining activity. In Ghana, the government invested a modest US$1.4 million to build regional buying stations that pay world prices to small-scale miners for their gold, and established district licensing centres. The move has resulted in the collection of over US$140 million in revenues that would have otherwise been lost (Labonne, 1996), and by the early 1990s, had contributed to well over US$70 million in foreign exchange earnings for the government (Davidson, 1993). In other African countries, such as Guinea and the Central African Republic, mineral production is almost entirely confined to small-scale mining. In Guinea, the share of small-scale mining in national gold production rose from 66% in 1990 to almost 100% in 1993. In the Central African Republic, where diamonds and gold account for nearly all of national mineral exports, 90% of diamond and 100% of gold production is carried out by small-scale miners (UNECA, 1993; Bocoum and Samba, 1995; UN, 1996).

The Asian case has also been well documented in the literature. In India, 3000 small-scale mining operations generate 50% of the country's non-fuel mineral output (Jennings, 1994), and in the Philippines, it has been estimated that the small-scale mining sector produces as much as 150 tons of gold each year. Indonesia also has a thriving small-scale gold mining sector comprised of some 77,000 operations that generates US$58 million in earnings each year (Hollaway, 1997). In China, over 93,000 coal mines distributed over 1258 counties with a workforce of 3.4 million,

Table 3. Common environmental impacts resulting from small-scale mining activity

Environmental problem	Description
Deforestation	Mass tracts of forest cover are removed during exploratory and excavation processes.
Air pollution	As a result of ore roasting, quantities of sulphurous gases are emitted, many over which are loaded with heavy metal particles, mercury and arsenic.
Mercury pollution	Mercury, which is used in the processing of precious metals on a small-scale, is released uncontrollably into the environment, where it is transformed into toxic methylmercury.
Erosion	Overturning of land leads to erosion, leaching and inevitable siltation of streams.
Acid mine drainage (AMD)	Results from oxidation of discarded tailings, and the resulting acidic solution is toxic to aquatic animals and plant life.
Land degradation	Incomplete mine closure leads to "pot-holed" landscapes, which collect water and serve as breeding grounds for malaria-infested parasites.

account for well over 50% of total national coal output (Ghose, 1994).

Brazil is by far the largest regional producer of gold in Latin America. Here, an estimated one million people are involved in small-scale gold mining, and are responsible for between 75 and 90% of the annual gold output (Buntenbach *et al*., 1995). Other Latin American countries, however, have flourishing small-scale mining industries as well. In Bolivia, for example, where 95% of foreign currency at the beginning of the 1980s was earned by exporting mining products, some 4000 small-scale operations were engaged in extraction of tin and tungsten alone (Priester *et al*., 1993), with many miners earning on average US$3000 per year, well above most other income alternatives (McMahon *et al*., 1999). In Suriname, where small-scale gold mining has been practiced since 1876, it is estimated that today, as much as 3000kg of gold is produced annually, by some 8000 workers and accounting for some 30% of national production (de Kom *et al*., 1998). Venezuela, Mexico, Guyana, Chile and Colombia also have well-developed small-scale mining sectors that are mainly involved in the extraction and processing of gold and silver.

4. Weighing the good against the bad: common problems with small-scale mining

The most pressing problems in the sector are related to environment, health and safety. These problems often stem from a vicious cycle: few tangible benefits are derived from small-scale mining because governments do not provide needed support to the industry, and the local private sector chooses not to invest in small operations (see Berger, 1982). Though some small-scale mining regions have received certain assistance in the form of technical and economic support, most efforts have been marginal at best.

Of the aforementioned problems, environmental degradation caused by small-scale mining is the topic of greatest concern within the scientific and academic communities. The most serious environmental impacts include: mercury contamination (as discussed by Veiga and Hinton in this issue); mass deforestation from intensive prospecting and mining; small-scale acid mine drainage (AMD) and accompanying heavy metals leaching; mass soil erosion; small-scale habitat destruction; and "pot holed" landscapes resulting from incomplete mine closure (see Table 3 for a summary of these problems). There are, however, numerous opportunities for improving the environmental conditions at mines. Governments and international agencies could provide miners with the badly needed training and equipment required to avoid environmental problems and accidents. In addition, imprecise environmental regulations and legislation in many developing countries, along with ineffective monitoring and enforcement programmes in place for small mines, need to be improved outright.

There is also a problem in the industry with deteriorating health and safety, much of which stems from poor environmental conditions. Mining is inherently hazardous, and although it employs only 1% of the global workforce, it is responsible for almost 8% of fatal industrial accidents (Barry, 1997). As Jennings (1994) explains, many operators of small-scale mines are willing to accept a higher degree of personal risk in order to maximize profits, and relatively high wages and a general unavailability of alternative employment are sufficient reasons for miners to ignore such risks. A second, and perhaps more serious, risk relates to the stability of underground mine workings, which, more often than not, are constructed haphazardly. Compounding the problem are poor ventilation and inadequate roof supports. Injuries, therefore, can result from cave-ins and from fires commonly ignited by lanterns catching on flammable material in the mineshaft.

In addition, a number of the techniques and chemical agents employed in small-scale mineral extraction and processing activities have serious human health implications. For example, in the case of mercury, acute overexposure can cause severe epidemiological poisoning (Lacerda and Salomons, 1998). Small-scale mines typically operate between 12 and 24 hours a day year round, and workers often complain of irritability, sleeping disorders and appetite loss (ILO, 1999). Although data are not readily available, there have been well-documented cases of mercury poisoning in small-scale gold mining regions. Studies have

verified that miners utilizing mercury have elevated levels of mercury in blood, hair and urine, and are very susceptible to the many sicknesses the chemical can cause. Direct inhalation of gaseous mercury is of chief concern, since it is readily absorbed through lungs and after some time, partially oxidizes and accumulates in the kidneys (Malm, 1998), leading to poisoning, which can result in a loss of appetite, and sometimes, death.

Additional health problems can result from the poor ventilation, lighting, hygiene, sanitation and dust control in shafts. In fact, the inhalation of mine dust, which contains crushed ore particles along with toxic heavy metal particulates, is a major health threat in both small-scale underground workings and in processing areas.

Other serious health complications include:

- An overexposure to dust (silicosis): prolonged exposure to dust with high silica content can likely lead to silico-tuberculosis or silicosis;
- Side effects from excessive noise and vibration: frequent headaches and permanent ear damage;
- Waterborne diseases: water is often contaminated with harmful pathogens;
- Side effects from poor ventilation: breathing difficulties can persist;
- Over-exertion: fatigue from overwork; and
- Inhalation of noxious gases: can lead to different types of bronchial damage.

A great number of developing countries have only limited medical services, and most workers are well out of reach of whatever health services are available. Other health problems include: malaria, spread by mosquitoes that often breed in abandoned small-scale mine pits; dysentery; tuberculosis; AIDS and typhoid fever.

A serious safety hazard results from the illegal nature of small-scale mining and mineral trading, primarily with high-value mineral products, such as gold, silver and precious stones. Though illegal mining may be a result of devalued currencies and an unavailability of foreign exchange resources, it is most commonly being practiced in nations where state enterprises have ownership and control of operations (Kambani, 1995). Kambani provides estimates of illegal small-scale mining activity in a number of developing countries, including:

- Colombia: 80% of emeralds, valued at US$800 million per year;
- Zambia: 50% of emeralds, valued between US$200 and US$300 million per year;
- Zaire: an estimated US$400 million worth of gold and diamonds are smuggled illegally each year;
- Zimbabwe: 50% of emeralds, valued at US$3 million, and mined and sold illegally each year; and
- Brazil: most of the US$2 billion worth of gold mined by small-scale miners.

In these and other developing countries, illegal small-scale mining is clearly causing significant economic losses to the government.

How, then, can these and related problems be addressed and small-scale mining promoted in a sustainable manner in developing countries? The steps identified in the next section could lead to both enhanced socio-economic development and improved environmental, health and safety conditions in the sector.

5. Toward a sustainable small-scale mining industry

It is clear from the discussion thus far that whilst small-scale mining is an indispensable socio-economic activity in the developing world, it is also a sector in dire need of further technical, financial and environmental assistance. Regional governmental bodies and international agencies must therefore work in cooperation to improve the sustainability of small-scale mining operations. To reiterate, as sustainable development in the context of mining and minerals extraction has been ill-defined in the literature, for the purposes of this article, improved sustainability, as it relates to small-scale mining, is simply strategizing to continuously improve both the socio-economic and environmental conditions of the industry. This section of the article presents a procedurally simple framework for improving the sustainability of small-scale mining operations.

5.1. Legalize small-scale mining activity and implement sector-specific legislation

Governments have three primary roles with respect to industry: to enhance investment and profitability; to act as a regulator; and to ensure that the additional benefits from the industry — employment, technological acquisition and infrastructure development — accrue to the nation (McKechnie, 1995). A fundamental first step to improving the sustainability of small-scale mining, therefore, is to recognize it nationally as an industry by legalizing the activity through recording and licensing. Legalization, intervention and control are keys to eliminating unacceptable work practices and the illicit marketing of minerals, and are a necessary prerequisite for removing operational constraints limiting productivity and competitiveness (Noetstaller, 1994). It has been shown through experience that such objectives can only be accomplished if official prices offered to small-scale miners reflect real world prices, more specifically, if the difference between government and global price does not exceed a margin of 5%.

Because small-scale mining operations vary significantly in composition, particularly with respect to the mineral mined and level of mechanization, it is suggested that governments should adopt a licensing system that reflects the diverse nature of the industry. It is recommended that one of the following systems be adopted (adapted from Bugnosen, 1998; Bugnosen *et al*., 1999):

1. Mineral type: already commonly used in developing countries, different licenses can be issued to miners engaged in different mineral extraction activities. An example would be to issue separate licenses for quarry operations, precious metals, gemstones and building materials.
2. Strata, location or region: governments can take into account geographical features (i.e. sensitive ecological regions, population distribution, etc.) to determine where small-scale miners can mine and to what depths they can excavate.
3. Individual or 'staggered' licensing: governments can issue one license that covers the entire mining and mineral marketing process, or individual licenses for each stage in the process (known as staggered licensing) from exploration, through development and extraction, to marketing.
4. National or state licensing system: governments can establish a universal licensing system, or have separate licensing systems in different counties or states.

Once a satisfactory licensing system is in place, governments must then implement legislation that properly regulates small-scale mining operations and addresses:

- Mineral and mineral property rights;
- The rights of land owners and indigenous peoples;
- Health and safety aspects;
- Environmental components; and
- Labour rights: women and children.

The existing national mineral policy of many developing countries fails to identify the needs of small-scale mining operations and to recognize the importance of the industry. Countries such as India, Zimbabwe, Brazil and Ghana have made attempts to pass sector-specific legislation and to introduce policies that address certain areas of the industry. Though little information is available on the impact of such legislation, it can be assumed that because the laws are not comprehensive, they have had minimal impact in improving the sustainability of regional small-scale mining. In fact, it is reported that in Brazil and Zimbabwe, recent legislation has not led to any significant improvements in the social and environmental conditions at small-scale (gold) mines (Bugnosen, 1999).

Sector-specific legislation is particularly important if environmental and related issues are to be addressed properly. The conventional route of most developing countries has been to implement a national environmental policy or action plan (e.g. Ghana, Mexico), accompanied by a select group of general environmental laws under which industry-specific regulations occasionally exist. The problem with much of this legislation is that it is either in its infancy or again, is not comprehensive. Precise details pertaining to chemical inputs and outputs, management needs, and operational techniques are typically absent. It is imperative that more specific regulations pertinent to small-scale mining are included; there is also need for more precise environmental impact assessment, environmental impact mitigation, monitoring and reporting, environmental auditing and reclamation techniques. Further, there is a pressing need for health safety standards for small-scale mining. Specific codes should be drafted that address relevant accident, evaluation, guideline and instructional issues.

5.2. Community development and increased economic assistance

Once pertinent legislation is in place, governments must then promote socio-economic sustainability in the industry by financing various infrastructure developments and providing economic assistance to small-scale miners. Though small-scale mines are temporary, regionally they are at specific locations where economically viable geological deposits occur. There would be merit, therefore, in developing appropriate infrastructure to ensure sound socio-economic development at those locations, such as the creation of regional hospitals and first aid centres. The construction of such facilities could help reduce the occurrences of disease amongst small-scale miners, and help treat workers that have sustained injuries on the job. Similarly, road development could benefit miners trying to market their products in urban centres. Bus and truck routes could accompany road development to help miners deliver products to market and to enable merchants and government inspection people from nearby cities to visit small-scale mining projects.

Provision of these and similar services would lead to improved socio-economic quality-of-life and hence contribute enormously to sustainable development at the community level. In addition to providing support through financing the development of improved infrastructure, governments and international bodies must expand economic assistance. Again, small-scale miners are confronted with significant economic challenges that in most cases, inhibit sufficient environmental improvement. One strategy would be to offer direct credit lines to miners seeking to use improved technologies and equipment. In Brazil, for example, BNDES, the development bank of the national government, has, since 1986, offered credit lines to support pollution control, more specifically funding for end-of-pipe technologies, equipment process changes, and recycling/recovery projects.

Banks may be reluctant to provide small-scale miners with loans, however, because of anticipated problems with collateral and the risk of non-payment of loans, but there are practical means for alleviating these financial constraints. As is summarized in *The Berlin Guidelines* (UN, 1992), Chile and Zimbabwe provide illustrative examples for overcoming such difficulties. In Chile, the Empresa Nacional de Mineria (ENAMI) has been established with the main purpose of promoting mining activities and improving the sustainability of small- and medium-sized mines (McMahon *et al*., 1999). It provides loans to small-scale miners, grants

emergency advances and advance payments on ore purchases, and provides repayment guarantees on credits for the purchase of equipment (by small-scale miners). In Zimbabwe, the government, in addition to providing various types of loans to small-scale miners, has introduced a plant-hire scheme that is executed through regional mining engineers and administered by the Chief Mining Engineer. The project is designed as a hire-to-purchase arrangement with terms between 12 and 36 months, where equipment is hired out to small-scale miners upon payment of a small deposit.

In summary, governments must provide at least basic infrastructure in small mining districts and the necessary economic assistance. These are the key to improving socio-economic quality of life amongst small-scale miners.

5.3. Improved training and education, and dissemination and transfer of technologies

If, for argument's sake, the appropriate mining technology were available in developing countries, given current networking capabilities, could it, in fact, reach small-scale miners? In all likelihood, it could not, because effective networks do not exist for transferring imported or new domestically-produced technologies to small-scale mines. However, with improved training and education, and increased technological demonstration, critical information and technological gaps could be bridged. To make this possible, regional governments must coordinate the work and research of educational units and NGOs, and design and implement effective educational and training programmes. They must also ensure that effective environmental technology reaches miners, in order to minimize complications with wastes and pollution.

Environmentally, there is merit in constructing regional small-scale mining centres, which could serve as a valuable platform for disseminating essential environmental and health information. One option is to create a series of general centres that provide a wide range of services to small-scale miners. Such a setup exists in Ghana, where, shortly after the legalization of small-scale mining in 1989, eight district centres were established in the southern part of the country. Each is staffed by a mine engineer and a mines inspector who help register claims, provide technical advice, and encourage the safe and productive operation of local mines (UN, 1996). Such an idea was novel, and with increased hiring of professionals, could serve as an important catalyst for distributing needed knowledge. Alternatively, small-scale mining centres could be designed to have more specific research agendas. The UN Industrial Development Organization (UNIDO), for example, has helped finance the establishment of South American UNECA (Unit of Gold Extraction and Controlled Amalgamation) Centres, the aim of which is to provide small-scale gold miners with extraction services and training. Highly skilled technicians and engineers operate each Centre, which features advanced amalgamation processes from which mercury emissions are controlled (Veiga and Beinhoff, 1997). Each also plays an important role in providing key information on mercury to the public, and in transferring technical skills to miners. The idea is that miners bring excavated material to the Centre for processing, which immediately helps improve control of mercury in the system. Courses on environmental- and health-related subjects can also be provided at local universities for small-scale miners that could emphasize specific aspects of environmental management, health and safety, and be designed with the purpose of teaching the basics.

Governments must also play a lead role in disseminating clean technologies and accompanying environmental and health information to small-scale miners. This can be accomplished in a number ways, including through:

- Internet media, such as the Mineral Resources Forum (www.natural-resources.org), which can provide dialogue and exchange of information between people interested in environmental issues relating to minerals development from across the entire spectrum (though most small-scale miners do not have access to high-tech equipment such as computers, most local universities and agencies do provide internet services);
- Technical publications (e.g. tailings management, environmental management systems, occupational health, etc.), which can act as valuable resources for miners and aid them in the performance of their duties;
- Surveys and studies of relevant issues, which can help identify problem areas and lead to promising solutions;
- Training, training support and curriculum support for education and training institutions and for use in in-house training programmes in small-scale mining regions of all types; and
- Forging partnerships with various research and international institutions to work cooperatively on policy development.

Technological demonstration projects must also be financed, which help bridge critical information gaps concerning possible environmental technologies and strategies. Take, for example, the issue of mercury, which, if mismanaged, poses a number of serious environmental threats. As Wotruba (1997) explains, a number of the simple technological devices available on the market, including sluices, jigs, shaking tables, spiral concentrators, amalgam drums, upward-current separators, and retorts could help to minimize emissions of mercury. In fact, implementation of mercury control technologies has already led to vast environmental improvements. In Bolivia, for example, approximately ten tons of mercury per year is no longer released into the environment as a result of utilizing jigs, sluices, tables and concentrators. Similar improvements can be achieved in other small-scale mining regions worldwide if teams of highly skilled experts conduct government-sponsored

demonstration projects. Demonstration projects can also provide training in the areas of blasting, excavation, transport and mineral processing.

Clearly, a combination of legislative changes, enhanced socio-economic development and financial support, and improved training and education could greatly improve sustainability in the small-scale mining sector.

6. Summary and conclusion

The aim of this article has been to provide an overview of the socio-economic impacts of small-scale mining in developing countries. Clearly, from the analysis, though small-scale mining is inherently environmentally destructive and can cause a number of health and safety complications, it also provides a number of important socio-economic benefits to millions of people in Africa, Latin America and Asia, and contributes significantly to national revenue earnings in many developing countries. These contributions alone make the industry indispensable.

It is important, however, that progress be made toward improved sustainability in the sector. Many of the sector's problems are pressing and require immediate attention, though it is unrealistic to expect that miners can achieve sufficient improvements on their own, given current economic and technological conditions at most small-scale mines. Governments and international agencies must therefore play an expanded role, and do what is necessary to eliminate critical technological, economic and information gaps. The costs in promoting a more sustainable small-scale mining industry could initially be economically challenging for regional governments but over the long term, rewards would certainly be reaped from the improved industrial performance. To highlight a few: a 'cleaner' small-scale mining industry would translate into fewer environmental problems, and reduced cleanup costs for governments to finance. Addressing the needs of small-scale mining in national mineral policies would improve the credibility and stability of the sector, and intraducing more support schemes would improve regulation and decrease illegal mining activities. More importantly, by promoting sustainable development in the industry, the government facilitates increased mineral production, which in turn contributes positively to foreign exchange earnings and exports. International organizations, such as the United Nations and the World Bank, could further help deliver assistance to small-scale miners in a number of regions around the world, since most employ experienced staff from a wide range of educational disciplines. These agencies, in effect, could play the role of facilitator, not only by assisting small-scale miners directly, but also by helping to coordinate the activities of governments.

Improved sustainability can be achieved in the small-scale mining sector if governments legalize small-scale mining activity and implement sector-specific legislation, and, with cooperation from international agencies, provide increased economic assistance to miners and contribute further to enhanced community development, and assume an expanded role in relevant industrial training, and education technology transfer processes.

Acknowledgements

The author would like to thank Ms Marcia Brewster, Dr Mario Sánchez and an anonymous reviewer for their impressions and comments on an earlier version of this article. The author would also like to acknowledge the staff of the Institution of Mining and Metallurgy (UK) for their support of future research activities in this area.

References

Al-Hassan, S., Suglo, R.S., Cobblah, A., 1997. The socio-economic impact of small scale mining in Ghana. In: Strakes *et al*. (Eds.) *Mine Planning and Equipment Selection*. Balkema, Rotterdam.

Amegbey, N.A., Dankwa, J.B.K., Al-Hassan, S., 1997. Small scale mining in Ghana — Techniques and environmental considerations. *International Journal of Surface Mining, Reclamation and Environment* 11: 135–138.

Amavilah, V.H.S., 1998. Cross-sectional Profitability of the Namibian Formal Small-scale Mining Firms in 1990. *Small Business Economics* 11: 57–73.

Astorga, T.S., Duran, N.M., 1994. The Rural Youth Artisan Mining Sector. *Small Mining International Bulletin* 7: 12–15.

Ávila, E.C., 2000. *La llamada pequeña minería: un renovado enfoque empresarial*. División Recursos Naturales e Infraestructura, Santiago, Chile.

Barry, M., 1997. Addressing Social Tensions in Mining: A Framework for Greater Community Consultation and Participation. In: Ghose, A.K. (Ed.), *Small/Medium Scale Mining* Oxford & IBH Publication Company, UK.

Berger, A.R., 1982. The Importance of Small-Scale Mining: A General Review. *Strategies for Small-Scale Mining and Mineral Industries*, Association of Geoscientists for International Development (AGID) Report No. 8. UNESCO Workshop, Kenya.

Bocoum, A., Samba, A., 1995. *Le secteur artisanal en Republique Centrafricaine: Aspects socio-economiques et organisationnels.* International Roundtable on Artisanal Mining, World Bank, Washington, D.C.

Borla, G., 1996. Artisanal mining activities in developing countries. *Geoingegneria Ambientale E Mineraria* 33(4): 171–177.

Bugnosen, E.M., 1998. *A Preliminary Assessment of Small-Scale Mining Legislation and Regulatory Frameworks*. Department for International Development (DFID), Intermediate Technology Development Group, UK.

Bugnosen, E., Twigg, J., Scott, A., 1999. Small-Scale Mining Legislation and Regulatory Frameworks. *Minerals and Energy: Raw Materials Report* 14(2): 35–38.

Buntenbach, S., Shoukry, B., Pret, N., 1995. Traditional Processing of Gold, Its Significant Environmental Problems and a Notice for Small-Scale Goldmining. *Proceedings of the XIX International Mineral Processing Congress: Precious Metals Processing and Mineral Waste and the Environment, 4*. SME, Littleton, Colorado.

Carman, J.S., 1987. Why Small Mining? *Episodes* 10(3): 159–164.

Davidson, J., 1993. The transformation and successful development of small-scale mining enterprises in developing countries. *Natural Resources Forum* 17(4): 315–326.

De Kom, J.F.M., van der Voet, G.B., de Wolff, F.A., 1998. Mercury Exposure of Maroon Workers in the Small Scale Gold Mining in Suriname. *Environmental Research* 77: 91–99.

Ghose, A.K., 1994. New Configurations of Small-scale Mining for Developing Countries. In: Ghose, A.J. (Ed.), *Small-Scale Mining: A Global Overview* A.A. Balkema, Rotterdam.

Hollaway, J., 1997. Small-scale mining: how to combine development with low environmental impact. *Industry and Environment*, December, 44–48.

International Labour Organisation (ILO), 1999. *Social and labour issues in small-scale mines*. Report for discussion at the Tripartite Meeting on Social and Labour Issues in Small-scale Mines. International Labour Organisation, Sectoral Activities Programme, International Labour Office, Geneva.

Jennings, N.S., 1993. Small-scale mining in developing countries: Addressing labour and social issues. *Guidelines for the development of small/medium-scale mining*. United Nations, New York.

Jennings, N.S., 1994. Small-scale Mining: A Labour and Social Perspective. In: Ghose, A.J. (Ed.), *Small-scale Mining: A Global Overview* A.A. Balekma, Rotterdam.

Jennings, N.S., 1997. Addressing Social Tensions in Mining: Framework for Greater Community Consultation and Participation. In: Ghose, A.K. (Ed.), *Small/Medium Scale Mining*. Oxford & IBH Publication Company, UK.

Kambani, S.M., 1995. The illegal trading of high unit value minerals in developing countries. *Natural Resources Forum* 19(2): 107–112.

Kumar, R., Amaratunga, D., 1994. Government policies towards small-scale mining. *Resources Policy* 20(1): 15–22.

Labonne, B., 1994. Small- and medium-scale mining: The Harare seminar and guidelines. *Natural Resources Forum* 18(1): 13–16.

Labonne, B., 1996. Artisanal mining: an economic stepping stone for women. *Natural Resources Forum* 20(2): 117–122.

Lacerda, L.D., 1997. Global Mercury Emissions from Gold and Silver Mining. *Water, Air and Soil Pollution* 209–221.

Lacerda, L.D., Salomons, W., 1998. *Mercury from Gold and Silver Mining: A Chemical Time Bomb?* Springer-Verlag, New York.

Malm, O., 1998. Gold Mining as a Source of Mercury Exposure in the Brazilian Amazon. *Environmental Research* 77: 73–78.

McKechnie, K.R., 1995. Impact of mineral and fiscal legislation on and role of governments in the development of mining industries in developing countries, in *African Mining '95*. Institution of Mining and Metallurgy, London.

McMahon, G., Evia, J.L., Pasco-Font, A., Sanchez, J.M., 1999. *An Environmental Study of Artisanal, Small, and Medium Mining in Bolivia, Chile, and Peru*, World Bank Technical Paper Number 429. The World Bank, Washington D.C.

Meech, J.A., Veiga, M.M., Tromans, D., 1998. Reactivity of Mercury from Gold Mining Activities in Darkwater Ecosystems. *Ambio* 27(2): 92–98.

Noetstaller, R., 1994. Small-scale mining: practices, policies and perspectives. In: Ghose, A.K. (Ed.), *Small-scale Mining: A Global Overview*. A.A. Balkema, Rotterdam.

Noetstaller, R., 1995. Historical perspective and key issues of artisanal mining. *Paper presented at the International Round Table on Artisanal Mining*. World Bank, Washington The D.C.

Peiter, C., Villas-Boas, R.C., Shinya, W., 2000. The stone forum: implementing a consensus building methodology to address impacts associated with small mining and quarry operations. *Natural Resources Forum* 24 (1): 1–9.

Priester, M., Hentschel, T., Benthin, B., 1993. *Tools for Mining: Techniques and Processes for Small Scale Mining*. Vieweg, Gate Publications, Germany.

Solomon, M.H., 1997. Small and mid-scale mining in South Africa: beyond the rhetoric. *Raw Materials Report* 12(3): 23–30.

Traore, P., 1994. Constraints on small-scale mining in Africa. *Natural Resources Forum* 18(3): 207–212.

Traore, P., 1997. Strategies for development of Small/Medium Scale Mines in Africa. In: Ghose, A.K. (Ed.), *Small/Medium Scale Mining*. Oxford & IBH Publication Company, UK.

United Nations (UN), 1972. *Small-scale mining in developing countries*. Department of Economic and Social Affairs, United Nations, New York.

UN, 1992. *Mining and the environment: the Berlin Guidelines, a study based on an international Round Table in June 1991*. Mining Journal Books/UN Department of Technical Cooperation, United Nations, New York.

UN, 1996. Recent developments in small-scale mining: A report of the Secretary-General of the United Nations. *Natural Resources Forum* 20(3): 215–225.

UN Economic Commission for Africa (ECA), 1993. *Development and utilization of mineral resources in Africa*. Report of the Fifth Regional Conference. ECA, Addis Ababa., Ethiopia.

Veiga, M.M., Beinhoff, C., 1997. UNECA Centres: A way to reduce mercury emissions from artisanal gold mining and provide badly needed training. *Industry and Environment* 20(4): 49–51.

Veiga, M.M., Meech, J.A., 1999. Reduction of Mercury Emissions from Gold Mining Activities and Remedial Procedures for Polluted Sites. In: Azcua, J.M. (Ed.), *Environmental impacts of mining activities: emphasis on mitigation and remedial measures*. Springer-Verlag, New York.

Wotruba, H., 1997. Environmental protection in small-scale primary gold mining in Bolivia. In: Holberg, H. (Ed.), *Proceedings of the XX International Mineral Processing Congress. Material Analysis, Plant Design, Operating Practice, Control and Simulation*, 1 GMDB, Aachen, Germany.