Introducing New Technologies for Abatement of Global Mercury Pollution in Latin America

Marcello M. Veiga.

UNIDO
United Nations Industrial Development Organization

UBC
University of British Columbia

CETEM
Center of Mineral Technology

- 1997 -

INTRODUCING NEW TECHNOLOGIES FOR ABATEMENT OF GLOBAL MERCURY POLLUTION IN LATIN AMERICA

Marcello M. Veiga*

*Metallurgical Engineer, MSc, PhD,
Consultant for UNIDO
Assistant Professor of the Department of Mining and Mineral Process Engineering
University of British Columbia, Vancouver, BC, Canada

All requests for extra copy of this issue shall be addressed to:

CETEM-Centro de Tecnologia Mineral
Rua 04, Quadra D, Cidade Universit'aria, I. do Fundão
21941-590 - Rio de Janeiro - RJ - Brazil

Veiga, Marcello M.

Introducing New Technologies for Abatement of Global Mercury Pollution in Latin America - Rio de Janeiro: UNIDO / UBC / CETEM / CNPq, 1997

94p.: il

1. Mercury-Pollution. I. Pollution-Latin America. II. Center of Mineral Technology. III. Title

ISBN: 85-7227-100-7 CDD:620.8

Executive Summary

The new gold rush in Latin America which started in the 1980s has involved millions of people who became artisanal miners to escape complete social marginalization. For developing countries, the presence of artisanal miners represents an embarrassing situation, a strong contrast with the concept of modernity and efficiency pursued by the dominant society. Most Latin American countries face enormous social and environmental problems derived from poor mining practices taken together with lack of economic alternatives. The UN technical departments, especially the Department for Development Support and Management Services and UNIDO have shown consistent interest in this field. Strategies to deal with this situation have been developed and shared with governments and specialists around the world.

This document reports the extent of artisanal gold mining activities in Latin America. Solutions to reduce mercury emissions and amend highly polluted sites are also suggested. It is possible to estimate that about 1 million artisanal miners are currently mining for gold in Latin America and their annual production can be as high as 200 tonnes (6.4 Moz) of gold. Apparently, more than 200,000 women are participating in the labor force of the artisanal mining as individual panners, employed as cooks or as owners of mining operations.

Some facts contribute towards reduction of mercury emission in Latin America from the extremely high levels observed at the end of the 1980s:

1. Reduction of the informal mining activities in Brazil and consequently the gold production, due to scarcity of easily exploitable ores.
2. Introduction of retorts and cyanidation in some more-organized artisanal mining regions. More information about mercury poisoning is reaching those artisanal miners associated with Associations and Cooperatives and they are adopting some precautions. The NGOs have played an important role in suggesting technical improvements.
3. High production costs are driving miners to recycle mercury. Many miners are amalgamating just the gravity concentrates, instead of the whole ore.

The paucity of alluvial ores in the Brazilian Amazon is pushing “garimpeiros” (artisanal miners) to invade neighboring countries creating diplomatic problems between governments. Guyana, French Guyana, Bolivia, Venezuela and specially Suriname are experiencing a rampant increase in illegal mining activities.

Mercury is a very inexpensive reagent to extract gold (US$ 6.7/kg price in N.Y. in April 1997). A variety of mining and amalgamation methods are used in artisanal mining operations. Taken together with the fate of contaminated tailings and Au-Hg separation procedures, these methods will define the extent of mercury losses from a specific site. When the whole ore is amalgamated the mercury losses can be as high as 3 times the amount of gold produced. When only concentrates are amalgamated, the main source of mercury emission is the burning of amalgam in open pans. The process produces a gold sponge containing about 20 g of mercury per kg of gold which is released when this gold is melted at gold shops. Studies have shown that the majority of Hg emitted by gold smelters is deposited near the emission source (i.e. within 1 km), contaminating the urban areas.

Considering a ratio of 1:1 for gold produced and mercury lost, an approximate estimate of the mercury levels being emitted in Latin American countries is obtained. The emission might be around 200 tonnes of mercury annually. Since the beginning of the new gold boom in Latin America, at the end of 1970s to the present, around 5,000 tonnes of mercury might have been discharged into the forests and urban areas. The high content of organic acids in sediments and waters favors oxidation of metallic mercury dumped by

miners into the waterstreams or precipitated from the atmosphere. Soluble Hg-organic complexes transform into methylmercury which is rapidly taken up by species in aquatic environments. Symptoms of mercury poisoning are detected in miners, gold dealers and citizens living near the emission sources. Riparian communities who have fish as the main diet have shown high levels of mercury in blood. Women and children, are the main victims because of the lack of information about the danger of this insidious pollutant. The future generations of Latin Americans will inherit a legacy built upon the continuing discharge of mercury. Solutions must be provided rapidly for affected communities to avoid a future epidemic situation.

Despite the fact that some miners are still amalgamating the whole ore, the use of mercury to extract gold only from gravity concentrates represents an important evolution to reduce mercury losses. Reduction of mercury emission is a feasible and practical way to cope with the problem in Latin America. There are two approaches to be followed :

1. Systemic Solutions are those which consist of measures dependent on institutions, agencies and even private companies for implementation.
2. Individual Solutions are those brought to miners by various sources but their use depends on each individual to adopt the suggested measures.

In both approaches, education is a pre-requisite for the long-term solution of the mercury emission problem. Educational measures can be seen as an assembly of recommendations addressed at the people involved directly or indirectly with mining in order to convince them to adopt safe methods for the environment and themselves. Miners must be convinced that they are being affected by mercury vapors and causing irreversible health problems to their neighbors, friends and family members. A few brochures explaining the danger of mercury vapors are being distributed by international institutions and association of miners. Disorganized and incorrect information on hazardous problems with mercury, usually creates hysteria and increases the gap between artisanal miners and different sectors of society.

The creation of Processing Centers to amalgamate or leach gravity concentrates is emphasized as the most concrete systemic solution to reduce emissions or even eliminate mercury use. Since miners agree to bring gravity concentrates to these Centers, as observed in Venezuela, the amalgamation can be conducted safely and with no Hg emission. Leaching processes, such as an electrolytic process using salt table is a practical and environmental friendly alternative to dissolve gold from concentrates.

Other systemic solutions to reduce mercury emissions are:

- Formal education is schools.
- Creation of Miner Associations as a form of organization.
- Law Enforcement.
- Permanent biological monitoring and technical assistance.

Individual solutions comprise a group of procedures focusing directly at the individual artisanal miner and gold dealer to reduce mercury emissions. Occupational exposure can be drastically reduced with simple measures which frequently are ignored by or never shown to unskilled miners. Methods to minimize Hg emissions, such as the use of special Hg-plates to amalgamate gold from gravity concentrates, use of home-made retorts and filters in shops melting gold are simple solutions to be promoted to gold miners.

The possibility of other sources of mercury are contributing to increase mercury levels in aquatic biota in Latin America is likely and has been investigated. Forest fires can release natural mercury from vegetation or remobilize mercury emitted by miners. Mercury bioaccumulation is also favored by water impoundment as the rate of mercury methylation increases with decomposition of submerged vegetation.

Techniques to reduce mercury bioaccumulation in aquatic environments are only applicable for enclosed systems. The high cost of these measures is a major impediment. Unfortunately, the only practical and immediately applicable option for regions where mercury is dispersed and bioaccumulation is occurring is a massive educational campaign to change food habits of riparian people.

In the mine sites, it is recognized that women are excellent couriers of information. They can advocate changes on the poor amalgamation methods practiced by their relatives. As women are the most sensitive victims of mercurialism (either by mercury vapors or methymercury ingestion) they must be the target of campaigns to reduce mercury emissions. As they are usually the family cooks, they must be informed about the risk of intensive carnivorous fish consumption. As well, they can change family food habits.

The transitory nature of the artisanal mining activity in Latin America is clear. Extinction of surface ore is a natural consequence of artisanal mining activities. The manual operations will persist for many decades for subsistence of those rural communities living in remote areas. However, the large mechanized rudimentary operations tend to disappear. When these miners extract gold from quartz veins, this is the beginning of the end of their activities, i.e. they do not have technology, geological information or capital to invest in underground mining and the result is usually bankruptcy. Governments must find a way to transfer legal titles to those who indeed have discovered large majority of the gold and diamond deposits in Latin America. This is a way to stop migration of these miners and create concern about the environment. Alternatives for the future of the artisanal miners must be searched with legal and technical support to include these unprivileged people into the organized society.

Since 1990, UNIDO has provided assistance to the artisanal mining sector in promoting low cost techniques to improve gold recovery, in advising governments about mining policies, in devising sustainable small-scale concepts and in suggesting measures to reduce environmental and occupational impacts. This document intends to provide technical subsidies for decision-makers who are coping with high levels of mercury emission and remediation of polluted sites. Several possible solutions are examined and the most practical and feasible measures are highlighted.

TABLE of CONTENTS

LIST of TABLES

LIST of FIGURES

ACKNOWLEDGMENTS

This work was originally written as a report to UNIDO.

This work was conducted with the active participation of Dr. Sonia M. B. Veiga in collecting data and writing about Women in Gold Mining Activities.

Mr. Christian Beinhoff - UNIDO, Vienna is acknowledged for his idea to originate this work as well as for his permanent support and supervision.

By all infrastructure and administrative support, The Department of Mining and Mineral Process Engineering of the University of British Columbia is acknowledged.

The contribution of the following individuals, institutions and companies is accredited:

- Dr. Alvaro Sanchez-Crispin and Dr. Maria Teresa Sanchez Salazar, Inst. Geografia, UNAM, Univ. Autónoma de Mexico.
- Mr. Armando Salazar Gutierrez, Unidad de Información Minero-Energética, Ministry of Mines and Energy, Colombia.
- Dr. Bernardo Hernandez Morales, Dept. Ing. Metalúrgica, UNAM, Univ. Autónoma de Mexico.
- Mr. Eduardo Baeza H. from CID Computación, Chile.
- Dr. Eduard H. Dahlberg (Henk), Hibbing, MN, USA.
- Mr. Frederico Grant from Bennet & Associates, Costa Rica.
- Dr. Jan Quik, Environmental Research Center, University of Suriname.
- Dr. John Meech, University of British Columbia, Vancouver, Canada.
- Dr. John Twigg, Intermediate Technology, United Kingdom.
- Mr. Michael Priester, Projekt-Consult GmbH, Germany.
- Dr. Roberto Villas Boas, Mr. Ronaldo Santos and Mr. Ramon V. V. Araújo, CETEM, Brazil
- Mr. Unmesh Wankhede, UBC, Vancouver, Canada.
- Mr. Victor Jaramillo for information about Peru.
- Mr. Victor Lahmer, Eaglecrest Explorations, Vancouver.
- Mr. Victor Garcia, Direción de Mineria, Domincan Republic.
- Mr. William Woolford, Guyana Geology and Mines Commission, Guyana.
- Mr. William Lady an important part of the Mining History of Honduras.

1. Context of Artisanal Gold Mining Activities in Latin America

1.1. A Brief History of a New Gold Rush

The History of Latin America is intimately associated with prospecting and extraction of gold, silver, diamond and gems. In the 15th century, the feudal European development was limited by the need of precious metals as the basis of the *Metal Mercantilism*, an ideology that considered rare metals as the only authentic form of wealth. In Europe, gold was considered the main precious metal whereas in Asia, silver had more value. Transylvania was the only gold producer in Europe and silver was mined in Germany, Austria, Hungary and Bohemia[1].

At the beginning of the 16th century, the interest of the Iberian Peninsula countries was focused on searching for gold and silver in their colonies. The first Portuguese expedition to Brazil occurred in 1504 along the Atlantic shoreline. No positive result was registered. Many other expeditions did not result in finding important deposits of precious metals. Small amount of gold was mined in 1552 near São Paulo[2]. In 1545, Spanish mineralogists discovered silver in Cerro Potosí, in nowadays Bolivia. The agreement between Portugal and Spain to form a single government, so-called Iberian Union (1580-1640), had reduced interest of the Portuguese merchants for expeditions to Brazil. They took advantage of the Spanish silver mines already in production in Mexico and Bolivia. A significant gold rush started in Brazil at the end of 17th century when gold was discovered in Vila Rica (currently the town of Ouro Preto). Many expeditions have found gold in inaccessible areas of South America. Nowadays, vestiges of pioneer work are found in remote regions of the Amazon. In 1750, Brazil was the main world gold producer with an annual output of 500,000 oz or 15.5 tonnes[3]. A clear relationship between extensive extracting of natural resources and colonization was observed during the colonial times and, as seen in North America, many villages were formed based on gold production and later, other economic activities were developed.

Gold mining in South America increased in the 70s, by the end of the Breton-Woods agreements (1944), which fixed the price of a troy-ounce (31.1g) of gold at US$ 35 for a long time. The price of gold gradually rose during the 70s, leading to the reworking of ores hitherto considered as low grade. In early 1980 gold reached a record peak of US$ 850 per troy-ounce.

It is recognized that the contemporary gold rush in Latin America was triggered in January 1980 in Brazil when a solitary panner, José Feitosa, found gold in Serra Pelada, in the Amazon region. The mineral claim was already staked by a State-owned mining company, which had not investigated the presence of gold but only iron and manganese. Serra Pelada is a historical landmark and a social phenomenon that very unlikely will be repeated. At the end of the 70s, the military Brazilian government was missing popularity and the petroleum crisis was consuming country's monetary reserves. When Serra Pelada was discovered, the government intervened in the matter, creating the first artisanal mining reserve and encouraging people to move to Amazon. About 80,000 men[4] from different parts of the world were working like ants in Serra Pelada to produce from a single open pit about 90 tonnes of gold[5]. All technologies from wooden sluice to

---

[1] Albuquerque, M.M. 1981. Small History of the Brazilian Social Formation. Ed. Graal Ltd. Rio de Janeiro. 728 p. (in Portuguese).

[2] METAMIG - Metais de Minas Gerais, 1981. Gold. 3rd edition. Belo Horizonte. 222 p. (in Portuguese).

[3] Coppola, M. 1994. Gold Rush in Brazil. Randol at Vancouver '94 - Latin America Mining Opportunities. Oct 31-Nov. 2. p.43-50.

[4] Women were not allowed in Serra Pelada. Curionopolis is the nearest village formed to hold the infrastructure for the mining activities.

[5] Feijão, A.J. and Pinto, J.A., 1992. Amazon and the Gold Saga of the 20th Century. In: *Garimpo, Meio Ambiente e Sociedade Indígenas*, p.18-36. Ed. L. Barbosa; A.L. Lobato; J.A. Drummond, EDUFF- Ed. Univ. Fluminense, Niteroi, RJ (in Portuguese).

bioleaching were used in Serra Pelada to extract gold.

Presently, the open pit is flooded and less than 800 miners are struggling to survive by reprocessing tailings. Recently, Serra Pelada came back to the headlines of the international press, when the mineral claim owner announced that 300 tonnes of gold were discovered in an area 12 km far from Serra Pelada. About 3000 artisanal miners invaded the company camp, stopping all drilling activities. The conflict resulted in deaths, but now an agreement between miners and company is about to be completed.

In the 80s, Brazilian government spread news with exaggerated patriotic indoctrination that Serra Pelada would produce enough gold to cover a US$ 100 billion external debt. At that time, all military governments in Latin America were adopting a similar development speech to justify gigantic infrastructure projects. The mechanized mining was spread across the Amazon changing the characteristic of the manual mining work hitherto used by gold panners. News about Serra Pelada echoed in neighboring countries, such as Ecuador, Peru, Colombia, Guyana, Venezuela, French Guyana and Bolivia and ordinary people, oppressed by poverty, started small mining operations using mechanized processes, as well.

Around 2,000 mining sites were worked by artisanal miners in 1990 in the legal Brazilian Amazon Region. They were responsible for the highest steel consumption per capita in Latin America as well as diesel oil, carpets (for gold sluices) and other goods. That year, more than 25,000 units of mining equipment, 20 helicopters, 750 airplanes and 10,000 boats (some as large as ships) were used to produce an estimated 100 tonnes of gold. The environmental costs that have been paid for this production are only now being measured. The impacts of artisanal mining include deforestation, river silting, invasion of indigenous reserves, mercury poisoning, dissemination of prostitution and diseases, degradation of moral standards, depletion of non-renewable resources, soil destruction, etc.

Experts[6] have estimated that 1 in 900 Latin Americans are employed in gold and silver artisanal mining and virtually all countries in Latin America have artisanal miners. Some countries are facing enormous social and environmental problems derived from poor mining and processing practices associated with lack of economic alternatives.

1.2. Some Definitions

A wide range of mining and mineral processing activities are classified as <u>artisanal mining</u>. This ranges from individual panning to large dredging operations. Quite often the terms artisanal and peasant miners are applied to make reference to low-tech manual panners. However, even in a large-scale production, most of those miners do not follow conventional technical approach adopted by organized mining companies. The way of working makes a difference. The artisanal miner works, based on instinct, need for feeding his family and paying bills. There is no previous “classical” geological exploration, no drilling, no proven reserves, no ore tonnage establishment and engineering studies. The concept of survival is constantly the driving force for those miners.

<u>Informal mining</u> is a broad term that usually indicates illegal activities. Miners are not examples of taxpayers. When gold is sold locally to banks or gold shops, more control is exerted than when it is sold to individuals who use the metal for money laundering. Often, contracts are not signed and production is not shown. Informal is an appropriate denomination for those miners who are indeed part of a hidden, but regionally important, economy.

---

[6] Inter Press Service, 1995. Development-Mining: Small-Scale Miners Get World Bank Attention. Website: http://www.lead.org/ips/demo/archive/05_22_95/1.html

In many countries the official definition of these miners is based on the production scale. In Chile, an operation processing less than 20 tonnes daily is characterized as small mining[7].

The term small mining does not imply in informal or rudimentary operations. There are many small mines in North and South America using adequate technologies to extract gold from small primary gold deposits respecting legal and environmental regulations.

In Venezuela, to be a small miner, one has to fill out forms requesting an area and the criteria to classify a small mining operation is established by a group of analysts (Contract Committee). This includes representatives from Government, National Guard, Cooperatives and natives' representative. However, unofficially, a small mining operation in a river is considered that one which uses dredges smaller than 15 m. The Mining Law of Jan. 18, 1945, establishes as 20,000 ha as the maximum area for an alluvial mining.

In Brazil, the Mining Law 227 of Feb. 1967 defined "garimpagem" (artisanal activities) as*: individual work performed by panners*; *rudimentary form of mining using manual or portable equipment; mining process to be applied only to alluvial, colluvial and elluvial deposits*. This old fashion definition excludes the fact that "garimpagem" in the 80s and 90s became more mechanized with numerous external investors and employees. It also limits the mining activity to secondary ores. In the law 7805/1989, the classification of "garimpagem" is still attached to the type of ore deposit. The geological characteristic delimits the type of useful technique. The Decree 98,812 of Jan. In 1990 limits the type of minerals available to "garimpagem" (gold, diamond, cassiterite, tantalite and wolframite), instead of the type of ore deposit. Now primary ores of these minerals are legally available for artisanal work, but the sites where artisanal miners can work were also limited. Artisanal mining is only accepted in the "Reservas Garimpeiras" (reserves for "garimpagem") and a special permit to work ("lavra garimpeira" permit) must be obtained from the National Mining Department. This measure did not stop the migratory characteristic of the miners. The most organized miners were privileged. To obtain this special permit, an individual must present an elaborated report on Environmental Impact Assessment. A miner faces a huge bureaucracy if he/she wants to negotiate this type of permit with companies. After seven years, it seems that the idea of designating specific sites to be mined by artisanal miners has brought relative benefits to some miners. On the other hand, with no technical support, the social and environmental problems in these reserves were augmented. The concept of artisanal mining reserves is currently being reviewed.

The nature of the deposit and the operation size are vague concepts to define which mineral is allowed to be mined by artisanal methods. In South America there are some operations with capacity to process over 5 million m^3 of ore annually using rudimentary methods. The lack of control in mining and processing confers an artisanal characteristic to those operations. It is clear that the definition of a mining activity should start by identifying who is involved in this activity, how technically and economically skilled is the individual (or company), which grade of mechanization is employed, which mining plan is established rather than define the activity by the size or type of ore. The technical approach to extract minerals can clearly distinguish between an artisanal and a conventional miner.

In Canada and US there are thousands of "artisanal" miners, applying their own mining and processing concepts to extract gold from placers. The informal characteristic of several operations is quite obvious and is not infrequently the use of mercury to amalgamate concentrates. An insignificant gold production is officially attributed to these "invisible" miners. Most of these miners have private companies. Usually,

[7] Davidson, J. 1995. Enabling Conditions for the Orderly Development of Artisanal Mining with Special Reference to Experiences in Latin America. International Roundtable on Artisanal Mining sponsored by the World Bank, Washington, DC May 17-19, 1995; unpublished. 16 p.

these miners are not gladly received in institutions which represent the organized mining society. Even while these miners represent an important potential for jobs and wealth, members of the formal mining institutions do not even mention the possibility of having those miners as allies or affiliates. For the conventional mining sector, these miners tarnish the image of mining industry. Like in Latin America, the lack of planning often causes high turnover of professionals and constant financial problems. Another type of artisanal miner in North America is the gold prospector that is fundamentally different from a producing miner. North American prospectors are geochemical explorers who use concentration techniques to evaluate gold content in stream sediments with the primary intention of staking claims to sell to mining companies. The importance of these gold seekers is acknowledged by the formal society and most of them are organized in associations. Other category of artisanal miner in North America is the week-end panner. There are lots of manuals, journals and equipment available in the market to flavor the dreams of these adventure seekers who are a part of the West-side culture.

The term artisanal miners is preferred to be used as a simple way to encompass all small, medium, large, informal, legal and illegal miners who use rudimentary processes to extract gold from secondary and primary ore bodies. The History has shown that without technical support and investment, primary ores are the worst nightmare for artisanal miners. So, artisanal activity is “naturally” controlled by the type of ore deposit. Governments need to provide assistance to guarantee that artisanal miners shall have access to legal titles and work safety concepts when working with primary ores.

In some countries in the South and Central America, the artisanal miners have different local denominations, sometimes with negative connotations. For example, in Brazil the term “garimpeiros” comes from thieves of caves (“grimpas”). In the 18th century, only a selected Portuguese elite was granted by the crown with mining permits. At night, unprivileged Brazilians used to invade the mining shafts and tunnels for panning gold furtively. The Portugueses named those individuals “grimpeiros” and Brazilians have adapted the name to “garimpeiros”. Later on, this term is improperly applied to those individual panners, who for three centuries have tried to make their fortune, or even to survive from the river gravels or surface gold ores. The term “garimpeiro” is included in the formal language to designate artisanal miner. “Garimpo” is the worksite or village and “garimpagem” is the mining activity conducted by “garimpeiros”. In the Portuguese dictionary, these terms are still associated with “smuggling or clandestine” activities.

In other Latin American countries, the artisanal miners were named by local inhabitants. In many cases, the names are derived from native’s words or regional terms that do not have a clear meaning about their origins.

- “barequeros” - in Colombia, usually are the very small panners,
- “chichiqueros” - in Southeastern Peru,
- “coligalleros” - in Costa Rica,
- “gambusinos” - in Mexico,
- “güiriseros” - in Nicaragua,
- “lavaderos de oro” - in Dominican Republic, are gold washers,
- “pirquineros” - in Chile and Argentina,
- “porknockers” - in Guyana and Suriname.

The terms “mineros artesanales” (artisanal miners) and “pequeños mineros” (small miners) are widely used in the Spanish-speaking countries in Latin America.

1.3. Artisanal Miners in Latin America and their Adversaries

The migratory, transient and usually illegal nature of the artisanal gold miners in Latin America does not bring to mine sites the same benefits of settlement as observed in the colonial times. In regions where the easily exploitable gold (alluvial) is being scarce, miners are discovering and extracting gold from quartz veins (primary ores). Usually this is the beginning of the end of the artisanal activities as the miners do not have technology, geological information and capital for underground mining operations. The solution used by the miners is to search for another gold deposit. This has created huge social and economic problems for remote communities formed exclusively based on mining activities. No economic alternative is left behind for those individuals who stay in the mining region. As it happened in North America, many ghost towns are being created in Latin America.

The economic structure of artisanal miners is not different from any other capitalist activity. The concept of maximum profit with minimum investment is always present. Regardless of the size of the activity, this always creates a kind of organization with hierarchy, duties and rules for all participants. The boss is the main investor who hires employees or, as preferred, shares part of his/her production with the workers. Likewise in any society, there are different types of people hidden behind professional categories. Some artisanal miners are trying to evolve, but some just think about immediate benefits regardless of the hazards to themselves and the environment because of their activities.

There is a wide range of reasons why an individual becomes an artisanal miner. For some, gold mining is the principal livelihood and for others, a quick way to get rich. Many wealthy farmers become miners when gold is discovered in their lands. With no technical support and low investment, many lawyers, economists, physicians adopt the artisanal mining behavior lured by the gold mystique. Nowadays, their ranches are so scrambled and contaminated that they can hardly return to their farming activities.

Protests from international environmental groups have led Latin American governments to enforce laws about miners. However, most governments handle the problem with a dual speech or simply ignore it, since they cannot provide the social services and economic stimulation to replace the positive economic benefits generated by this informal economy. As the artisanal miners do not have political power, the scorn of the dominant society has also contributed to hinder solutions for the problem.

For developing countries, the presence of artisanal miners represents an embarrassing situation in strong contrast to the concept of modernity and efficiency pursued by the dominant society. However, the artisanal mining activity is absolutely coherent with the awkward development policy adopted by most Latin American governments in the 70s and 80s. Colonization projects in remote regions have created disastrous consequences. They promote the use of natural resources (latex, nuts and cattle farming) in areas with poor soil quality and no technical assistance. In this context, artisanal mining has also the characteristics of territorial occupation, development frontier expansion[8] and somehow colonization. Nowadays, projects based on natural resources extraction are evolving to incorporate diversity of activities as well as sustainability concepts. The international change of the paradigm related to the environment, that struck the world at the end of the 80s, has created the main adversaries to the progress of artisanal mining. Since then, artisanal mining became a marginal activity with no support from governments.

In the Amazon region, concern for the environment became the focus of harsh criticisms of the miners in the 90s. For many people, Amazon is regarded as "the lungs of the world" an untouchable sanctuary of

---

[8] Barbosa, L., 1992. Garimpo and Environment: Sacred Waters, Profane Waters. In: *Garimpo, Meio Ambiente e Sociedade Indígenas*, p.49-65. Ed. L. Barbosa; A.L. Lobato; J.A. Drummond, EDUFF- Ed. Universitária Fluminense, Niteroi, RJ (in Portuguese).

nature. Deep ecologists believe that living organisms have rights and humanity must adjust to this[9]. The distinct characteristics of the Third World ecological practices are quite often disputed by First World environmentalists. The aesthetics, amenity and conservation concepts established in developed countries signify resource use and poverty for many developing people[10]. In spite of being a habitat for five million species, few people realize that over 25 million people (about the same as the Canadian population) live poorly organized in the Amazon, using inadequate farming methods and coping without technical assistance in agriculture projects that attracted thousands of peasants to such a harsh environment. A strong centralization of the economic and political power into hands of small elite groups occurs in these regions. In 1996, the conflict between landless groups and Southern Amazon's cattle farmers ended up with almost 30 deaths.

Most people in developing countries become miners to escape complete social marginalization. As a result of the inequities in rural-land ownership, mining is an important escape valve for the predictable outcomes of an agrarian crisis[11].

When the contemporary gold rush boomed in Latin America, artisanal miners met a strong adversary: the formal mining companies. In their attack, the environmental component is rarely used, but rather the illegality and inefficiency of crude technologies used by the artisans. In many cases, artisanal miners, acting as gold prospectors, have been much more successful than professional geochemical exploration teams, not only because of experience but also as a result of their willingness to endure harsh environments. Companies claim that miners invade properties, but quite often these miners are ones who have actually discovered the ore bodies. The formal sector constantly applies political pressure on the national governments to ensure that favorable mineral exploration laws are not revised.

Frequently, the Press plays a significant role in creating fantasies about mining activity and mercury pollution resulting in misunderstandings by society. Actually this is not a "privilege" of Latin Americans. Many shows in North America have highlighted the negative sides of artisanal mining. In the Walt Disney cartoon, Pocahontas, miners (colonizers) are depicted as villains who destroy trees, lands and native cultures. On January 16, 1997, the TV series "Tarzan" presented an episode in which an artisanal miner with a small sluice box killed more than 100 animals, including fish, panthers, monkeys, birds by discharging mercury into the river. Of course, Tarzan stopped this ecocide and saved the rain forest from further perils. In Venezuela, a local newspaper published stories about metallic mercury dripping out of water taps in the villages. In Brazil, even with no evidence, newspapers attribute to mercury the birth of brainless children in the Amazon. In all Press matters, there is a clear indication that mercury is a taboo that cannot be discussed by ordinary people, but is reserved only for a privileged elite of "specialists". The Press, the courier of information for the dominant society, frequently looks for sensationalism instead of reliable advice. Fantasies, panic and political interests result from the poor role played by the Press. Affected communities (miners and fish-eating people) have been ignored.

It is clear that the conflict related to artisanal mining activities is not between humanity and nature but between humans at the bottom of society's hierarchy versus those on higher levels. Artisanal miners are a diffuse, under-represented minority who because of their limited economic situation are particularly vulnerable to exploitation and government duplicity. For many developing countries, small-scale mining can represent a more labor intensive activity, which accommodates non-skilled workers, and be less

---

[9] Merchant, C. 1992. Radical Ecology: The Search for a Livable World. Routledge Pub., New York.

[10] Redcliff, M. and Goodman, D. 1991. Environment and Development in Latin America: The Politics of Sustainability. Manchester Univ. Press.

[11] Hecht, S. and Cockburn, A. 1990. The Fate of the Forest: Developers, Destroyers and Defenders of the Amazon. Penguin Books, London.

susceptible to the impoverishing ravages of the economic cycles[12]. The main questions related to artisanal mining are: is it possible for developing countries to accommodate this sort of informal economy in a controlled and organized fashion? Is it possible to integrate artisanal mining activities in specific regions into a sustainable environment? How can appropriate legal framework be provided to administer mining activities attempting to transform the diffuse workers into mining companies? Can this activity contribute to poverty reduction by providing order to the chaos? What kind of technological and economic support is needed to find less environment-impacting extraction processes? How can women be supported as an important element for stable colonization programs and to implement sustainability concepts in their communities?

Governments must be prepared to move beyond the establishment of legal frameworks, to identify deposits and areas amenable to artisanal miners. Governments should be further encouraged to recognize the constructive possibilities of working closely with local and international organizations; of expanding the scope for local participation including special attention to educational and gender issues and opportunities; of establishing technical support; of promoting local credit facilities and partnership arrangements with the domestic and foreign private sector as well as environmental responsibility and occupational safety[13].

1.4. Role of Women in Artisanal Gold Mining in Latin America

The world has been affected by fundamental changes in its economic relations in which women are the major factor. The economic development and growth appear to be related to the advancement of women. Despite a renewal in economic growth worldwide, the number of people living in absolute poverty has increased in developing and developed regions alike. The relationship between poverty and gender is linked strongly with the situation of female-headed households, which is considered to be a significant indicator of female poverty. The female-headed households mean that there is no adult male present and women are the only support. Female headship can be a result of migration, family dissolution or male mortality. Whether employed or not, women have the major responsibility of household, work and the care of children and other family members[14].

Poverty is particularly acute in rural areas and has consequences for women. A combination of factors such as cutback in services, female illiteracy, male out-migration and limited access to factors of production lead to feminine rural poverty. The employment of women relative to men has been increasing due to their qualifications, but it is underpaid and has a short-term perspective. In developing countries, the work is typically in agriculture and informal sectors where the conditions are poorly regulated and often precarious.

The participation of Latin American women in the labor force has depended on the patterns of social and economic development prevailing in their countries and by the status of their gender. Due to cultural reasons, in Latin America, the work division in families is usually practiced. Women are responsible for housework even whether they participate in the labor market or not and men are responsible for activities considered inherently economic. Data from the population censuses in 19 Latin American countries have shown that the participation of economically active women in the labor force increased 50% in the 1960-1990 period, whereas the participation of economically active men reduced 10% in the same period. In

[12] Brooks, M. 1993. Garimpagem in the Brazilian Amazon: A Political Ecology Perspective. Notes of the author's seminar at the University of British Columbia, Dept. of Political Science; unpublished. 30 p.

[13] Davidson, J. 1993, The Transformation and Successful Development of Small-scale Mining Enterprises in the Developing Countries. Natural Resources Forum, Nov. 1993, p. 315-326.

[14] United Nations, 1996. The Advancement of Women, 1945-1996. Dept. of Public Info. UN Blue Series, Vol. VI, New York.

Dominican Republic, Cuba, Uruguay and Mexico, women participation in labor force increased above 100% from 1960 to 1990 due to the urbanization process[15]. One out every three economically active individuals in Latin America is a woman and this ratio is lower in countries with large rural population.

Due to harsh economic conditions of the rural communities, participation of women in artisanal mining activities has grown, however it remains controlled by social and cultural aspects. The number of women involved directly with mining is not officially recorded. Female miners are rare in the macho-dominant environment. In Brazil, there are some examples of the presence of women working in medium-size "garimpos". Usually, they have secondary-level education and own their mining property. They are successful miners leading teams of male laborers and implementing innovative solutions into their mines.

In the rest of Latin America, most women are working in very small productive systems. They pan for gold to help their families and rarely they work with their partners. Frequently, women work with their children on river banks using "batea" or sluice boxes to concentrate gold from placer deposits. This is typical subsistence work when the woman is head of the family. Most women live in villages and female migration is less intense than that observed in the case of male miners.

In Colombia, it is usual to find women processing gold ore in the backyard of their houses. Usually, the ore is brought by a miner who shares the result of the process or simply donates the raw material to the woman. Recently, Mining Cooperatives have implemented courses of jewelry to open a new market for women participation in the gold business[16].

Sometimes, women do the delicate work in the mining operation, which includes amalgam-burning step. Most women do not have idea about the danger of mercury vapors and are daily exposed to deadly fumes. Numerous cases of stillborn children are reported informally in Latin America, but no official record makes reference to mercury poisoning.

Ingestion of mercury-contaminated fish is also another constant danger for pregnant women. As more than 90% of mercury in fish is already methylated, methylmercury can penetrate into the placental barrier transferring mercury to the fetus. It has been observed that when a female's intake of poison is large and she becomes ill, sterility occurs. When the dosage is smaller, pregnancy can take place but the fetus may be aborted spontaneously or stillborn. An even smaller dose permits conception, but the baby will have severe neurological symptoms. A dosage too small to cause noticeable neurological symptoms in the child may cause congenital mental deficiency. But in any of these cases, the mother's symptoms are relatively mild[17]. Swedish[18] researchers have observed that recent exposure to methylmercury from fish consumption is reflected in mercury levels in the blood but not in the mother's milk and sucklings uptake more methylmercury via milk than inorganic mercury.

Reduction of carnivorous fish consumption has been part of the strategy developed by UNIDO with Government of Bolivar State and La Salle Foundation in Venezuela. To meet the Allowable Daily Intake (ADI) of 15 µg of Me-Hg, women must avoid carnivorous fish. Even ingesting 200 g of uncontaminated fish with 0.1 mg/kg of Hg, women in age of pregnancy expose themselves to 20 µg of Me-Hg daily which

---

[15] Valdes, T. and Gomariz, E., 1995. Latin American Women, Compared Figures. Instituto de la Mujer - Spain and FLACSO, Santiago-Chile. 200 p.

[16] Hartnagel, B.; Cramer, S; Bermudez, R., 1994. Reduction of Environmental Contamination from Small MIners in Bucaramanga. Division Regional de Minas de Bucaramanga. Conv. Germany-Colombia (in Spanish).

[17] Bakir, F.; Damluji, S.F.; Amin-Zaki, L.; Murtadha, M.; Khalidi, A.; Al-Rawi, N.Y.; Tikriti, S.; Dhahir, H.I.; Clarkson, T.W.; Smith, J.C.; Doherty, R.A., 1973. Methylmercury Poisoning in Iraq. Science, v.181, p.230-241.

[18] Oskarsson, A.; Hallén, I.P.; Sundberg, J., 1995. Exposure to Toxic Elements via Breast Milk. Analyst, v. 120, p. 765-770

can cause problems for their future babies.

It is recognized that women are excellent couriers of information in the mine sites. Together with their children, women can influence their partners to change their poor amalgamation methods. As women are the most sensitive victims of mercurialism (by mercury vapors and methymercury ingestion), they must be a significant target of campaigns for reducing mercury emissions. As they are usually the family cooks, they must be informed about the risk of intensive carnivorous fish consumption. As well, they can change family food habits. Diet options must be researched and indicated for them.

The most significant way by which women participate in the artisanal mining in Latin America is through marginal activities as cooks or prostitutes. Their living condition is usually on the boundary between poverty and misery. As the majority of the labor force in artisanal mining, women are also lured by the gold mystique. They expect to have mining as a temporary way to make quick money to become a “real” farmer in the near future, i.e. to be a landowner. Women have been involved with mining activities usually by an invitation from someone who convinces them about an easy way to make money. In this case, women migrate to the mines leaving behind their families (children and mother) who periodically receive some money by mail.

The cook is an important person in the mine site. She is responsible for supplying goods, groceries and performing household chores. The presence of women in the production fronts is fundamental for the stability of the team. The cooks share the administration tasks with the mine owners bringing an important feminine presence to the workplace that contributes for a better relationship among miners. The quality of food is a significant reason for improving the miners’ mood and consequently the gold production. As most women are former peasants, the food is prepared in a tasty and spicy country style. Whether a refrigerator is available or not in the barges or huts, cooks must prepare the right amount of food sufficient for one meal. They establish a pattern of family economy in the mines and most cooks play “doctor” and “mother” to the miners. A cook in Brazilian “garimpos” works 6 days a week, from 4 a.m. to 7 p.m. to make between 15 and 20 g of gold monthly which is almost twice the minimum wage in urban areas and much more than that she could make in rural regions. A cook can also make additional money by washing and ironing extra clothes or with prostitution. It is estimated that all production units in Brazilian “garimpos” employ a woman, i.e. one woman out every six employees (17%). The Brazilian Mining Department (DNPM) has never acknowledged the presence of women in artisanal gold mining as a significant production factor[19].

Many women are also attracted to mine sites to work in night clubs. The recruiter is usually a night club owner or a person contracted to entice girls. This person offers a lump sum of money in advance to lure those women who live in extreme miserable conditions. This loan, which is paid monthly, is a way to exert control over them. Rarely, these women involved in this prostitution system can afford to pay the loans. These women work seven days a week, are poorly fed and are controlled by violence. Death is the usual end for those insubordinate ones who run away. The common way by which women are released from this slavery life is when they contract sexual-transmitted diseases such as AIDS. Girls as young as 13 are involved in this grievous job. Sometimes these women find a way to become cooks and to go home, but soon they return to the promiscuous life in a mine site as a result of the poor living conditions in the rural regions of the Latin America.

[19] Rodrigues, R.M., 1994. Women of Gold: the Feminine Work in the Tapajós “Garimpos”. Secretaria de Indústria, Comércio e Mineração do Estado do Pará. 131 p. (in Portuguese).

1.5. Solutions for Artisanal Mining - A Continuing Pursuit

According to a report of the Interamerican Bank of Development, Latin America, as a whole, showed positive indications of economic growth in 1996:

- growth of 3.0% of the Gross Domestic Product (GDP),
- inflation rate declined from 13% in 1995 to 11% in 1996,
- flow of investments is stable around US$ 48 billion

Unfortunately these numbers do not mirror the unfair income distribution and meager living conditions of poor rural communities in Latin America. The unemployment rate of 17 countries, which represent 90% of the Latin America population, actually increased from 6.6% in 1995 to 7.8% in 1996. This is the highest rate since 1983. This situation definitely has contributed to drag even more people into the informal economic activities.

Mineral resources are a possible source of wealth for many rural communities in developing countries. The presence of artisanal gold miners is reported all over the developing countries in Africa, Asia and Latin America. Since the beginning of the contemporary gold rush, governments and development-aid organizations have discussed the social, economic and environmental problems generated by almost 10 million people involved directly in artisanal mining worldwide. International meetings have taken place in Mexico (1978 and 1981), Kenya (1980), Finland (1983), UK (1987), Turkey (1988), Zimbabwe (1993), Indonesia (1995), India (1991 and 1996).

Few international meetings took place in South America and the majority of them focused on environmental problems caused by mercury pollution emitted by artisanal gold miners. A common outcome pointed by environmentalists who attended these meetings was to "stop" all artisanal mining activities. How to implement this decision is a matter never discussed in these conferences, since law enforcement is not a sufficient measure.

In May 1995, 80 experts from 25 countries attended a meeting about artisanal or informal mining held by the World Bank in Washington, D.C.[20]. In November 1995, UNIDO organized an International Workshop on Ecologically Sustainable Gold Mining and Processing in Jakarta, Indonesia; 41 delegates from 14 countries attended this meeting. Some of the most important topics discussed in both meetings are listed and commented as follows:

1. ***None of the other problems of lack of technology and financial support can be tackled effectively until a prime need is met: legal titles. Legalization of artisanal miners was agreed to be the essential first step in transforming them into small miners. Legal status also improves the creditworthiness of artisanal miners and their willingness to invest (or negotiate properties). Attention needs to be given to both legalizing this sector and to creating alternative finance assistance, including linkages with the formal sector, the use of development bank finance and appropriate taxation regimes.***

The end of informal economy has been a dream of most governments. This is a very delicate issue, since it derives conflicts between organized mining companies and artisanal miners. In many Latin American countries a few miners have the legal titles of the sites where they work. Using satellite images and with technical infrastructure, organized companies have staked mineral claims in areas discovered and worked by artisanal miners. So nowadays, these miners are called outlaws and it is unlikely that organized mining

[20] Suttill, K.R., 1995. Round Table on Artisanal Mining Charts the Road Forward. *Engineering and Mining Journal*, July 1995, p.40-42.

companies will compensate them for their findings. An example how to conduct a pacific conviviality between company and small miners, is being experienced by Placer Dome in Las Cristinas, Venezuela. The company is giving part of its property to artisanal miners as well as providing technical and social assistance for their mining activities. On the other hand, another large foreign company, working in the same region, relies on armed force to keep control of its leases. Time will tell us which company will have better and durable benefits.

In the Amazon, four companies have more than 80% of the gold-richest mineral claims. These sites were discovered and are being worked by “garimpeiros”. As these companies have the legal mineral titles, no effort to negotiate a coexistence with “garimpeiros” is observed. The conflict is established and the Government is constantly under pressure to enforce laws.

Another point to be highlighted is the fact that many people who hold legal titles have never been miners. Many farmers and businessmen have mineral titles to speculate with them. As they can afford to hire a geologist to go through all bureaucratic and technical issues to obtain titles, these individuals negotiate properties with miners or simply stake claims in areas where miners are working. Not infrequently these mineral-title holders are politicians or highly ranked employees of Mining Departments. The end of the titles usually is into the hands of a junior company in Canada.

The concept of junior companies has been successfully applied in Canada since 1950. These agile companies are capable of raising risk capital in the Stock Exchanges to be invested in the early stages of the geological exploration. Vancouver Stock Exchange is one of the main “homes” of junior companies. The juniors are always promoting their properties, sometimes with exaggeration. Rarely these companies proceed with the mining activities. When reserves are established, a major mining company takes over the properties (Fig. 1.1).

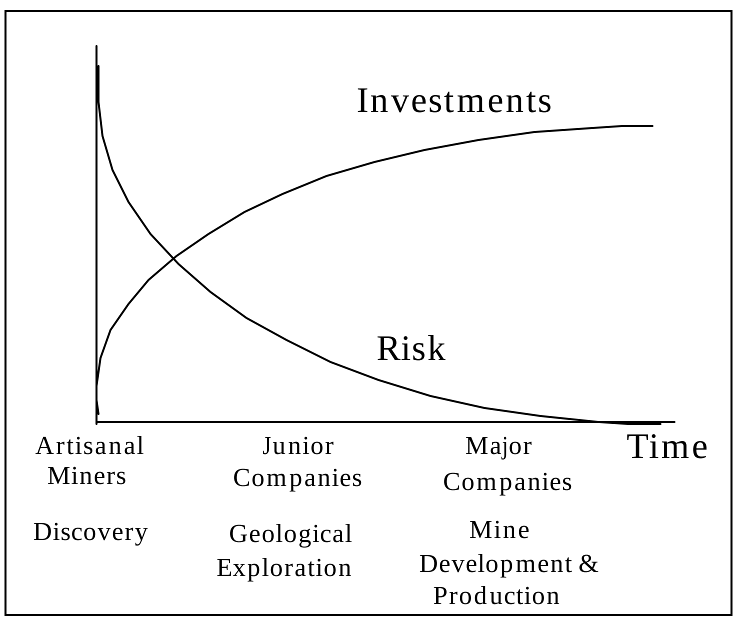


Fig. 1.1 - Protagonists of a mining business

Examples of two successful junior companies - Bre-X which announced the finding of the biggest gold deposit in the world in Busang, Indonesia and Arequipa which discovered a large gold deposit in Peru - came recently to the attention of the public. Both deposits were negotiated with major companies and left millionaires the junior’s shareholders. The veracity of the gold content in the Busang deposit is recently (April 1997) being questioned and the exaggerations of the announcements are becoming public.

Examples of spectacular discoveries are not usual and quite frequently junior companies find small gold deposits which are obviously more abundant. As the market is not impacted by small discoveries, but by large expectations, the junior companies are frequently moving from one project to another. The migratory character of the Canadian junior companies is similar to those Latin American artisanal miners, but differently, junior companies are not prepared technically or psychologically to conduct a small mining operation.

Canadian junior companies do not understand the idiosyncrasies of the developing countries and frequently try to impose procedures which are not accepted by miners. The role of the junior companies in negotiating with artisanal miners has been criticized by Davidson[21]. He poses that the speculative approaches have not resulted in the establishment of commercially and technically viable small mines anywhere. Too frequently, the occasional conflicts between foreign and local parties have been resolved on political, rather than judicial basis. Projects have also failed because of shortcomings in the experience of foreign management teams.

The speculative character of the junior companies is being bad-mouthed in Latin America where the tradition to invest in Stock Markets to raise capital is rare. In addition, this type of investment is not as accessible to small investors as in North America. A successful relationship between junior companies and local miners can occur if miners are considered real partners in the venture, not only property sellers. Most miners are apprehensive about junior companies because they do not understand stock market operations, but they are definitely prepared to take risks along with the foreign companies. A trustworthy relationship must exist between miners and foreign companies. Unfortunately, the most common procedure adopted by junior companies in Latin America is illustrated below in a pictorial example which is not distant from the reality at all:

- A miner and his family worked for 3 years in a secondary (alluvial or elluvial) gold deposit. He finally discovered the primary ore, a mineralized subvertical quartz vein. Advised by a friend he paid a geologist to obtain a mineral claim, a title valid exclusively for geological exploration[22]. Illegally, he proceeded with a small mining operation using rudimentary techniques that he had used for alluvial ores. He excavated shafts 50m deep, worked for 2 years and realized that he could not achieve the same production level as he had when secondary ore was processed. He looked for technical assistance, but the engineering companies refused to help him (the price is too high as well). The local government was not prepared to provide specialized personnel or appropriate technology. He visited Research Institutions and Universities, but only inaccessible high-tech was suggested to him. Finally, he met a “technician” who suggested a “magic” process to extract more gold. He invested all his money to buy equipment to work with this “new” technology, but the problem was not only in the processing plant, but also in the lack of geological information and mining method. His production is lowered and he faces a huge debt.
- No drilling is available and consequently no gold reserve is established. The miner meets a geologist who represents a Canadian junior company. Proud of his discovery, he establishes an acquisition price for his property and mineral title based simply on the gold potential that he believes his property has. He asks something between US$ 1.5 to 3 million to buy out his property and he wants all cash in one shot, which is typical[23]. A long negotiation takes place between the junior company’s local representative and the miner to convince him that more information is needed to pay that much for the

[21] Jeffrey Davidson (1993 - op.cit.) is an specialist in small mining. He is currently working for Placer Dome, a large Canadian mining company, implementing projects in Venezuela to conciliate the interests of small miners with those of the company.

[22] In most countries, a mineral claim title does not allow mining activities, but only geological exploration.

[23] In Venezuela, when junior companies triggered the gold rush in 1990, a mineral lease has achieved prices as high as US$ 15 million, even with no geological data available.

transfer of the mineral rights.

- A short-term contract between the junior company and miner is signed. The company pays the miner usually less than US$ 100,000 to have the right to proceed with geological exploration on the property for 12 months.
- The junior company registers a contract in the Vancouver Stock Exchange together with technical reports and a legal opinion from a lawyer who certifies that all documents are in good shape and the titles are legal. With this contract, a junior company can raise some money (something around US$ 300,000) from the shareholders with VSE approval.
- The junior company issues brochures and news release to promote the property (usually with exaggeration) and attract more investors.
- The junior company hires a professional geologist to elaborate a technical plan for exploration.
- The junior company tries to raise more money with financing companies to support its geological exploration program, which consists of drilling in areas where the miner was extracting gold (the geochemical anomalies were already indicated).
- At this point, not infrequently, some junior companies just walk away from the project with the money they raised. They look for another property in Latin America to apply the same fraud. For the shareholders, the company makes up an excuse, usually blaming the small miner for the fiasco. The miner is not informed what has happened.
- A serious junior company uses the money to conduct geological exploration work. Targets are established and a preliminary drilling program initiated.
- After one year of drilling (about US$ 1 million invested), if spectacular results are obtained, a major company is immediately contacted and most shares of the junior company are sold at a price 100 times higher than one year ago. If nothing impressive is found, the junior company insists on promoting its geological work and negotiates one more year of drilling with the miner.
- If no significant results are obtained to account for a large gold deposit, the junior company becomes confused and usually takes a long time to make a decision. If the decision is to give up the property, the company will be bad-mouthed by the miner who did not receive the initial acquisition amount.
- As an option, the junior mining company can implement a small mining operation. As the company does not have background in mining, they look for a mining engineering company which charges a fortune for lab testwork, pilot plant tests and a simple feasibility study. Rather than pay for engineering, the junior company adopts the artisanal miner’s technology and starts a small production.

This is an example how a junior company starts an artisanal mining activity. This is occurring in Latin America in small proportions, but the usual behavior of junior companies is to walk away from the property instead of implementing a producing unit. Small production does not increase the value of shares, the primary goal of these exploration companies. Unfortunately, very soon, most junior companies will face a harsh reality: there are much more small gold deposits than gigantic ones. As a result, it is expected that junior companies must be resigned of this fact and some companies will implement their own small operations across Latin America.

In mid-1994, the Vancouver Stock Exchange had 1605 companies listed of which 813 were designated as mineral resource companies. Of these companies, 470 or 58% have reported interest in Latin America and over US$ 200 million dollars were invested in exploration. Considering the three more important Canadian Stock Exchanges (Vancouver, Toronto and Alberta), about 630 companies are investing in mineral exploration in Latin America. Until 1994, most companies were in Mexico, Venezuela, Chile, Peru, Brazil, Bolivia, Argentina and Ecuador. Venezuela and Mexico have received the main funding for exploration[24]. This picture has changed owing to the Mexican crisis at the end of 1994 and instability of

[24] Brock, J.S., 1994. VSE Exploration Companies in Latin America, 1994. Randol at Vancouver ‘94 - Latin America Mining

the Venezuelan policy concerning foreign investments into the mining sector. Another fact that has also contributed to evade foreign investors from Venezuela, is the frequent invasion of properties by artisanal miners. In 1996, Argentina and Brazil have received major attention of the foreign exploration companies due to changes in their Constitutions which eliminated restrictions on foreigners owing mineral properties. Peru, Ecuador, Bolivia and Colombia are also targets for gold exploration but the presence of guerrillas and lack of infrastructure in the field are still discouraging investors.

In order to highlight the fact that Latin America has been focus of a new gold rush by mining companies, the major exploration companies, which encompass 80% of total exploration spending, shows overall expenditure of US$ 2,130 million in 1994. Exploration in South America, which also includes property acquisition from artisanal miners, was responsible for 26.5% or US$ 544 million.

The evolution of artisanal miners into organized companies happened in North America and the history is unlikely to be different in developing countries, unless society and government refuse to participate in this evolution. Legalization of artisanal miners is necessary but not sufficient condition to introduce these workers into the organized society with duties and rules. Miners need to see the benefits of this transformation. They need to have assistance from the formal economy. They need to be treated with appropriate policies. They need to evolve.

2. *Artisanal mining activities are usually an island of prosperity in a sea of poverty. The existence of informal mining is largely due to poverty, lack of alternative employment and "get rich quick" mentality.*

This latter point seems to be an important and historical driving force for informal mining in Latin America. The mystique of gold mines is in our fairy tales as a way to get rich easily and quickly. There are numerous books and soap operas feeding the imagination of the ordinary people about gold mining. Less than 10% of the gold seekers made money out of their adventures in Serra Pelada.

The common criticism that only the property owners are getting rich with artisanal mining is not quite true. In Brazil, where data about artisanal miners are readily available, an official report[25] indicates that, in the Amazon, “garimpeiros” work 60 hours a week and four years in average. Working in teams of about 6 people, partnership is the preferred working relationship (53% of the artisanal miners); 22% of miners own their mining operations and hire laborers which represent 12% of the human contingent in the Brazilian artisanal mining. The remaining 13% comprises “requeiros” - those reprocessing tailing or “bateadores” - individual panners. The average income of “garimpeiros” is five times the current minimum wage in Brazil which is currently US$ 100/month.

3. *Governments almost universally wish that artisanal miners would disappear. Miners have little political clout and provide no tax revenues. They usually operate far from government control.*

A few governments in Latin America have recognized artisanal miners in their constitutions or mining laws. Even though, no incentives or special programs are established to support evolution of artisanal miners. In Ecuador, the government has granted the miners titles to their claims and encouragement to come to agreement with established mining companies[26]. This is real protection and assistance for those who discovered mineral deposits.

Opportunities. Oct 31-Nov. 2. p.233-239.

[25] DNPM - Departamento Nacional da Produção Mineral (National Dept. of Mineral Production), 1993. Levantamento Nacional dos Garimpeiros. Série Tecnologia Mineral, n.45, Brasília, DF, 90 p. (in Portuguese).

[26] Suttill, op. cit.

Governments have inadequate human resources to control and devise solutions for artisanal miners. As miners usually do not pay taxes, governments do not provide any type of service for the community. An example is observed in Ikabaru, South of Venezuela. This mining village with 7,000 inhabitants was founded in 1940 by diamond and gold seekers. The Association of Miners provides all type of support for the citizens including elementary education, power generation, public services, etc. The community is completely ignored by the government.

4. *There are many mineral deposits which because of their size will never be of interest to a major mining company but which could be mined profitably on a small scale. But in most countries there is nothing between the small worker on his usually illegally held patch and the mine treating hundred of thousands of tons per day.*

Mr. Michael Allison, president of the International Agency for Small-Scale Mining, a Montreal-based non-governmental organization, has declared that small-scale mining is a natural phase in mineral development in developing countries. Small deposits are being mined employing low-skilled labor in rural areas[27].

It seems that the concept of small mining adopts different shapes. In most Latin American operations, when primary ores are mined in a rudimentary fashion, the results are disastrous. The concept of small mining operations is not necessarily attached to that one of artisanal mining. Small primary ores need technical skills and investment to be developed. Governments can subsidize activities on small primary deposits but unlikely the mining operations can be conducted in an artisanal fashion.

With the recent gold price crisis since November 1996, many gold mines worldwide are shutting down their operations or suspending new projects. The gold futures trade on the New York Mercantile Exchange’s Comex division have plunged US$ 353.40 a troy-ounce from more than US$ 380. Worldwide, gold is produced at an average operating cost of US$ 257 an ounce. However the total cost including capital expenditures comes to US$ 315 an ounce, only US$ 40 an ounce lower than the current gold price. The crisis has origin in Europe where the central banks have been pressured to sell gold reserves to meet debt requirements for European monetary union in 1999. Unless the price experiences adjustments of 15%, many new developments will be postponed[28]. This crisis has also affected the artisanal mining sector which is already facing high production costs in those mechanized operations. In Poconé, Brazil, where gold is bought at 85% of the refined gold price and the operating cost ranges from US$ 200 to 300 an ounce, the large tonnage artisanal operations with low grade ores (0.3 g of gold extracted per tonne of ore processed) will face meager times. Most mining companies will give up small projects where the perspective of large gold deposits has not been indicated. This will give opportunities for small mining activities with creative, but organized, procedures.

5. *Attempts to form cooperatives have usually failed. Most "cooperatives" are legal conveniences where each miner works for himself rather than true revenue sharing arrangements. Artisanal miners need to be encouraged to become entrepreneurs and look upon mining as a business.*

It seems that this is the only way to create a sense of citizenship and environmental concern. As mentioned before, artisanal miners need to see the benefits of being part of an organized society. Associations and cooperatives are excellent ways to bring education and technical concepts to miners. However, most

[27] Allison, M.; Berger, A.; Dahlberg, H., 1996. The Significance of Small Scale Mining for Developing Economies. CRS Perspectives, n. 52, Jan. 1996. Queen’s University, Kingston, Canada.
[28] Heinzl, M. and Lucchetti, A., 1997. Gold Miners Struggle with Price Slump. Wall Street Journal, Jan. 27.

Associations do not have any technical support to improve the production of their members or any incentives from the governments. In some regions in Venezuela artisanal mining activity is allowed to be conducted exclusively by members of Associations and Cooperatives. In some instances, the Associations act as an aggregate of people, who conveniently follow the rules established by the government, i.e. with no spirit of cooperation, since there is nothing to be shared. This cannot be generalized. Many Cooperatives and Associations in Latin America are the only contact of artisanal miners with formal economy. Through the Associations, they pay taxes, they have their legal mining titles and sometimes, medical assistance. The simple fact of existing Associations and Cooperatives is a significant indication of organization. This must be used by governments and organizations to introduce important changes.

In the Tapajós Gold Province, the largest artisanal mining reserve in Latin America (2,894,500 ha), created in 1983 in Pará State, Brazil, the only miner eligible to be member of the Tapajós Gold Miners Association - AMOT is that one who owns a mechanized operation and a mining permit ("lavra garimpeira"). Gold panners and employees are not acceptable. As observed by some authors[29], the "garimpagem" laborer is a seasonal worker, usually from other region, with migratory habits and no attachment to the land. In contrast, the "garimpagem" entrepreneurs are established in the region and own farms. They care for regional problems, fight for better local infrastructure and want to evolve. Mrs. Marlene Ficks, a dynamic young entrepreneur, has a significant role as the president of this organization. As the gold production is declining, the Association is providing assistance to its members to find partners to invest in their properties or negotiate their titles. Unfortunately, neither the government nor the Association have mechanisms to incorporate the seasonal workers and very small miners into the local community.

USAGAL, a conglomerate of unions and associations which represents interests of informal miners ("garimpeiros") in the Legal Amazon is the most important organization of artisanal miners in Latin America. In 1989, USAGAL encompassed 1 million members directly and indirectly involved with "garimpos" in the Legal Amazon area (5.6 million km^2). Mr. José Altino and Ivo Lubrina, founders of USAGAL, are important channels to lead the artisanal miner's aspirations to high level politicians.

6. *Environmental destruction is the single most visible aspect of artisanal mining. Although the total area affected is small (e.g. less than 1% of the Amazon basin in Brazil has been affected by "garimpos"), the local impact is high.*

The physical impact of the artisanal mining activities has been recently evaluated. The idea that mining activities deliberately degrade natural forests is often transmitted to the public. In Venezuela, environmental organizations as well as media spread rumors that 50% of the State of Bolivar is already degraded by artisanal mining activities. On the other hand, the satellite images has shown that 0.03% (6300 ha) of the State is affected by miners.

The forest destruction caused by artisanal miners cannot be compared with farming activities which have already destroyed 12% of the Amazon area. The main physical impact of artisanal mining is usually associated with incorrect tailing disposal that silt up waterstreams. Reclamation and revegetation projects with direct participation of artisanal miners have been conducted in Brazil and Venezuela. The role of the Association of Miners is fundamental in disseminating these projects. Many simple techniques can be brought to miners to teach them to restore the organic layer of soil. The use of liquid humus produced by earthworms is one method successfully applied to mining impacted areas in Venezuela. Hydro-seeding is another efficient and rapid method for revegetation.

[29] DNPM-Dept. Nacional de Produção Mineral, 1992. Study of the Environmental Impacts in the "Reserva Garimpeira do Tapajós"- Pará State. Serie Tecnologia Mineral, n.2, Brasília, 227 p. (in Portuguese).

The chemical pollution caused by mercury emissions has been considered the worst impact to the human heath and wildlife caused by artisanal mining activities. The reaction of the dominant society about mining is biased and mercury has been used by some ecological groups to attack miners. However, many environmentalists do not have clear knowledge about mercury toxicity and its transformations in the environment; let alone the artisanal miners. Few programs, usually conducted by NGOs, have focused on bringing solution to stop mercury emissions and providing safe technology for miners. On the other hand, a large amount of money has been used by Universities, Research Institutes and International Agencies into monitoring programs to establish levels of mercury in sediments, air, water and biota. The Amazon region bas been used as a living laboratory for academic researchers.

Recently, a group of researchers spent three weeks in the Amazon region eating the same fish as the local riparian people. Back to their labs, they published a paper about the amount of mercury accumulated in their hair. No advice for affected communities derived from these experiments. In most monitoring programs, human beings are merely hair, blood, or urine sample donors. In many cases, affected people never learn the results of the monitoring program, unless, of course, they read the scientific literature.

UNIDO has provided assistance related to avoidance mercury pollution in different countries: Botswana, Niger, Vietnam and recently (1995) in Venezuela. Practical solutions directly applicable to affected people have been pointed out and are discussed in chapter 3 of this document.

7. *Education and the communication of information are key to making all interested parties aware of the situation and encouraging them to improve it. This can be done through newsletters, comics, seminars, videos and radio and TV campaigns.*

Education is one of the most important measures to help minimize environmental impacts from gold mining operations in developing countries. A disorganized propaganda on hazardous problems with mercury, usually creates hysteria and increases the gap between artisanal miners and different sectors of society. As the issue is fraught with complex and vague concepts, an intelligent approach, understandable by non-technical people, is necessary to move miners toward safe working methods envisaging long-term solutions and improvement of gold production.

A multiplying effect can be obtained if people interacting directly with these miners are aware of the toxic effects of mercury, methods to minimize emissions and diagnose critical situations. Simple solutions such as home-made retorts can be suggested and demonstrated as a first step to minimize occupational exposure and environmental pollution. Any solution, preventive or remedial, should be aimed at providing better knowledge about mercury behavior in the environment.

Through UNIDO, about 20 interactive lectures were given in Venezuela to technical people, mining association leaders and miners from different regions. Relevant points about artisanal mining techniques, gravity concentration, including mercury contamination, role of women, legal issues, treatment for mercury intoxication and methods for mercury abatement were discussed with local miners who widely accepted these ideas.

2. Review of the Artisanal Miners in Latin America

2.1. Gold Production and Mercury Emission by Artisanal Miners

Establishment of population of artisanal gold miners and their production is a difficult task since these numbers fluctuate considerably. Furthermore, it is also recognized that significant amount of gold is illegally shipped out of Latin American countries basically due to the following:

- control by government of foreign currency entering the country
- existence of foreign currency black market
- better price of non-refined gold in other countries
- tax avoidance
- money laundering

Virtually all countries in Latin America have artisanal mining activities in which gold is the most mined mineral. Table 2.1 lists the main gold producing countries in Latin America. For simplification, Guyana was also considered in the list. These countries must encompass over 90% of the artisanal gold mining activities occurring in Latin America. Information was obtained from field visits, contacts with Departments of Mines, mining companies, international agencies, consulting companies involved in small-scale mining, individuals, news on the Internet and a few publications available in local newspapers and international technical journals.

The number of artisanal miners is not an information frequently available with local Mining Departments. However, it is observed that there is a certain correlation between gold production and number of miners (Fig. 2.1). The number of miners per kg of gold produced annually ranges from 2 to 8. For countries producing less than 10,000 kg of gold annually this ratio lies between 2 and 3 and for those regions with gold output from artisans above 10,000 kg, this ratio usually ranges between 4 and 6. A possible reason for higher ratio in regions with larger gold production can be the higher number of unsuccessful miners[30] lured by gold rushes than in other small producing areas.

It is possible to estimate that artisanal miners from all countries not included in the Table 2.1 contribute additional 2 to 5 tonnes of gold annually, but this should be confirmed.

Based on this investigation, it is estimated that as many as 1 million artisanal miners are currently mining for gold in Latin America and their production can be as high as 200 tonnes (6.4 Moz) of gold annually. Considering that one out of six miners is a woman, as observed in Brazil, there are likely around 170,000 women participating in the labor force of the artisanal mining in all Latin America. However this number is definitely higher in those countries with less mechanized operations. As individual panners, employed as cook or as owner of a mining operation at least 200,000 women are involved with this economy.

[30] In Brazilian “garimpos” these individuals are called “blefados” - misled by bluffing.

Table 2.1 - Estimated gold production and number of miners in Latin America

Country	**Gold (tonnes)**	**Number of Miners**
Brazil	30 - 50	200,000 - 400,000
Colombia	20 - 30	100,000 - 200,000
Peru	20 - 30	100,000 - 200,000
Ecuador	10 - 20	50,000 - 80,000
Venezuela	10 - 15	30,000 - 40,000
Suriname	5 - 10	15,000 - 30,000
Bolivia	5 - 7	10,000 - 20,000
Mexico	4 - 5	10,000 - 15,000
Chile	3 - 5	6,000 - 10,000
French Guyana	2 - 4	5,000 - 10,000
Guyana	3 - 4	6,000 - 10,000
Nicaragua	1 - 2	3,000 - 6,000
Dominican Republic	0.5 - 1	2,000 - 3,000
Others	2 - 5	6,000 - 15,000
Total	**115.5 - 188**	**543,000 - 1,039,000**

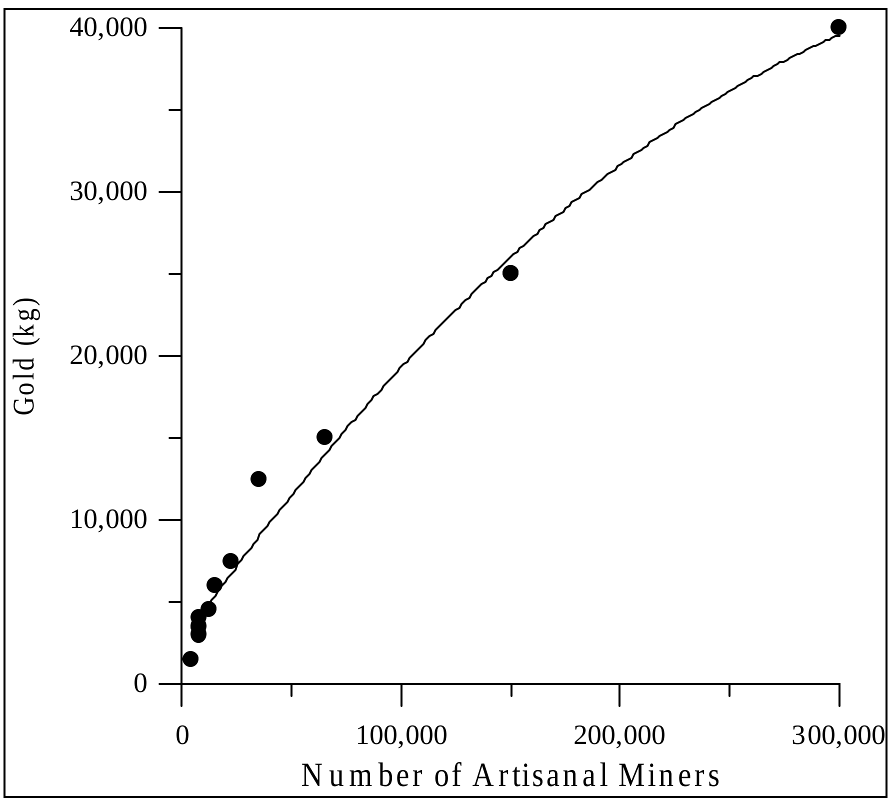


Fig. 2.1 - Correlation between gold production and number of miners

Many factors are contributing for the reduction of mercury emission in Latin America from the high levels observed at the end of the 1980s:

1. Reduction of the informal mining activities in Brazil and consequently the gold production, due to scarcity of easily exploitable ores.
2. Introduction of retorts and cyanidation in some more-organized artisanal mining regions. More

information about mercury poisoning is reaching those artisanal miners involved with Associations and Cooperatives and they are adopting some precautions. The NGOs have played an important role in suggesting technical improvements.
3. High costs are driving miners to recycle mercury. Many miners are amalgamating just the gravity concentrates, instead of the whole ore.

These facts lead one to believe that a ratio of 1:1 for gold produced and mercury lost can be used for a rough estimate of the mercury levels still being emitted in Latin American countries. So, approximately 200 tonnes of mercury are still being released annually by artisanal gold miners. Since the beginning of the new gold boom in Latin America, at the end of 1970s to the present, around 5,000 tonnes[31] of mercury might have been discharged into the forests and urban environment. Part of this mercury is being transformed into methylmercury to be bioaccumulated. The future generations will inherit the legacy to cope with this level of pollution. Workers and their families as well as fish-eating people, especially women, are the main victims of the lack of information about the danger of this pollutant.

In the following pages, a brief scenario about the main gold producing countries in Latin America and their amalgamation procedures is provided.

Bolivia

Mining represents the most important economic sector in Bolivia and accounts for approximately 50% of its foreign exchange. The State owned company COMIBOL, which owns 800 mineral properties, is experiencing a tremendous crisis. Since the price of tin decreased in the international market in 1986, COMIBOL exports plummeted. The company closed the majority of its mining operations and 28,000 workers were laid off. However, the private mining sector has continued growing. The Bolivian Miners' Union, formed basically by COMIBOL's laborers, has strongly opposed foreign investment[32].

In 1995, Bolivia has produced 14 tonnes of gold[33] in which almost 10 tonnes (321,000 oz) were attributed to one of the largest gold producing companies in Latin America, Empresa Minera Inti Raymi S.A., which is an association of a Texan company, Battle Mountain (88%) with Bolivian government and private companies. The mine of Kori Kollo, located 150 km South of La Paz, has gold reserves of 7 million oz (218 tonnes) with average grade of 2.4 g/tonne.

Unemployed miners have been able to earn a meager living through Cooperatives. About 40% of the 320 Cooperatives in Bolivia are mining for gold. There are about 45,000 members of small-mining Cooperatives in which close to 20,000 are involved with a production of 5 to 7 tonnes of gold annually. Not necessarily all artisanal miners are members of Cooperatives. Projekt-Consult[34] estimates that 400,000 people in Bolivia have artisanal mining as the main livelihood. This estimate includes miners, their families, goods and services suppliers. The Department (Province) of Potosí, in which mining activities were initiated 400 years ago, has been strongly impacted by 8,000 miners. There are 33 gold processing plants working with gold flotation and amalgamation. All wastes are dumped into the La Rivera river.

---

[31] North Americans are also facing huge mercury-related problems: from 1860 to 1890 about 7,100 tonnes of mercury were released into the Carson river system, Nevada, USA during the gold rush to Virginia City (Wayne, D.W. et al. 1996. Water, Air and Soil Pollution v.92, p.391-408)

[32] TED, 1994. Bolivia Gold Mining and the Environment. Website: http://gurukul.ucc.american.edu/TED/bolgold.htm.

[33] Bowen, S., 1995. Bolivia's Gold Acts as a Magnet on Prospectors. Financial Times Nov. 28, 1995.

[34] Projekt-Consult is a Germany-based organization specialized in technical assistance for small-scale mining. In Latin America, they work in Colombia, Bolivia, Ecuador and Brazil. They have done excellent work in providing simple and affordable technologies for artisanal miners as well as conducting environmental impact assessment in mining areas.

In the Department of Pando, Northeastern region of Bolivia near the Brazilian Border, it is estimated that about 80 tonnes of gold were produced from dredging operations since 1979. Between 100 and 500 tonnes of mercury were discharged into the aquatic environment[35].

Diagnostics of mercury pollution and other environmental impacts caused by artisanal miners have been conducted by various NGOs, State Institutions and Bolivian Universities. The Swiss Government has sponsored monitoring and technology transfer projects. The Swedish Geological Service is also participating in projects sponsored by the World Bank to identify the priority impacted areas for future remedial actions.

Bolivia has an extremely favorable environment for gold mineralization. Relatively limited recent exploration has revealed a number of gold deposits in Bolivia associated with Upper Cenozoic volcanic rocks and some copper-gold deposits on the Pre-Cambrian shield[36]. Considering that the demand for tin and tungsten has been depressed, numerous small gold-silver polymetallic deposits are being discovered by small miners across the Cenozoic Andean volcanic belt and with the unemployment rate increasing in the mining sector, the informal gold mining activities will definitely receive more adepts.

Brazil

Brazil is the largest and richest Latin American country with an area of 8.5 million km^2, population around 160 million and a GDP of US$ 590 billion in 1996. The low inflation level, experienced since 1994, has brought about a positive growth of 7% to the industrial sector. Despite its enormous mineral resources, the mining sector accounts for less than 2% of GDP[37].

The official gold production in 1996 was 71 tonnes (2.28 Moz) consisting of 41 tonnes from mining companies and 30 tonnes from artisanal miners, “garimpeiros” [38]. Most mining companies are located in the Central part of Brazil, but the largest gold producer, CVRD-Igarapé Bahia Mine, with an output of 10 tonnes (321,000 oz) is located in the Amazon region. The National Department of Mineral Production (DNPM) has granted permits for “garimpagem” in 9 areas (32,000 km^2), most of them in the Legal Amazon (5.6 million km^2). The DNPM has recorded the decline of gold production from “garimpeiros”. In 1990, their production accounted for 71 tonnes (2.28 Moz) and in 1995, 23 tonnes (739,000 oz) of gold. In 1993, the DNPM reported that 85,000 people were officially registered as “garimpeiros”. However, the Department believes that there were about 400,000 “garimpeiros” in the country, mostly in the Amazon, in which over 82% are involved with gold and diamond extraction[39]. A gold production of 50 tonnes/year is estimated by non-official sources[40].

About 16% of the “garimpeiros” in the Amazon live with their families and less than 15% would like to have their families with them. This shows the extremely rough quality of life in the villages and camps of the Amazon region as well as highlights the migratory characteristic of those miners. Over 85% of the

---

[35] Zapata, J.Q., 1994. Environmental Impact Study of Gold Mining in Nueva Esperanza, Departamento de Pando, in the Madeira River Bolivian-Brazilian Border. Proc. Int. Workshop on Environmental Mercury Pollution and Its Health Effects in the Amazon River Basin. Rio de Janeiro, Nov. 30 - Dec. 2, 1994. Ed. National Institute for Minamata Disease, Japan and Inst. Biophysiscs of Univ. Federal Rio de Janeiro, Brazil. p. 23-24.

[36] Stewart, J. 1994. Bolivia - The Future Nevada of South America. Randol at Vancouver ‘94 - Latin America Mining Opportunities. Oct 31-Nov. 2. p.31-34.

[37] Barbosa, F.L.M.; Chamber, W.; Santana, P.; Maron, M.C., 1995. Brazil. Mining Annual Review. p. 78-82.

[38] Data provided by ANORO - National Association of Gold and Exchange, São Paulo, Brazil.

[39] DNPM, 1993 - op. cit.

[40] Projekt-Consult, 1996. Mercury Contamination from Gold Mining Activities in the Tapajós and Madeira Rivers. Leaflet of the project sponsored by European Commmunity. 2p.

"garimpeiros" in the Amazon are originally from other regions, mostly from the Northeastern region of Brazil in which 64% had agriculture as main occupation. About 28% of the "garimpeiros" are illiterate.

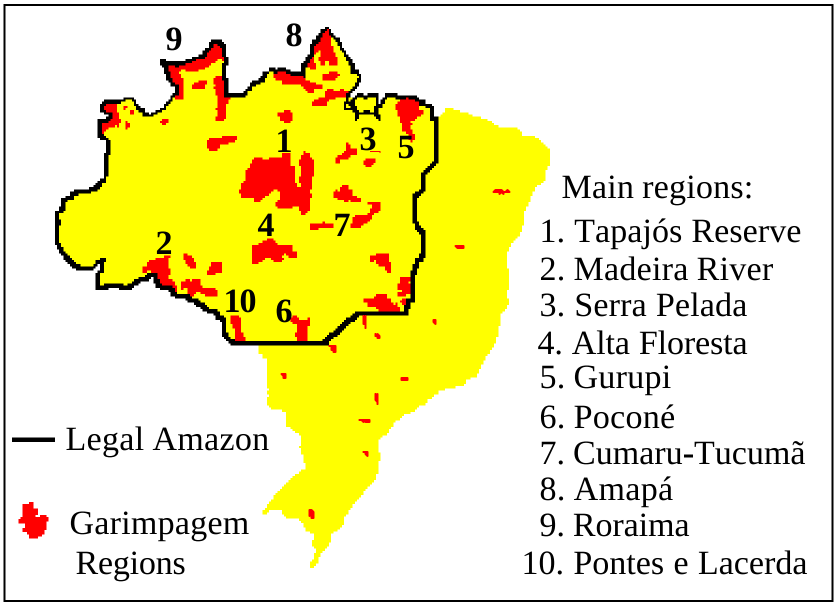


Fig. 2.2 - Main gold fields worked by "garimpeiros" in Brazil

In all "garimpagem" regions, there are many "garimpos" (worksites), i.e. ore bodies being worked by a group of "garimpeiros". The Association of "Garimpeiros" (USAGAL) estimates that, at the beginning of the 1990s in the Legal Amazon Region, almost 2000 "garimpos" were being worked (Fig. 2.2) by 1 million miners. Then, the human contingent involved directly and indirectly with this economic activity, could be as many as 4.5 million. An average of 100 tonnes of gold was produced annually[41].

Gold has been extensively used for money laundering in Brazil. In 1984, Uruguay, which is not a gold producing country, exported 29.4 tonnes (945,000 oz) of gold, most of which must have come from the Brazilian Amazon via São Paulo[42].

The largest artisanal mining reserve in Latin America (28,945 km²) is located in the Tapajós river, but "garimpeiros" are spread widely in this area. In 100,000 km² there are 460 "garimpos". It is estimated that over 500 tonnes (22.5 Moz) of gold were produced in this region since 1980. In 1992, an estimated 230,000 miners were active in the region. The most adopted mining system is the hydraulic mining[43] which pumps material from the river terraces to be concentrated in rudimentary sluices boxes. Quite often, the hydraulic monitors are used near watercourses. The misuse of this mining process silts up streams. Some dredges work on Teles Pires river, a tributary of Tapajós. The gold province extends up to the Southern border of the Amazon Basin where Alta Floresta is a representative mine site.

Alta Floresta, with area of 20,000 km² and 140,000 people, is located in the Mato Grosso State almost at the border of Para state, Southern part of the Amazon region. It was founded in 1976 by a colonization project and became a municipality in 1979. At this time gold was discovered in Teles Pires river attracting miners. The official gold production is 1 tonne of gold per month. Around 5% of the population has

[41] Feijão, A.J. and Pinto, J.A., 1992 - op. cit.

[42] Cleary, D., 1990. Anatomy of the Amazon Gold Rush. Macmillan Ed., Oxford, 250 p.

[43] Hydraulic monitor mining represented in 1990, 50% of the "garimpagem" method in Brazil.

entered the hospital annually with malaria[44].

Madeira river is another important region of “garimpagem”. It is located in the Southwestern part of the Amazon region, in Rondonia State, close to the Bolivian border. Madeira is an important Amazon river tributary. Its watershed covers about 100 km^2, only in Brazilian territory. Since 1975 miners (“garimpeiros”) have exploited gold from the bottom sediments using dredges (in excess of 2000 dredges) to produce between 1 and 1.5 tonnes/month of gold. Dredges pump the sediments to a riffled sluice box where the concentration takes place. Sometimes mercury is placed in the riffles or amalgamation is done in a separate water box. Many miners dump the content of these water boxes (amalgamation tailings) into the river. Amalgams are burned with or without retorts on the barges[45,46].

Until 1980, few “garimpeiros” have worked with gold deposits other than alluvial ones in Brazil. The most famous “garimpo” in Brazil, Serra Pelada changed this idea. Weathered ferruginous siltite ore was mined by 80,000 men who have extracted about 90 tonnes (2.9 Moz) from 1980 to 1990. This atypical “garimpo” was controlled by a Cooperative which charged 7% of the gold production. Every group of garimpeiro received from the Cooperative a permit to work on a plot of about 30 m^2. A large open pit 100m deep, 1,000 m long and 500 m wide resulted. All material exploited from the pit was manually conveyed in bags to be treated in thousands of different processing plants, all of them using mercury to amalgamate the whole material or only the final gravity concentrate. Nowadays, the pit is flooded and the area is a shanty town, with about 2,000 families (men, women and children) living in complete poverty, struggling to survive from reprocessing tailings.

Another region where “garimpagem” has been conducted on weathered and primary ore is Poconé, State of Mato Grosso. Since 1777, gold mineralization is known by pioneers. “Garimpeiros” started their activities in the 80s, grinding weathered phyllitic ore with hammer crusher and using centrifuges with capacities of 20 or 32 tonnes of solids/h as the main gravity concentrator. “Garimpagem” continued even when primary quartz orebodies were found. In 1990, there were about 4,500 “garimpeiros” in 100 “garimpo” sites in the region, which is near the Ecological Park of “Pantanal”. The ore has been mined by hydraulic excavators and trucks up to a depth of 40 m. The low grade ore, lack of geological information as well as poor mining and mineral process techniques are the main reasons for declining gold production. Poconé is suffering serious economic difficulties. The city is returning to its prior economic activity, cattle farming. The social and educational level of the Poconé miner is higher than that in other “garimpagem” regions in Brazil. Poconé has been an example of technological improvements made by “garimpeiros” or, as they prefer to be known, entrepreneurs of “garimpagem”. The centrifuges, introduced in the 90s, are cheap Poconé-made copies of the Canadian Knelson Concentrator. This was an extraordinary improvement in gold gravity concentration in the region. Lack of gold liberation[47] is the main reason for low gold recoveries. Currently, there are about 20 “garimpos” reprocessing old tailings by using ball mill circuits (usually two ball mills with capacity of 5 tonnes/h each). Those plants are processing 200 tonnes of tailing producing 100 to 150 g of gold daily (Fig. 2.3). Using ball mills, the gold recovery has increased due to gold liberation, but there is room for improvement. After grinding, the pulp passes through centrifuges and the circuit is closed by using home-made hydrocyclones. Despite the fact that fine gold is lost, the circuits are very well conceived and simple to operate. The first circuit was built by a engineer,

---

[44] CETEM - Centro de Tecnologia Mineral, 1991. Preliminary Diagnostic of Environmental Impacts Caused by Gold “Garimpagem” in Alta Floresta, MT. Technical Report RT 11/91, Rio de Janeiro, 124p. (in Portuguese)

[45] Malm,O.; Pfeiffer, W.C.; Souza, C.M.M.; Reuther, R., 1990. Mercury Pollution Due to Gold Mining in the Madeira River Basin, Brazil. Ambio, vol.19, n.1, p. 11-15.

[46] Pfeiffer, W.C.; Lacerda, L.D.; Malm, O., Souza, C.M.M., Silveira, E.G.; Bastos, W.R., 1989. Mercury Concentrations in Inland Waters of Gold-Mining Areas in Rondonia, Brazil. The Science of Total Environment, v.87/88, p.233-240.

[47] Hammer mills cannot grind fine enough to liberate gold from quartz particles.

who was also a "garimpagem" entrepreneur, and soon other miners copied his technology.

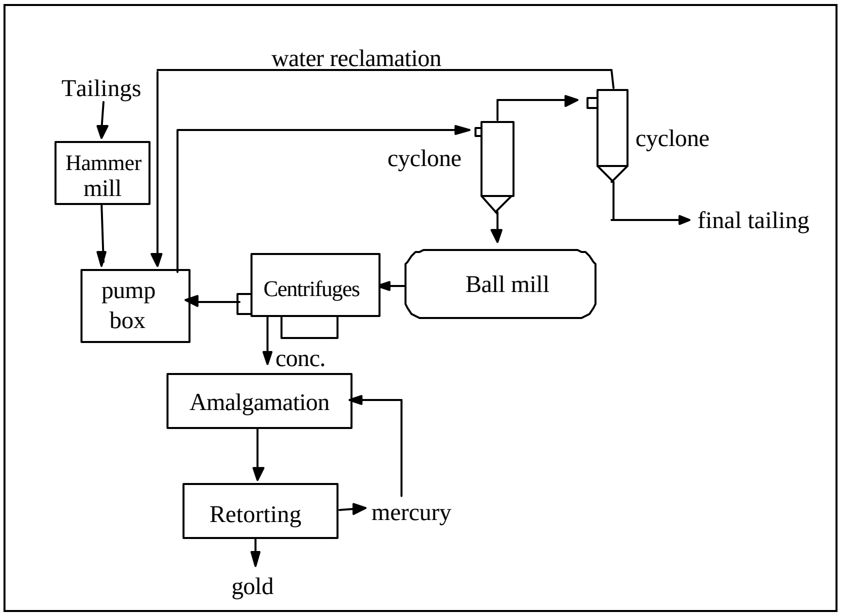


Fig. 2.3 - Typical plant to reprocess tailings being used in Poconé, MT, Brazil

Mercury is used in Poconé to amalgamate gravity concentrates. When a centrifuge is discharged every 8 hours, about 60 kg of concentrate is produced. Amalgamation of concentrate is performed in barrels or in pans using a ratio Hg:conc.= 1:100. A mercury balance of 15 "garimpos" (Fig. 2.4) has shown that over 99% of mercury can be recovered when amalgamation is properly done. Mercury loss can represent as much as 50% of that introduced into the amalgamation process when retorts are not used.

"Garimpagem" in Poconé, by the proximity of the Ecological Park has been the target of harsh criticisms of ecological groups. In 1989, the Center of Mineral Technology - CETEM, a federal research center located in Rio de Janeiro reached the conclusion that lateritic soils, rich in hydrous ferric oxides, can adsorb soluble mercury species reducing bioavailability. Neither the media nor environmentalists understood these results and attacked CETEM[48]. However, the conclusions brought relief to citizens in some affected areas. Knowledge about mercury behavior in tropical environments was the main breakthrough for this group of researchers, but unfortunately this experience was not transferred to miners as well as was planned.

[48] CETEM, 1991. Poconé Project. Final Report. Ed. CETEM/CNPq, Rio de Janeiro, Brazil, 91p (in Portuguese).

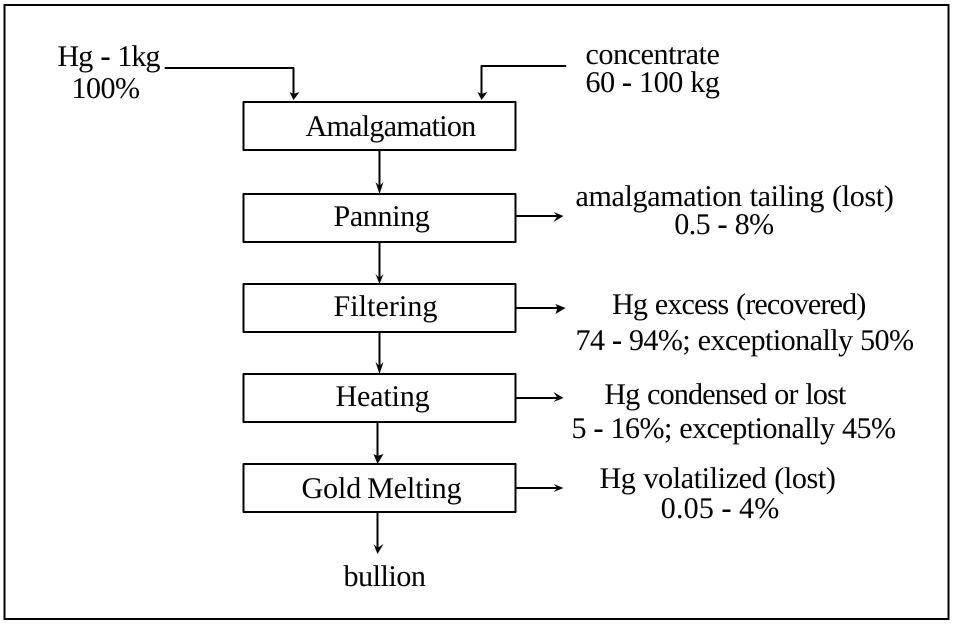


Fig. 2.4 - Balance of Hg in the amalgamation, Poconé, Brazil[49]

Although mercury is not allowed for use by Brazilian miners, amalgamation is the main process used. The miner who did not use mercury is regarded as eccentric by his peers[50]. More than 90% of the gold present in gravity concentrates can be trapped in amalgam according to field observations at some operations. Price is not an impediment for reducing use. Even at 5 times the international price, mercury is still a cheap reagent for extracting gold, with a cost equivalent to 0.012 g of gold per tonne of ore processed[51]. The mining and amalgamation methods used in “garimpos” are variable, which together with the fate of contaminated tailings and Au-Hg separation procedures, define the extent of Hg losses. The following distribution of **mercury losses** can be estimated based on Fig. 2.4:

- 70% by volatilization during amalgam distillation (when retorts are not used),
- 20% dragged with the amalgamation tailings and
- 10% volatilized in the gold shops when gold is melted.

When gold bullion is melted after amalgam distillation, about 20 g of mercury per kg of gold are released[52]. This operation is usually carried out by the gold buyers under the miner’s supervision. Mercury in the interior of these shops is extremely elevated. The fume hoods used for this are usually very rudimentary comprising just a fan which blows out the mercury vapors into the urban atmosphere. This represents the most dangerous emission source, since innocent people living in cities, near those gold dealers are being exposed. Studies[53,54,55] have shown that the majority of Hg emitted by gold smelters is

[49] Farid, L.H.; Machado, J.E.B.; Silva, O.A., 1991. Emission Control and Mercury Recovery from Garimpo Tailing. In: Poconé: Um Campo de Estudos do Impacto Ambiental do Garimpo, Ed. M.M.Veiga and F.R.C. Fernandes, CETEM/CNPq, Rio de Janeiro, Brazil, p. 27-44 (in Portuguese).

[50] Cleary, D., 1990 - op. cit.

[51] Veiga, M.M. and Fernandes, F.R.C. 1990. Poconé: An Opportunity for Studying the Environmental Impact of the Goldfields. In: Proc. 1st Intern. Symp. Environmental Studies on Tropical Rain Forests - Forest'90, p.185-194, Manaus, Oct. 7-13, 1990.

[52] CETEM, 1995. Evaluation of the Social and Environmental Impacts of Mercury Emissions from “Garimpagem”. Coordinated by Araújo, R.V.V. CETEM/CNPq Report, Rio de Janeiro. 100 p. (in Portuguese).

[53] CETEM - Centro de Tecnologia Mineral, 1991 - op. cit.

[54] Marins, R.V.; Imbassahy, J.A.; Pfeiffer, W.C.; Bastos, W.R., 1991. Preliminary Study of Atmospheric Hg Contamination in Poconé, MT. In: Poconé, um Campo de Estudos do Impacto Ambiental do Garimpo p.85-93. Ed. M.M. Veiga e F.C.R. Fernandes. CETEM/CNPq, Rio de Janeiro (in Portuguese).

deposited near the emission source (i.e. within 1 km). A case of mercurialism caused by vapors from gold shop is reported by BBC[56] in an Amazon city. Mr. Pereira lives on the second floor of a house in which a gold shop operates down stairs. After 10 years of receiving toxic vapors, Mr. Pereira, an 60 year old retired citizen developed tremors and had a dramatic reduction of his neurological functions. A filter containing granulated charcoal impregnated with iodine could drastically reduce this emission[57].

In "garimpos", amalgamation tailings are usually recycled to the gravity concentration circuit. When this occurs, gold recovery is very low. Mercury in those tailings is dispersed to the tailing ponds with the possibility of reaching watercourses. In Poconé, the State Environmental Agency determined that all amalgamation tailing must be confined in huge concrete tanks under alkaline pH. This is only a temporary solution and can cause future problems, because, contrarily from most heavy metals, mercury solubility increases with pH. Processing Centers to extract residual mercury and gold are seen as a definitive solution for amalgamation tailings. This is described in section 3.3 of this document.

In the beginning of "garimpagem" in the Amazon (1975), some irrational amalgamation practices were observed, such as:

- mercury was placed on riffles of sluice boxes to amalgamate the whole ore;
- mercury was mixed with the whole ore in excavated pools (hydraulic mining operations).

These poor amalgamation practices seem to be "exported" to other South American countries. Many miners in Brazil are amalgamating only gravity concentrates in buckets, barrels or pans and the mineral portion is separated from amalgam by panning. This operation takes place either in waterboxes or in pools excavated in the ground, leaving behind the amalgamation tailing. This usually is still rich in gold (20 to 50 ppm) and contains high levels of mercury (as high as 500 ppm). In dredging operations, amalgamation is done on board using a high-speed blender and amalgamation tailings are dumped into the rivers creating "hot spots". Everywhere, the method used to remove the excess mercury from amalgams is squeezing by hand using a piece of fabric. The amalgam obtained, usually with 60% gold content is retorted or simply burnt in pans.

The ratio $Hg_{consumed}$:$Au_{produced}$ has been used by many authors to measure mercury losses. This ratio can give very inaccurate results, since mercury can be lost even when no gold is produced. However for regional quantification, this ratio gives an approximate picture of the mercury losses. In regions where only concentrates are amalgamated and retorts are not used, the ratio is usually equals 1. When mercury is spread on the ground, as occurred in hydraulic mining activities, this ratio can be as high as 3.

Mercury losses in 20 years of "garimpagem" in Brazil have been reported as between 1,000 and 2,000 tonnes[58,59]. Other sources of mercury input into the Amazon environment must also be considered. It is widely recognized that significant areas of the rain forest have been destroyed to create fields for cattle farming activities. Fire has also been used for pest control. The total area consumed in the Brazilian Amazon up to 1991 is estimated at 404,000 km^2. Deforestation may play an important role in emitting natural mercury contained in vegetation as well as transferring Hg emitted by miners, gold smelters and any other source from the forest into other sites. So, over 700 tonnes of mercury might be released from

---

[55] Fernandes, E.T.; Alves, R.C.M.; Hacon, S.; Artaxo, P; Campos, R.C., 1996. Dispersion of Atmospheric Mercury in Alta Floresta. Report of the Institute of Physics, University of São Paulo. 11p. (in Portuguese).
[56] BBC - British Broadcast, 1993. TV Documentary "The Price of Gold".
[57] Veiga, M.M. and Fernandes, F.R.C., 1990. - op. cit.
[58] Malm, O. et al., 1995. An Assessment of Hg Pollution in Different Goldmining Areas, Amazon Brazil. The Science of the Total Environment, 175, p.127-140.
[59] Veiga, M.M.; Meech, J.A.; Hypolito, R., 1995. - op. cit.

this source[60]. NASA researchers[61] analyzed about 1,000 ppm Hg in smoke particles smaller than 2.5 µm during the burning season in the Amazon region.

Mercury accumulation in humans has two main pathways in the Amazon:
1. occupational exposure to vapors,
2. methylmercury transferred by fish.

Inhalation of Hg vapor is more significant for "garimpeiros" and gold shop workers. Once in the lungs, Hg is oxidized forming Hg (II) complexes, which are soluble in many body fluids. Since inorganic Hg poisoning affects liver and kidneys, high Hg levels in the urine can indicate undue exposure to Hg vapor. Samples of urine have shown high Hg levels (as high as 370 µg/l)[62] for workers burning amalgam daily. Some of these individuals should show signs of mercurialism, such as erethism (exaggerated emotional response), gingivitis and muscular tremors, however the diagnosis is not easy, as symptoms are often confused with fever, alcoholism, malaria or other tropical diseases.

Metallic mercury must be oxidized to be transformed into a extremely toxic compound, methylmercury. Oxidation of metallic mercury emitted by any source is feasible in the presence of organic acids. This process depends on the amount of dissolved oxygen and organic acids in water[63]. Mercury becomes soluble as a complex and can be converted into methylmercury by biotic or abiotic process. From 70 to more than 90% of the mercury in fish is in the methylated form[64]. Because methylmercury is assimilated rapidly and is eliminated slowly, the mercury levels in top predators are always higher than in their food[65]. When contaminated fish are consumed, methylmercury is much more available for intestinal absorption than metallic mercury and passes into the blood stream to be distributed throughout the tissues. Accumulation of methylmercury in the kidney is lower than metallic mercury, but the brain is affected significantly. Methylmercury poisoning, or "Minamata disease" has five classical symptoms[66] :
1. visual constriction
2. numbness of the extremities
3. impairment of hearing
4. impairment of speech
5. impairment of gait

The first evidence of mercury bioaccumulation in Amazon fish was reported in 1984 by the Jacques Cousteau Society[67] as a result of an expedition of the scientist to Serra Pelada in 1982. A limited number of monitoring expeditions took place in the following years.

Many environmentalists do not have clear knowledge about mercury toxicity and its transformations in the

---

[60] Veiga, M.M.; Meech, J.A.; Oñates, N., 1994. Mercury Pollution from Deforestation. Nature, v.368, p.816-817.

[61] Kaufman, Y.J. et al., 1992. Biomass Burning Airborne and Spaceborne Experiment in the Amazonas (Base-A). J. Geophysical Research, v.97, n. D13, p.14,581-14,599.

[62] GEDEBAM, 1992. Mercury Contamination in the Brazilian Amazon. Report for the Commission of the European Communities, Contract ref B946/89. Ed. I. Thornton, A.R.B. Silva, N. Brown, T.C. Souza, L.R.D. Abreu, A. Messias, D. Cleary, S. Worthington. A cooperative research study by Gedebam and SOL 3 - Switzerland and Luxembourg. Monte Alegre, Para, Brazil, 104p.

[63] Tromans, D.; Meech, J.A.; Veiga, M.M., 1996. Natural organics and the environmental stability of mercury: electrochemical considerations. J. Electrochemical Society, v. 143, n.6, p. L123-126.

[64] Huckabee, J.W.; Elwood, J.W.; Hildebrand, S.G., 1979. Accumulation of Mercury in Freshwater Biota. In: The Biogeochemistry of Mercury in the Environment. p.277-302. Ed. J.O. Nriagu. Elsevier/North-Holland Biomedical Press, Amsterdam, 696p.

[65] D'Itri, F.M., 1972. The Environmental Mercury Problem. CRC Press, Cleveland, Ohio, 124p.

[66] According to Dr. Hirokatsu Akagi from National Institute for Minamata Disease, Japan.

[67] Hacon, S., 1990. Mercury Contamination in Brazil. Technical Report, FINEP, Rio de Janeiro, Brazil. 85p.

environment, and so not infrequently they are surprised by theatrical performances of "garimpeiros" with the intent to embarrass ecologists. In 1987, José Altino Machado, a "garimpeiro" leader, ingested metallic mercury in front of TV cameras to show that mercury is inoffensive. Mercury became an interesting weapon to attack "garimpos" although little knowledge about its effect was understood by the accusers. The frightening term "methylation" changed the image about mercury. How methylation happens and how it is measured was another mystery and a taboo to be addressed and discussed only by a selected elite. In some cities, fish consumption declined and mineral water started to be a good business. The media has been creating panic instead of alerting and providing solutions for affected communities.

Many studies have established the extent of concentration in fish in the Amazon region. Levels higher than 0.5 ppm Hg are mainly related with carnivorous species[68,69,70,71,72]. A recent work[73] stressed that children under 15 years old are the group at the highest risk of taking mercury through mother's milk, through fish ingestion or via the placenta.

In 1991-92, an international team of scientists[74] analyzed 52 fish from three areas of "garimpo" in the Brazilian Amazon region showing values ranging from 0.01 to 2.6 ppm Hg. About 30% of fish samples exceeded the guideline of 0.5 ppm Hg established by the Brazilian Government as the safe limit for consumption. The impact of the high mercury levels in fish is seen from the high mercury levels in the blood of fish-eating people (10 to 206 µg Hg/l). So considering normal Hg levels in the blood range from 6 to 12 µg/l, the gravity of the situation is apparent.

Natives from Madeira river Region, Brazil, have more mercury in the blood (32 µg/l) than miners (17 µg/l) due to a higher fish consumption habit. About 3% of the fish-eating people showed methylmercury concentration in hair ranging from 50 to 300 mg/kg (ppm)[75]. The normal level for humans is around 2 ppm, but fish-eating people usually have 6 ppm as normal background. The critical level for pregnant women is 10 ppm[76].

Brazil is not a mercury producer and imports around 340 tonnes annually. From 1972 to 1984, Mexico was the main Hg supplier to Brazil. Since 1984 this picture has changed and non Hg-producing countries (the Netherlands, Germany and England) are responsible for almost 80% of the Hg entering Brazil. Mercury imports are allowed only for registered industrial uses, however the declared uses (electronic industries, chlorine plants, paints, dental, etc.) are declining. The updated Brazilian laws intend to exert more control on Hg imports. In 1989 this represented about 22% of the total 340 tonnes of Hg. The remainder was imported for re-sale to industries, but it is estimated that over 170 tonnes were illegally

---

[68] Pfeiffer,W.C. and Lacerda, L.D., 1988. Mercury Inputs into the Amazon Region, Brazil. Env. Techn. Let. v. 9, p. 325-330.

[69]Pfeiffer, W.C.; Lacerda, L.D.; Malm, O.; Souza, C.M.; Silveira, E.G.; Bastos, W.R., 1989. Mercury Concentrations in Inland Waters of Goldmining Areas in Rondonia, Brazil. The Sci. of the Total Environm, v.87/88, p.233-240.

[70]Pfeiffer, W.C.; Malm, O.; Souza, C.M.; Lacerda, L.D.; Silveira, E.G.; Bastos, W.R., 1991. Mercury in the Madeira River Ecosystem, Rondônia, Brazil. Forest Ecology and Management, v.38, p.239-245

[71] Martinelli, L.A.; Ferreira, J.R.; Fosberg, B.R.; Victoria, R.L. 1988. Mercury Contamination in the Amazon: a Gold Rush Consequence. Ambio, v.17, p.252-254.

[72] Fernandes, R.S.; Guimarães, A.F.; Bidone, E.D., 1990. Hg Monitoring in Carajás Project Area. Saneamento Ambiental, n.6, p.34-41 (in Portuguese).

[73] Boischio, A.A.P. and Henshel, D.S., 1996. Risk Assessment of Mercury Exposure through Fish Consumption by the Riverside People in the Madeira Basin, Amazon, 1991. NeuroToxicology, v.17, n.1, p.169-176.

[74] GEDEBAM, 1992. - op. cit.

[75] Barbosa, A.C. et al., 1995. Mercury Contamination in the Brazilian Amazon: Environmental and Occupational Aspects. Water, Air and Soil Pollution, v.80, p.109-121.

[76] Malm, O., 1991. Environmental and Human Contamination of Mercury in "Garimpos" from Madeira River. Doctoral Thesis. Federal University of Rio de Janeiro, Inst. Biophysics. 54 p. (in Portuguese).

diverted to "garimpos"[77].

Chile

Mining represents 8% of the GDP of Chile and 49% of the exports (copper alone represents 40%). Chile is the world's largest copper producer and exporter with a production over 2.5 million tonnes of copper or 26% of the world production. The Chilean government is encouraging foreign companies to invest in the mining sector. Actually, Chile has been the main target for both junior and major Canadian and American mining companies.

In 1995, gold production reached 44 tonnes (1.4 Moz) in which the majority of this production came from medium-size gold plants. The copper mines have contributed with 7 to 8 tonnes (about 240,000 oz) of gold. There are more than one hundred small amalgamation plants in Chile producing between 2 to 3 tonnes (about 80,000 oz) of gold annually. The small copper miners have also produced about 1.2 tonnes (38,600 oz) of gold[78].

The city of Coiapó, located in the Southern part of the Atacama desert, 800 km north of Santiago, is a region with a significant number of small gold and copper mines. The technology used by small miners to recover gold is amalgamation by using the "trapiche", a sort of Muller pan. This Chilean equipment has a fixed bowl and a very heavy cast iron wheel (diameter usually of 2 m) which runs for about 8 hours over a mixture of ore-pulp and sometimes mercury. The ore is fed manually. The amount of ore ground is very small (0.5 tonne/h). Tailing is discharged by overflow and an amalgamated copper plate works as a scavenger of gold particles that were not amalgamated. A subsequent flotation of tailing concentrates fine gold and sulfides. The amalgam is scratched off from the plates and burnt in open pans representing a dramatic health problem for those workers. The University of Liège (Belgium) and the Center of Mining and Metallurgical Researches (CIMM) in Chile are introducing a project to replace amalgamation with gravity concentration in which centrifuges are the main processing unit. Encouraging results were achieved in lab tests[79].

Colombia

Since the Spanish colonization, the gold mining activities in Colombia represents an important source of wealth. Back then, Colombia produced 40% of the world's gold output. From 1864 to 1974, gold mining was in hands of foreign companies, most of them British. As in other countries, the decline of gold production started at the end of the World War II. At the end of the 70s, gold activities resurrected and nowadays gold mining operations are spread all over the country.

Geologically, Colombia has two gold provinces: the Andean and the Orinoquia-Amazon provinces. Located in Pre-Cambrian terrains, the latter represents 50% of the Colombian territory and its potential is still unknown. In 1995, the gold production in Colombia was 25.6 tonnes (823,000 oz) of which less than 12% (2.5 tonnes) came from formal mining companies. Most gold production, 88% of the national output, comes from informal miners[80].

---

[77] Ferreira, R.C. and Appel, L.E., 1991. Sources and Uses of Mercury in Brazil. Estudos e Documentos, 13. CETEM/CNPq, Rio de Janeiro, 33p. (in Portuguese).
[78] Chilean Mining 1995.
[79] Goffaux, D., 1995. Transfer of New Gravitational Gold Concentration Technologies to the Small Mining Sector of the Atacama Region. SIM Bull., n.8, p.11-12.
[80] Roa, L.T., 1996. Monography of Gold. Report prepared to Unidad de Planeación Minero Energética del Ministério de Minas y Energia (in Spanish).

The number of artisanal miners in Colombia is not known by authorities. The Ministry of Mines and Energy through its Unit of Information estimates a number of 21,500 small miners just in coal production. According to the Ministry of Mines and Energy, there are only 4 stable mining companies that use conventional technical approach in gold mining industry.

Projekt-Consult believes that more than 100,000 small miners are involved with gold extraction. Most likely, about 200,000 artisanal[81] gold miners are working in Colombia to produce 22.5 tonnes of gold annually. The gold mining activity in Colombia is classified by the size of the operations. The gold production in 1995 is shown in the Table 2.2.

Table 2.2 - Gold production in Colombia, 1995

	Ore processed/year	**Gold Output 1995 (tonnes)**
Type of Alluvial Mining:		
Large	> 1.5 million m^3/y	1.3
Medium	> 250,000 < 1.5 million m^3/y	5.5
Small	< 250,000 m^3/y	3.0
Subsistence		4.5
Type of Quartz Vein Mining:		
Medium	> 8,000 < 200,000 tonnes/y	1.8
Large	< 8,000 tonnes/y	9.5
Total		**25.6**

- Large Alluvial Mining Operations:

There is only one large alluvial operation conducted by Compañia Mineros de Antioquia, that dredges 12 million m^3/year of gravel in the Nechi and Porce rivers with a grade of 124 mg Au/m^3 to produce 1.3 tonnes/year of gold.

- Medium Size Alluvial Mining Operations:

This comprises mining activities with mechanical excavators, bulldozers and trucks. The concentration process is usually done in sluice boxes and mercury is always used. Mining activities were initiated in the Lower Cauca Antioqueño-Nechi river and later disseminated to Departament (Province) of Chocó, Córdoba and Nariños. Some operations are observed at La Dorada and Department of Bolivar. This type of mining has been reduced due to exhaustion of the alluvial deposits and environmental restrictions. Nowadays, it is estimated that 90 excavators are still working in Colombia, moving about 20 million m^3 of material to produce 5.5 tonnes of gold annually.

- Small Alluvial Mining Operations:

This type of mining encompasses those carried out by hydraulic monitors in alluvial-colluvial terraces. This practice can reach deep placer deposits. The gold production of 2 tonnes comes from the Departments of Chocó, Antioquia, Valle del Cauca and Nariño.

- Subsistence Mining Practice:

This category comprises a number of manual miners who use transportable pans, rockets and sluices. They do not have legal restrictions to work in the rivers and banks. Usually these "barequeros" work on the tailings of the other mining activities. In the Pacific coastal regions, the number of women associated

[81] This estimate is obtained comparing Colombian production with 30 tonnes of gold produced by 400,000 "garimpeiros" in Brazil.

to these kind of activity exceeds the number of men[82].

- Medium Size Quartz Veins Mining Operations:

There is no large mining activity working on quartz veins, only three companies are working with veins: Frontino Gold Mines, El Limón and Minero Nacionales. The gold recoveries of these plants are over 90% and 1.8 tonnes of Au were produced in 1995.

- Small Vein Mining Activities:

There are a large number of miners exploiting quartz veins to be processed in their own plants or in third party facilities. The miners bring bags of ore to the plants to be crushed by "machuqueros", rudimentary stamp crushers or by jaw crushers followed by ball mills. The processing plant design depend on the ore type. This ranges from sluices with amalgamation to homemade cyanidation tanks. Most of the small miners in the Department of Bolivar are working on weathered and fractured material. The production is reduced when they find fresh rocks. In 1995, gold production from these type of miners was around 9.5 tonnes/y (305,000 oz) in which 8 tonnes (257,000 oz) came from Department of Bolivar.

As a result of the end of the monopoly for buying gold in Colombia by the Bank of Republic, the statistics are losing credibility. In 1994, Colombia produced 20.8 tonnes (669,000 oz) of gold, 1.08 tonnes (34,700 oz) of platinum and 5.9 tonnes (190,000 oz) of silver. These official numbers indicate a drop of about 20% on precious metals production compared with 1993[83].

The Bank of Republic just pays those miners who sell gold cleaned by nitric acid. Those who retort gold must wait 15 days for chemical analysis prior to be paid. This has encouraged miners to use nitric acid to dissolve mercury from amalgam[84]. Mercury dissolution by acid is also practiced by small North American prospectors. When all the mercury is solubilized, the gold remains at the bottom of the vial. Part of the silver can be solubilized. The method is efficient but very dangerous. Mercury oxidation is the first step for methylation. After filtering, mercury in solution can be recovered by precipitation with aluminum (or iron or zinc or copper) wires immersed into solution. The major problems in acid dissolution technique is the fact that after precipitation, the solution still has some mercury and must be treated before disposal. In addition mercuric nitrate fumes are highly toxic. Mercury goes into solution as mercury pernitrate - $Hg(NO_2)_2.H_2O$. Human beings have a tolerance of only 0.05 mg per cubic meter of this compound in air. A very serious risk is also present when mercury pernitrate contacts alcohol as fulminate ($Hg(CNO)_2$) can be produced. This explodes readily when dry and is used in blasting caps and detonators. Currently, gold miners in Colombia are not precipitating mercury from nitrate solution. They simply discharge all mercuric solution into the waterstreams. The Cooperative of Nariños (Corpanariño) estimates that about 58 kg of mercury is lost annually in Nariños.

A few reports[85] have stressed the grave situation of mercury emissions in Colombia. In the mining districts of California and Vetas in Bucaramanga, it is estimated that between 400 and 500 kg of mercury is annually discharged. Cyanide is also another pollutant dumped by small gold miners into the Suratá river.

---

[82] INGEOMINAS-Inst. Investigaciones en Geociéncias, Mineria and Química, Min. Mines and Energy, 1995. Colombia, a Gold Mine. 25 p. (in Spanish).

[83] Mining Annual Review, 1995. p.83.

[84] Corponariño, Cooporación Autonoma Regional para el Desarrollo de Nariño, 1995. Evaluation of Social and Environmental Consequences of Mining with Excavators in Department of Nariño. Convenium Canada-Colombia, Fidufes-Corponariño. Doc. prepared by INCOAMPRO (in Spanish).

[85] Hartnagel, B.; Cramer, S; Bermudez, R., 1994. - op. cit.

Costa Rica

Costa Rica is considered one of the most industrialized countries in Latin America. Recently, the country has faced high inflation rates and a substantial foreign debt. Costa Rica is the oldest and most stable democracy in Latin America. Mining is limited in the country, accounting for only 0.1% of the GDP in which diatomite, sea salt, gold and silver are the main mineral resources extracted[86].

Gold was mined in the Southwestern part of Costa Rica by natives in Pre-Columbian times. The country was named by Columbus because of the many gold adornments worn by the natives. The first recorded discovery of mineralized gold veins was made in 1815 by a visiting Spanish Bishop, Nicolas Garcia in the Aguacate Mountain. This led to the mining of supergene enriched surface ores. Small-scale mining began in Aguacate and continued throughout the 1800s using rudimentary gravity techniques with amalgamation. By the 1890s several mines employed cyanidation to process high-grade ores. Most mining activities ceased working in the 1920s due to the fixed gold price. At the end of the 70s, when gold price became decontrolled, gold mining was reactivated. Significant placer gold deposits on the Osa Peninsula, near the Panamanian border has been worked by small miners. There is no known major placer mining activity at present, but the area has many active “coligalleros” working on the rivers[87].

The richest placer deposits in Costa Rica are located in the Corcovado National Park, which occupies one-third of the Osa Peninsula. Reports have indicated that at the mouth of the Carate river, the placer ore grades are as high as 5 g/m^3. Illegal miners have invaded the National Park for panning[88]. Mercury has been used to amalgamate concentrates. The Park Service and the Civil Guard is always removing “coligalleros” from the Park.

In the Northeast of Costa Rica, in the region known as Abangares district, “coligalleros” are mining primary ore and mercury has been used. This region comprises a group of former gold mines which was recently acquired by a Canadian company, Ariel Resources, which is at the present the largest active gold producer in Costa Rica.

The Costa Rica Mining Code of 1982 provides two types of concessions: exploration and exploitation. Landowners merely own surface rights and “coligalleros” are habitually conducting illegal mining activities on surface gold deposits. As the problem does not have large proportions, the Costa Rican government does not frequently enforce the law against these small miners.

Costa Rica is one of the most advanced Latin American countries regarding protection of the environment and natural resources. The environmental groups are extremely active.

Dominican Republic

The Dominican economy showed signs of slippage in 1994, although it overall performance in recent years has been relatively strong. The National Product Growth is increasing about 3 to 4% per year but the unemployment rate is still high, 30%[89]. The main mining activity in the country is conducted by the Canadian company Falconbridge which exported more than 31,000 tonnes of nickel contained in

---

[86] Notholt, A., 1995. Costa Rica. Mining Annual Review. p. 92.
[87] Bennet, W.C., 1994. Gold Mining Opportunities in Costa Rica. Proc. Randol at Vancouver '94. p.55-59.
[88] Corbin, R.K., 1988. Costa Rica: Golden Opportunity for 1989. Proc. 2nd International Conference on Gold Mining. Nov. 7 - 9, 1988. Vancouver, BC, Canada. AIME Edition.
[89] Welcome to Dominican Republic. Website http://caribecom.clever.net:80/infdom/idind6.htm

ferronickel produced from lateritic deposits[90].

Statistical data show that Dominican Republic was the main gold producer in Latin America in 1977 with an output of 10.7 tonnes (342,755 oz)[91] likely derived from Pueblo Viejo mine. The total production of the state-owned Rosario Dominicana Pueblo Viejo company in 1994 was only 1.65 tonnes (51,400 oz). Canadian, Australian and American companies are investing in geological exploration in the country. In 1985, United Nations conducted an evaluation of the gold potential of the Dominican terrains. About 145 sites were indicated as promising areas for gold.

The presence of artisanal miners in Dominican Republic is noticed in the Eastern (region of Miches) and in the Central Cordillera (region of Monsion, Ránico, San Jose de las Matas). According to Mr. Victor Garcia, Director of the "Direción General de Mineria" there are about 2,000 people involved directly in artisanal mining activities. Their production is not officially reported but about 1 tonne might be produced annually. In general, mercury is not extensively used by the "lavaderos de oro" who usually are after the easiest and coarse alluvial gold. No mining activity in primary ore deposits has been observed.

Artisanal mining activities are legal in Dominican Republic as long as they are not mechanized. The law allows manual miners to work without previous authorization if only "batea" and small dredges are used. The Mining Department is studying a way to promote alluvial mining by using barges and dredges through a cooperative system.

Ecuador

Mining represents a small portion of the Gross Domestic Product of Ecuador (1%). However, the geological potential of 100 km of the Andean highlands is indicative of a promising future for gold-silver and polymetallic sulfides in the country. The largest official gold producer in Ecuador, Oding Mining Company, with 0.7 tonnes (22,000 oz) shut down its alluvial operation around the end of 1994 due to technical constraints[92].

The main gold production comes from artisanal miners working in Portovelo-Zaruma, Ponce Enriquez-Bella Rica and Nambija-Guayzimi districts. Many dredging operations are reported in the following rivers: Esmeraldas-Santiago, Daule-Quevedo, Puyango-Balao, Zamora-Chinchipe-Upano and Napo-Pastaza-Aguarico. The unofficial gold production in 1994 was 10 tonnes and in 1995, 15.5 tonnes[93]. The large majority of the gold production (85%) comes from artisanal mining operations.

The number of artisanal gold miners in Ecuador can be as high as 100,000 and the annual mercury emission from these miners is estimated to be around 50 tonnes[94]. These numbers seems to be exaggerated based on the gold production of 13 tonnes, but even 50% of this emission level is already exorbitant. About 70% of the gold production is sold to the black market. Since 1991, the National Mining Department has granted 417 titles of small-scale mining operations.

Amalgamation and cyanidation are practiced by 10,000 informal miners in Zaruma and Portovelo municipalities. There are 68 plants in operation with a capacity to process 14,000 tonnes of ore/month.

---

[90] Ellis, G., 1995. Dominican Republic. Mining Annual Review, p.96.

[91] Wilkie, J.W., 1995. Statistical Abstract of Latin America and the Caribbean. UCLA Latin American Center Publications, LA, California. p. 538

[92] Puig, C.A., 1995. Ecuador. Mining Annual Review. p. 89-90.

[93] Ramos, P., 1996. Ecuador: El Dorado. Website: http://www3.vistazo.com.ec/sep12_96/htm/dinero1.htm.

[94] Hruschla, H.; Rodriguez, F.; Salinas, C., 1995. Environment Protection in Ecuadorian Gold Mining. SMI - Small Mining International Bulletin, n.8, p.3-4, Feb. 1995.

The ore is exploited through shafts to be crushed and ground in different mills (balls, rods, etc.). Concentration is carried out in sluices lined with carpets. Gravity concentrates are amalgamated in a sort of “Muller” pan for 2 to 4 hours. Amalgam is usually burnt in pans, sometimes wrapped in aluminum foil. Gold production is estimated at 1.4 tonnes/year with recovery around 50 percent[95].

Since 1990, International Institutions are evaluating the mercury emission from gold miners in Ecuador. The Swedish Geological AB has reviewed the environmental and health impacts on natives. “Mining without Contamination” is another project carried out by an Ecuadorian NGO, CENDA Foundation and Swiss Technical Cooperation, represented by the German company Projekt-Consult. The University of Loja is also a participant in this project which the main objective is the reduction of environmental impacts caused by small-scale mining in Portovelo-Zaruma region. Preliminary diagnostics have concluded that about 50% of miners are burning amalgam in their homes. Technical people are bringing new techniques for miners to reduce mercury emissions.

Numerous international companies are investing about US$ 40 million annually in geological exploration in Ecuador. By the year 2003, experts expect that mining will be a strong sector of the Ecuadorian economy, creating 40,000 new worksites.

French Guyana

French Guyana is the smallest country of the South American continent with an area of 84,000 km^2 and population of 130,000 inhabitants.

Gold was first discovered during the 1860s but, since then, production has been limited to placer deposits. The gold output is totally attributed to about 5,000 small miners who produces 3 tonnes (96,000 oz) annually[96]. Geologically, French Guyana is extremely favorable to gold mineralization. Canadian, American and French companies are investing in exploring the gold potential of the greenstone belts previously indicated by the “prospecting” work conducted by small miners.

The indiscriminate use of mercury by artisanal miners has attracted the attention of French and Canadian researchers, who have calculated that mercury has been discharged into the environment at a ratio of 0.7 kg of mercury for every kg of gold extracted. These researchers believe that approximately 300 tonnes of mercury have already entered the aquatic system. Up to 65% of Ameridian population, which has fish as the main diet, has shown mercury levels in hair above the upper limit of 10 ppm established by the World Health Organization[97].

Guyana

Guyana has a population of 750,000 that consists of 50% Indo-Guyanese, 36% Afro-Guayanese, 7% Amerindian and 7% of other origin. Over 90% of the population lives in the coastal area. The proportion of the population living in poverty is around 45% and this has increased. Guyana has the lowest GDP per capita in Latin America, US$ 330.

---

[95] Vaca, G.A., 1992. Gold Mining in Ecuador and its Impacts. In: Proc. 2nd International Conference on Environmental Issues and Waste Management in Energy and Minerals Production. v.2, Ed. R.K. Singhal et al., Calgary, Alberta, 1-4 Sept. 1992, p.969-984. (in Spanish)

[96] Mining Annual Review, 1995, p.90.

[97] Le Monde, March 30, 1996. Extensive River Pollution in French Guyana.

In 1720, Sir Walter Raleigh obtained gold from the Amerindians but gold production in Guyana was first officially recorded just in 1884. It has actively continued to the present day where it is dominated by artisanal miners operating generally as individual or small family concerns. The main mining method is dredging of alluvial gold occurring in river beds and banks. Small pit mining of alluvial deposits on lands adjacent to the rivers is also fairly widely practiced in certain areas. Nowadays, there are 1,000 permits issued by the Guyana Geology and Mines Commission (GGMC) and 400 dredges in operation in the country. The number of miners increased drastically from 6,000 in 1992 to 10,000 in 1996 according to estimate of Mr. Woolford from GGMC. No register of small miners is available in Guyana. Gold production from artisanal miners was 2.8 tonnes (90,000 oz) in 1994, 3.1 tonnes (99,000 tonnes) in 1995 and 3.4 tonnes (110,000 oz) in 1996.

With the growing world-wide concern for the environment in recent years, the government of Guyana has placed a high priority on environmental issues. Although dredge mining operations are generally being conducted on a small scale and in remote areas, GGMC recognized the need to minimize the adverse effect of the current mining activities[98].

Guyana's new Mining Act came into force in July 1991. While no general or specific provision is made for prevention of pollution or protection of the environment, the broad general framework providing for the granting of mining permits and claim licenses would enable inclusion of environmental protection provisions as conditions to obtain such permits. In addition GGMC is empowered to give directions to miners on matters of safety and good mining practice and they are obligated to comply promptly with such directions.

Dredging operations are concentrated on Essequibo river and its tributaries:

- the Mazaruni river and its tributaries, the Cuyuni, Puruni, Semang, Eping, Kurupung and Meamu rivers.
- the Potaro river and its tributaries, the Kuribrong river.
- the Konawaruk river

Mercury is used in Guyana gold mining operations to extract gold from the final concentrate produced in the gravity separation process. Mercury is added to a bucket containing the final concentrate and water. Amalgamation occurs as the gold and mercury are brought into contact by hand mixing the contents of the bucket. Approximately 14 grams of mercury are required to amalgamate 1 kg of concentrate (ratio Hg:conc.=1:70). The resulting amalgam is squeezed through a fine cloth to remove the excess mercury which is re-bottled and used again. The gold-mercury amalgam is then heated in a tin over a fire or blowtorch until the mercury vaporizes. Occupational exposure is obviously a very serious concern.

The GGMC considers unlikely the possibility of serious environmental contamination of the rivers because of the type, size and distribution of the gold mining in Guyana. According to GGMC, contamination, if it is occurring, is most likely localized. Nevertheless, any increase in alluvial mining activity during the next years, which seems inevitable following the development of the "missile mining" technique (suction/eductor dredge mining using a winch to manipulate the tapered suction end on the river bed) will need to be monitored. The government recognizes that the artisanal miners cannot afford sophisticated environmental impact assessment reports or advanced mineral processing equipment. In order to provide help to the small miners to implement environmental management and control procedures, the government has already accepted that it must provide:

---

[98] Watkin, E.M. and Woolford, W.H., 1992. Alluvial Gold Mining in Guyana - Environmental Aspects. Report of Guyana Geology and Mines Commission.

1. Technical assistance through establishment of research centers and technical advisory services for small miners.
2. Education and training of miners.
3. Public awareness program

Further, the government has arranged for help from foreign countries and international organizations in designing a program of environmental management and controls for the small scale mining sector.

The only gold producing company in the country is the Omai Gold Mines which reported in 1996 an output of 8 tonnes (257,000 oz) from its cyanidation plant. Omai is the single largest foreign investor in Guyana. The company is 60% owned by Canada-based company Cambior Inc., 35% by Denver-based Goldstar Resources and 5% by the Guyanese government. The US$ 250 million gold plant started in 1993 increasing the Guyanese gold output from 2.8 tonnes (90,000 oz), produced exclusively by small miners, to 9.6 tonnes (309,100 oz). In August 1995, Omai was in the headlines of all newspapers around the world[99]. A major rupture of the 3 million m^3 tailing pond discharged 1.25 million m^3 of slurry with cyanide concentration of 28 ppm into the Essequibo river[100]. The accident affected the aquatic biota but no human poisoning was reported. The Guayanese government issued a warning to residents along the Essequibo river not to use the water for drinking, bathing or feed to animals. Omai and Government authorities distributed bottled water and leaflets with instructions to riparian residents. Environmental groups as well as political parties in Guyana have compared this accident to the Jonestown suicides in which, in 1978, 900 cult members of Jim Jones' church died by cyanide ingestion in the Guyana jungle[101].

Most free cyanide degrades rapidly with sunlight. The impact of cyanide on the environment is not through bioaccumulation as occurs with mercury. The effect is immediate and catastrophic. The fact that Omai brought up Canadian scientists to attest that water and fish were no longer affected by cyanide did not convince the unions and natives' organizations. The company has followed all government resolutions and re-started its gold production. A permanent Disaster Control Commission was established in Guyana as an embryo of the Environmental Protection Agency which is an aspiration of the Guyaneses. The government is contemplating a possible financial support for EPA creation with resources from the World Bank and other international agencies.

Honduras

Honduras has a very low GDP per capita (US$ 580) and its economy is based on agriculture. In the 1940s and 1950s, some artisanal mining activity was observed on the Guayape River and its tributaries, the Patuca River and its tributaries, and the Sico (Grande and Negro) River and its tributaries. All of these are in eastern Honduras, principally in the Department of Olancho[102].

The Guayape placers were discovered early in the Conquest by Spanish explorers from the port of Trujillo, in Honduras, and explorers from Panama under Pedrarias. They found the placers at the same time, and a conflict between them followed. After this was settled, approximately 50,000 people were

---

[99] Office of the Prime Minister Press Release, 1995. Cyanide Pollution of Essequibo River. Website: http://www.guyana.org/GuyNews/spill_pm.htm

[100] The maximum concentration for cyanide efluents internationally accepted is 0.2 ppm to be dilluted to 0.02 ppm in the waterstreams.

[101] Guyana Environment: Cyanide Leak is Country's Worst Disaster. Website: http://www.environlink.org/action/news/toxics/cyanide.html

[102] All information was told by Mr. William Lady, a retired gold miner, living in Florida. He produced gold and conducted many geochemical programs in the 1950s and 1960s. Mr. Lady is an important part of the mining history of Honduras. His e-mail: blady@sunline.net

involved in working the placers, with some of them raising food, and the others working in the river and nearby creeks. Late in this period, when a few available natives remained, black slaves were imported into the area from Africa to work in mining.

These deposits were pretty much exhausted in the 1940s and the only workers in the creeks were women, and this was on a very small scale. The women would go to the creek nearby to wash their clothing, and, while the clothing was drying on the bushes, they would recover a little gold with a wooden batea. Over a period of time they would accumulate a little bit of gold which they would usually sell to Alberto Bu Castellon, a merchant in the town of Juticalpa, and to a few other merchants. With the proceeds from this, they used to buy some salt, cloth for a dress, and a few other groceries. The individual production was very small, and no reliable record is available in Honduras which would accurately reflect total production. Traces of mercury are not visible in the placers anywhere the Spaniards and later women have worked.

It is known a small mercury ore deposit in Honduras, west of the town of Talanga, was mined during the Conquest.

The Patuca River and tributaries were worked very little during the Conquest because of accessibility problems. During the 1940s and 1950s, small parties of men from the Valley of Azacualpa made expeditions to the Patuca during the dry season and worked the gravel of the river and its tributaries on a very small scale. It is assumed that they did not use mercury, and most of the recovery was by batea. Women normally did not accompany the men on these expeditions.

Not too long ago, several American miners took small scale underwater dredges to the area, and worked the river gravel with limited success. At the present time, there are an estimated 140 of these dredges working in the river, and most of these are owned by native miners. They are mostly very poor subsistence farmers, who now live in the area.

The Sico River and tributaries were worked very little during the Conquest. There was a little placer mining on some tributaries of the Paulaya River, just East of the Sico, since they were along the trail used by the Spaniards for traveling between Trugillo and the Guayape gold fields. When the banana plantations were abandoned in the Paulaya River Valley, in the 1930s, the then unemployed workers started mining the creeks, and the Sico itself on a fairly large scale. Outside of these three general areas, very little placer gold was produced in Honduras during the Conquest or in the later times.

The most important factor in the lack of mining activity by locals in Honduras during the last two hundred years, is a notable lack of interest in mining on the part of the wealthier Hondurans, and this is still very prevalent today. There were excellent miners from the beginning of the Conquest, and they found, and at least superficially explored, most of the mineral deposits in the country. One of the largest family fortunes in Honduras was essentially based on early mining activities. The operation of several excellent mines in the central area created a lot of wealth and prosperity in Tegucigalpa. For some reason, this interest waned, and organized mining activity for the past 100 years has been totally by foreign companies, with foreign engineers and capital. The most famous silver mine, dating back a little over 100 years, was the Rosario Mine. It was operated continuously for 85 years, and when it closed there were 300 miles of underground workings.

The lack of interest and activity on the part of the artisanal miners is due to the very low grade of most of the placer gold deposits remaining in Honduras, the remoteness of some of the better areas, and the difficulty and expense of working. The presence of small miners in Honduras ("güirises") is small and limited to subsistence. Greenstone Resources, a Canadian company conducting geological exploration in

Honduras, has indicated that a number of informal miners are exploiting and processing primary ores using mercury. No information about their production and contamination is available.

A few primary gold deposits were worked by using a water powered, or oxen-powered, “arrastra”. This is a circular stone and lime cement masonry trough with a central shaft attached to stones which were dragged around the trough. Water was introduced into the trough, and in some cases, mercury was probably used to amalgamate the gold. The ore was broken up as fine as possible with hammers before being placed into the “arrastra”. An “arrastra” was also sometimes used for silver ore.

A smaller scale gold recovery device was the “molinete”, which was a hole chipped into the rock beside a convenient creek, with another stone worked to fit inside of the hole as a grinder. The inner stone was moved through a wooden handle driven into a small hole in the grinder. Water was added to the ore in the “molinete”, plus a little mercury, and the ore was ground until powdered and the gold was released and amalgamated.

Most of the small silver mines were operated by smelting the ore, which required some relatively sophisticated technology. The smelters were usually built from stones and clay in the shape of an old European style beehive (six or eight feet high), with an opening at the top for charging and for a draft. Wooden and cowhide bellows were probably used to pump air (oxygen) into the smelter. The ore had to be charged with a varying mixture of charcoal/flux/ore, depending on the nature of the ore. Galena (when this was lacking in the ore itself) was added to provide the lead needed to extract the silver. Charcoal was the fuel.

Small silver mines have also used a different extraction process: the ore was ground and then put into masonry vats to soak in a mixture of water, salt, and mercury. This was called, “the chloride process”. Some of these sites, with the vats still preserved, can be found even today. Unfortunately all of this knowledge has totally disappeared in Honduras.

At the present time there are two mines producing precious metals in Honduras: El Mochito and San Andres. El Mochito, owned by an American company, produced about 25 tonnes of silver in 1994 in its underground operation. San Andres was acquired by a Canadian group that produced 138 kg (4,290 oz) of gold in 1994 from its heap leaching plant[103]. There is a very large amount of exploration activity by Canadian and American mining companies. The potential for development of a large mine in Honduras is very promising.

Mexico

Mexico has a long history of mining activities. For over four centuries the extraction of metals has been part of the economy of Northern, Central and Western part of the country. According to the Population Census of 1990, about 5 % of the economically active population is engaged in the mining sector. There are 72 municipalities in Mexico where mining activities play a significant role in the local economy. Fluorite, marble and other different non-metallic minerals are exploited from several hundred small mines. Apparently, small-scale enterprises and individual gold panners, “gambusinos”, are scattered all over the country, mostly in the mountainous regions (sierras)[104]. The Occidental part of Sierra Madre in the States of Durango, Sinaloa, Chihuahua and Nayarit, concentrates most of the small miners. The use of mercury in these operations has dangerous implications as the mines are near the water springs of the Santiago, San

[103] Donovan, P.R., 1995. Honduras. Mining Annual Review. p.94.

[104] Sanchez-Crispin, A., 1994. Mining Municipios of Mexico: Accessibility and Socio-Economic Marginality. Proc. Randol at Vancouver '94. p.79-83.

Pedro, Culiacán, Sinaloa, Pixatla and El Fuerte rivers. The artisanal activities in the municipalities of Otaéz and San Dimas in Durango are responsible for over 2 tonnes of gold produced[105] in 1994.

According to Mexican mining engineers, not all panners in Mexico are using mercury because most placer deposits have free coarse gold. As well, cyanidation is the preferred technique adopted by small gold processing plants to extract fine gold. Information about use of mercury by artisanal miners in Mexico is not quite available. It seems that there are many “gambusinos” panning for gold in inaccessible areas, where the living conditions and infrastructure are deficient. Occupational exposure to mercury vapors has been observed in Otaéz. Data compilation[106] (Table 2.3) reveals that almost 5 tonnes of gold are produced by rudimentary processes. The official number of artisanal miners is around 2,000 but this seems underestimated for a production level of 5 tonnes. Most likely this number might be at least 5 times higher. Mercury emissions cannot be directly correlated with gold production as cyanide is also used. A detailed assessment is recommended.

Table 2.3 - Mexican gold production from artisanal miners in 1994

Municipality	**State**	**Gold Production (kg)**
Otaéz	Durango	1330
San Dimas	Durango	701
Villa de la Paz	San Luis Potosí	548
San Ignacio	Sinaloa	414
Santiago Papasquiaro	Durango	338
Pánuco de Coronado	Durango	302
El Oro	Durango	194
El Rosario	Sinaloa	154
Guanacevi	Durango	137
Huajicori	Nayarit	86
Mocorito	Sinaloa	85
Temascaltepec	Mexico	57
Guazapares	Chihuahua	49
Mazapil	Zacatecas	48
Santiago Ixcuintla	Nayarit	35
Ocampo	Chihuahua	33
Zimapán	Hidalgo	29
Sombrerete	Zacatecas	23
Villa Hidalgo	Zacatecas	22
Concordia	Sinaloa	21
Matamoros	Chihuahua	19
Cerro de San Pedro	San Luis Potosí	16
Chalchihuites	Zacatecas	15
San Jerónimo Taviche	Oaxaca	14
Cosalá	Sinaloa	14
Veta Grande	Zacatecas	12
Tamazula	Durango	11
Total		**4707**

[105] INEGI - Instituto Nacional de Estadistica, Geografia e Informatica, 1995. La Mineria en Mexico.

[106] Data provided by Dr. Alvaro Sanchez-Crispin, Instituto de Geografia, Universidad Autónoma de Mexico. Apdo. Postal 20-850, 01000 Mexico. direc@igiris.igeograf.unam.mx. Compiled by Armando Garcia de León.

Nicaragua

The mining industry in Nicaragua has grown at rates as high as 10% per year, albeit it plays a minor role in the GDP which is considered very low, US$ 340 per capita.

Small companies have produced gold by using flotation/cyanidation techniques. The official gold production in 1994 was 1.08 tonnes (33,600 oz). Silver, as a by-product of gold extraction, had an output of 2.6 tonnes (84,500 oz)[107].

In the 1950s, Nicaragua was one of the top 10 gold producers in the world. The mines were largely developed in the 40s and 50s and worked by multinational companies which used cyanidation and amalgamation methods. Nationalized by the government in 1979, these mines were never modernized. All but two of these mines closed in 1991. The two remaining mines are still using mercury in a rudimentary way which results in losses of 3 kg of mercury daily. Unemployment in excess of 90% in the remote highland mining regions has created a class of artisanal gold miners, the “güiriseros”. It is estimated that 6000 people participate in gold mining activities, all of them using amalgamation as the main gold recovery method. Environmental and human health impacts of cyanide and mercury were so severe that in 1985 the indigenous Mayangna and Miskito communities, which receive water from the mining areas at Bonanza and Rosita, appealed to the international community for help. Ten years have passed and little has been done[108].

Since 1990, the Swedish Geological AB has been working with the Nicaragua Government assessing the cyanide content in water systems. The Ministry of Environment and Natural Resources have worked with a number of donors and has a strong relationship with the German agency GTZ. In 1995 and 1996, a USAID-EHP team worked with an Association of Miners (ASPIMINAS) in the Bonanza area to transfer to miners and affected public knowledge about mercury pollution and health protection. USAID-EHP personnel have observed that amalgam has often been burned in most every miner’s home, mostly in the kitchen where women and children spend most of the day. Miners are receiving homemade retorts[109] built with water pipes and plugs to retort amalgam. Remedial procedures for highly polluted sites have been investigated by the USAID-EHP professionals.

Hemco, a partially-owned Houston-based company, recently acquired a 1600 tonnes/day cyanidation plant in Bonanza. The effluents were discharged to the waterstreams without treatment. The company announced the construction of its first tailing pond. EHP team has already identified many health problems in the Bonanza region which can be related to water contamination. Hemco employs 800 “güiriseros” to exploit and deliver gold ore to the company. The miners are paid 2 weeks later based on gold extraction results. Miners have no way to verify the accuracy of the results. Instead of money, miners are paid with credits to buy groceries and other good in the nearby village. For the natives, the company is much more dangerous than the artisanal miners.

The government intends to privatize the mines. This has attracted a number of Canadian junior companies which has already been authorized to proceed with exploration programs. The Mining Office has also continued to issue permits for small mining operations.

---

[107] Bermudez-Mallol, R., 1995. Nicaragua. Mining Annual Review, p.94.

[108] U.S. Agency for International Development-Environment Health Project, 1996. Nicaragua: Scoping Visit for Reducing Health Impacts of Gold Mining. Trip Report n. 57, Washington, DC.

[109] Veiga, M.M.; Meech, J.A.; Hypolito, R., 1995. Educational measures to address Hg pollution from gold mining activities in the Amazon. Ambio, v. 24, p.216-220, 1995. Royal Swedish Academy.

Peru

Peru has a mining tradition that dates back to Pre-Hispanic times. Its gold and silver production became legendary in 1533 when on behalf of the Spanish Crown, Francisco Pizarro received Atahualpa's ransom consisting of 24 tonnes of gold and silver. Presently, mining industry accounts for 2.5% of Peruvian labor force, for 11% of the GDP and generates the highest amount of foreign currency from exports. Most of Peru's metals are mined from Andes mountain range that runs parallel to the Pacific coast for about 3,000 km[110].

Peru produced 59.6 tonnes (1.9 million oz) of gold in 1995. This output made the country the second largest gold producer in Latin America after Brazil. The Ministry of Mines expects 82 tonnes of gold produced from the Peruvian mines by the year 2000. Artisanal miners are responsible for 24 tonnes or 40% of the overall gold production[111]. The estimate of the number of artisanal gold miners is not provided by any official institution, but for a production of 24 tonnes of gold, more than 100,000 people should be involved.

In 1990, a gold rush triggered in "Departamento de Madre de Dios" attracted about 10,000 "chichiqueros" who produced 1.6 tonnes of gold annually[112]. Nowadays, the number of miners has doubled and about 8 tonnes[113] of gold are produced in Madre de Dios and its tributary rivers. Gold is recovered from alluvial and terraces deposits. Miners use buckets, shovels, wheelbarrows and hydraulic monitors to move material from terraces to the wooden sluice boxes. Dredging operations employ sluices as the main gold concentrator as well. Less than 50% of gold is recovered this way. Mercury is extensively used and lost to the environment. Dredges from Brazil are frequently invading Peru to extract 100 g gold/dredge daily. Gold is transported to Lima by plane or simply smuggled to other countries.

The President Fujimori continues to privatize all State-owned companies and eliminate barriers to trade and investment. Peru's Mining Ministry estimates that the sector will witness an estimated US$ 8.4 billion of investment between 1996 and 2003 of which US$ 4.4 to developing new projects[114]. The Government estimates that 148 new gold projects will be developed over the next 10 years.

Suriname

Suriname is undergoing a severe financial crisis. Mining accounts for 4% of the GDP in which bauxite is the main material exploited. Over 80% of the export revenues come from alumina and aluminum. Since 1993, crude oil exports have been increasing as well as oil reserves[115].

Gold has been worked by artisanal miners since 1875. A production peak of 1.2 tonnes (38,580 oz) was registered in 1911. After 1920 alluvial mining declined, but in 1974 the Surinamese government worked together with Placer Dome of Canada on a large-scale project in Gross Rosebel area. Alluvial reserves of 0.5 million oz (15.6 tonnes) were established. The project did not continue and in 1986, due to internal problems in the country, all gold exploration programs were deactivated. In 1992, the State mining

---

110 PromPeru, 1996. Investment Opportunities in Mining. Website: http://ekeko.rcp.net.pe/promperu/negocios/mining/mining.html

111 National Society of Mining and Petroleum, 1996. Monthly Informative, n.2, Mar. 1996. p.13 (in Spanish).

112 Bliss, J.D. and Olson, S.S., 1992. Current Gold Rush in Madre de Dios Department, Peru. Mining Engineering, July 92, p.693-695.

113 News@Peru, 1996. Small Outfits Produce 8 tones of Gold. Website: http://www.atamericas.com/pages/news/960530/pangold1.htm

114 TED, 1996. Trade and Environment:Peru Mining. Website: http://gurukul.ucc.american.edu/TED/Perumine.htm

115 Ridgway, J.M., 1995. Suriname. Mining Annual Review, p.91.

company Grassalco, the government and Golden Star Resources of Canada signed a gold exploration, exploitation and concession agreement to restart exploration in Gross Resebel. Production of 6 tonnes of gold annually is expected to start in 1999. Since 1990, the artisanal miners, porknockers, started a new gold rush in Gross Resebel, Lawa, Benzdorp and Sarah Creek. Gold production is not officially reported but something between 5 to 10 tonnes of gold annually is likely produced[116]. It is estimated that there are between 15,000 and 30,000 artisanal miners in Suriname of which most are illegal Brazilian "garimpeiros". Some sources[117] believe that gold production can be as high as 30 tonnes/y. About 3,000 mining units are in operation in the country. Indigenous Surinamese are also involved with mining activities of porknockers in Suriname. Much of the gold is smuggled into French Guyana and Brazil and the Central Bank of Suriname has been attempting, without much success, to buy as much of the gold as possible.

Mercury is widely used and burnt in open pans. Simple devices such as retorts are not known by porknockers. These miners are not organized and it is therefore difficult to approach them with information and alternative technologies. Many Marrons natives (descendants of run-away slaves) are directly involved in gold mining activities. A few reports about mercury bioaccumulation due to mining and hydroelectric impoundment were issued by the Environmental Research Center of the University of Suriname, but no structured program are being carried out yet as the government and University have limited facilities and personnel. So far, no analytical data about mercury are available in Suriname. The dimension of the problem is increasing every year.

Canadian junior companies are investing in exploring the potential of the greenstone-type prospects in Suriname, which have shown high gold grade anomalies. Conflicts between foreign companies, natives and porknockers are expected as for many communities artisanal mining has been the only means of a bare subsistence. The poor-nutrient characteristic of the lateritic soils of Suriname does not allow extensive agriculture programs.

Venezuela

Venezuela is one of the world's richest country in mineral resources with outstanding reserves of petroleum, gold, diamonds, iron ore, bauxite and coal. The Southern part of Venezuela, below the Orinoco river, involving State of Bolivar, State of Amazonas and the Federal Territory of Delta Amacuro is called Guayana Region. The main mining activities are developed in the State of Bolivar which has an area of 240,528 km^2, comprising 75% of the hydroelectric potential of the country. The Venezuelan population (1993 estimate) is around 20.2 million, in which 80% of the population lives in the Northern highlands or coastal regions. Less than 5% inhabits the Guyana Region which has about 80,000 natives from pemon, yanomami, piaroa, guahibo, yekwana and other 17 tribes (25% of the first nation's people of Venezuela)[118].

The natural resources and industrial development of Bolivar have attracted many foreigners. Between 1981 and 1991 the amount of foreigners increased 221.3%. Bolivar is the nation's major development area with steel complexes, aluminum plants, industrial gold production, hydroelectric plants, etc. The largest industrial activities are owned by "CVG - Corporacion Venezoelana de Guayana" which is a rector entity for the Guayana region, to promote and coordinate the social-economic development of the region. The privatization of the CVG's companies will occur in the near future.

---

116 Ridgway, J.M. - op. cit.

117 Data provided by Dr. Jan Quik Faculty of Technical Sciences University of Surinam P.O.Box 9212, Paramaribo Surinam. email: quik@sr.net

118 Comunniello, S., 1995. Venezuela: Gold and Ecocide. Correo n. 28, p.6-7, Nov. 1995 (in Spanish).

Venezuela's gold potential is in excess of 10,000 tonnes (322 Moz). In 100 years, almost 200 tonnes of gold (6.4 Moz) were extracted in Venezuela[119]. Almost all of this production was located in the State of Bolivar. CVG estimates that the gold production in 1995 was around 18 tonnes (579,000 oz) but the official numbers do not exceed 10 tonnes (321,000 oz)[120]. The government policy which fixed the exchange rate of Venezuelan currency relative to the U.S. dollar resulted in smuggling of gold and diamond to Brazil.

At the beginning of the 1990s, a gold rush occurred in State of Bolivar in the region known as km 88. In this rush, not only artisanal miners have participated but also Canadian junior companies. From 1990 to 1993, over 40 companies have acquired mineral titles in that region. With this high demand, the amount of people speculating with mineral titles was astronomical. This created a clear antagonism of the general public with mining activities, either conducted by artisanal miners or organized companies.

The main gold producer in Venezuela is CVG-Minerven with an output of 3 tonnes/y (96,450 oz). Monarch Resources, producing in 1996 about 1.6 tonnes/y (50,000 oz), represents the first private sector underground gold mine in Venezuela for decades. Crystallex, a small Canadian company, is producing 800 kg of gold annually by cyanidation in the km 88.

The number of artisanal gold miners in Venezuela is between 30,000 and 40,000 people with an output from 10 to 15 tonnes/years, as estimated by CVG in 1995. Between 7,000 and 10,000 artisanal miners are considered illegal miners. Most of them are very small Colombian, Guyanese, Brazilian and even Venezuelan panners. Lack of a clear political definition for artisanal miners has created conflict between miners and companies in Venezuela. At km 88, miners are invading companies' leases[121]. The Association of Miners of Ikabaru estimates that each artisanal miner supports a family of four people, on average.

The image of artisanal miners in Venezuela is extremely negative. Artisanal miners invade native reserves, destroy forests, silt-up rivers and dump mercury into the waters.

The Caroni river, a 640 km long tributary of Orinoco river, has been subjected to mining operations since the end of the last century. Until 1989, about 200 dredges were operating to extract gold and diamond from sediments of Lower Caroni river. Before 1991, amalgamation was performed on board using copper plates or simply adding Hg to riffled sluices. Contaminated tailing was returned to the riverbed. Using the ratio $Hg_{consumed}: Au_{produced} = 1$, an indication about mercury losses may be obtained. Considering that the maximum production of "Bajo" Caroni before 1991 was 700 kg annually and mining activities have intensified from 1985, so about 5 tonnes of gold likely were produced indicating that about 5 tonnes of mercury were discharged into the Lower Caroni before 1991.

Until 1991, only 30% of the miners from Lower Caroni river understood that amalgamation was more effective when applied to concentrates and so they conducted their amalgamation on shore. Decree 1448 of February 14, 1991 and Decree 1740 of July 25, 1991 prohibited all amalgamation activities on board or on shore. A concrete consequence of these Decrees has been the creation of three Amalgamation Centers and two Gold Processing Centers where gold is extracted from gravity concentrates produced on barges.

The first Amalgamation Center, in Playa Blanca, was created and administrated by CVG. Four technicians

[119] Rodriguez A., B.C., 1994. Gold and its Impact on the Venezuelan Economy. Paper presented at the 3rd Int. Symp. of Gold in Venezuela, Caracas. Oct. 1994. 20 p. (in Spanish).
[120] Mining Annual Review, 1995 p.87.
[121] UNIDO, 1996. Advisory Assistance on Avoidance Mercury Pollution from Artisanal Gold Mining Operations in State of Bolivar, Venezuela. Prepared by M.M. Veiga, contract SI/VEN/94/801/11-51. 147 p.

and one engineer operate the center that amalgamates concentrates from over 70 barges. Miners usually take 15 to 20 kg of gravity concentrate to be amalgamated in rolling barrels. The amount of mercury used is 200 to 250 g which gives a ratio of Hg:conc = 1:100. The amalgamation time is usually 30 min, which actually avoids mercury flouring. A dash of soap is added to clean the gold surface of natural fats and greases. After amalgamation, a mechanical spiral is used to separate heavy minerals from amalgam. The excess mercury is removed by hand squeezing using a piece of fabric. Amalgam, that usually contains 30 to 40% Hg is retorted in a building outside. There are four small retorts with water condensers operated by a worker under the supervision of miners. Operators process 200 to 300 kg of concentrates daily. This produces about 1 kg of gold daily. The Center does not charge the miners and all amalgamation steps are visible. The owner of the concentrate is the only person allowed to be present with the operators inside the Center.

This creative idea was copied and even improved by private companies. The Amalgamation Center of Carhuachi (Fig. 2.5) demonstrates that it is possible to handle mercury safely with a negligible level of Hg emission. This center should be used as an example for creating other similar centers across Venezuela and Latin America.

In Carhuachi, all heating steps (retorting and melting) are carried out in an isolated room with a gigantic fan in the roof. To avoid occupational exposure, a small fume hood is placed on top of all retorts to remove Hg vapor that occasionally escapes. The fumes are conducted through a series of scrubbers with iodine solution and finally through activated charcoal filters. The melting furnace has a water condenser to remove Hg from vapor and various small scrubbers with potassium chloride and iodine solutions to guarantee that no Hg is emitted into the atmosphere. A mass balance of Carhuachi Center indicated that more than 99% of Hg added is recovered. The majority of mercury recovery (70 to 82%) occurs when excess mercury is removed from amalgam by a innovative technique by using a centrifuge instead of hand-squeezing with a piece of cloth. No mercury vapor is lost and 17 to 25% of Hg added is recovered by condensing in the retorting operation and 2 to 4% in the melting step. The main Hg loss, around 1%, occurred with the amalgamation tailing. However this tailing, still containing 300 ppm Hg and 50 ppm Au, is not dumped into the rivers but sold to a cyanidation plant in El Callao which pays 50% of the value of gold content.

A labyrinth of concrete pools receives tailings. Clear water is recycled or discharged. In the Center, there is a chemical lab with a mercury analyzer (a Hg dedicated flameless atomic absorption) operated by a chemist, to ensure that the effluent water has less than 10 µg/l (ppb) Hg as required by Venezuelan Decree 2224 of March 23, 1992.

Many small mining activities are observed in the Southern and Western part of Bolivar State. Most miners are working on weathered ores using hydraulic monitors or manual excavating. In El Callao, where the cyanidation plant of CVG-Minerven is located, there are thousands of manual small miners excavating the hills manually. Most of them are illegal. The amalgamation process is performed by 40 “molineros” who are owners of plants which usually have three or four lines with jaw crushers, small hammer crushers (capacity of 5 tonnes/h) and sluices with carpet. The “molineros” receive the ore brought by miners in bags of 50 kg, carry out comminution, concentration and amalgamation and charge the miners 10 to 20% of the gold produced. The amount of gold produced from each bag varies from 3 to 20 g. All tailings become part of the property of the “molineros”. These “entrepreneurs” do not make effort to extract much gold in the first gravity process. Actually the poorer the concentration process, the better it is for them. The main profit comes from tailings when they are sold or reprocessed. Several “molineros” are interested in owning a large plant with ball mill, gravity circuit + flotation and cyanidation to reprocess tailings properly. Currently, the most adopted method to separate gold from mercury is by burning amalgam in a shovel placed 1.5 m from ground. They believe that by burning off mercury distant from soil, mercury vapors are dispersed rapidly. News about death caused by kidney dysfunction is common.

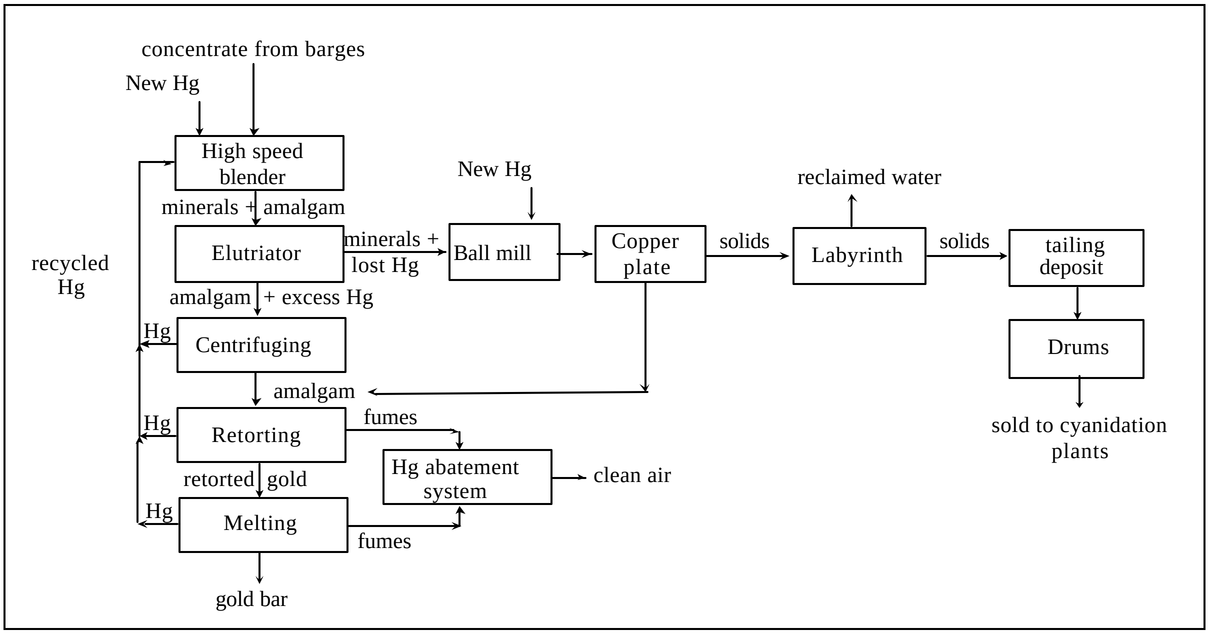


Fig. 2.5 - Amalgamation steps of Carhuachi Center

Low to medium level of mercury bioaccumulation has been detected in Venezuela by many researchers[122,123,124,125]. The Caroni river has been focused upon by most monitoring programs. Its water is rich in dissolved organic acids which favor dissolution of metallic mercury dumped by the miners in the past. From 119 fish sampled in the Lower Caroni river (40% were carnivorous species) 5.8 % of the samples have shown Hg levels above 0.5 µg/g (ppm) which is the upper limit established by the World Health Organization for human consumption.

Another cause for high levels of mercury in carnivorous fish from the Caroni watersystem was pointed by UNIDO in Venezuela in 1995. All over the world, high Hg levels in fish have been detected in man-made reservoirs[126]. In many cases, local mercury sources are not identified. Atmospheric mercury emitted by various sources (fuel or wood combustion, volcanoes, evaporation, etc.) travels long distances to be deposited with rainfalls (see Fig. 2.6)[127].. The influence of the submerged vegetation, type of organic matter and bacteria in flooded sediments are recognized as the main reasons for increasing methylation rate after impoundment. The Guri hydroelectric reservoir is located in the Caroni river upstream mining activities. Guri flooded an area of 4000 km^2. Members of the Guri Committee have analyzed 219 fish samples (50% were carnivorous species) in which over 42% of samples have shown Hg levels above 0.5 ppm. The average mercury in 31 samples of payara (*Raphiiodon vulpinus*) was 2.7 ppm and a sample with

[122] Bermudez, R.D.; Bastardo, H.; Pravia, R.; Ramos, S., 1994. Mercury Monitoring in the Lower Part of the Caroni River, State of Bolivar, Venezuela. Report of Univ. Experimental de Guayana (UNEG). 29 p. (in Spanish).
[123] Briceño, H. O., 1989. Mercury Contamination of "Bajo" Caroni. Preliminary Report. Litos C.A. 30 p. (in Spanish).
[124] Leal, F., 1994. Report on Environmental Conditions of Bajo Caroni prepared by the company Amconguayana. Ciudad Guayana (in Spanish).
[125] MINPROC, 1991. Bajo Caroni Project. Final Report to CVG-VPC Mineria. Phase I. Vancouver, B.C. 300p.
[126] Stokes, P.M. and Wren, C.D., 1987. Bioaccumulation of Mercury by Aquatic Biota in Hydroelectric Reservoirs. Chapter 16, SCOPE 31. John Wiley, New York, p.255-277
[127] Meech, J.A.; Veiga, M.M.; Tromans, D., 1995. Mercury emissions and stability in the Amazon region. Proc. Int. Symp. Waste Processing & Recycling in Mineral and Metallurgical Ind. v. II. 34th Annual Conf. Metallurgist, Metal. Soc. Canadian Institute of Mining, Metallurgy and Petroleum, p. 523-537, Vancouver, Aug. 20-24, 1995.

8.3 ppm was analyzed. No pre-impoundment data are available, however the effect of an impoundment to elevate Hg concentration in fish tissue is strongly indicated. The atmospheric mercury deposited in the soil before the reservoir formation, which also includes Hg evaporated by miners, is being methylated at a high rate. Researchers from La Salle Foundation and Experimental University of Guayana (UNEG) are confirming evidence of bioaccumulation associated with impoundment and humosity of the water in other remote areas of the State of Bolivar.

Fortunately, carnivorous fish from Guri represent less than 20% of fish mass in the reservoir. Fish-eating people, particularly pregnant women have been the target of campaigns conducted by La Salle Foundation, CVG-EDELCA, Ministry of Environment and the Government of the State of Bolivar. Reduction of fish consumption, mainly carnivorous fish has also been advertised.

UNIDO, has had an important role in Venezuela in transferring knowledge about mercury pollution to small miners as well as to indicate to authorities other sources of mercury pollution which were never considered before. Working with NGOs, Universities, companies and representatives of Ministry of Mines and Ministry of Natural Resources and Environment, UNIDO left an important seed in Venezuela which is resulting in monitoring programs, construction of equipment for mercury abatement, educational campaigns for fish-eating people, laboratory research, field testwork for clean-up operations, etc.

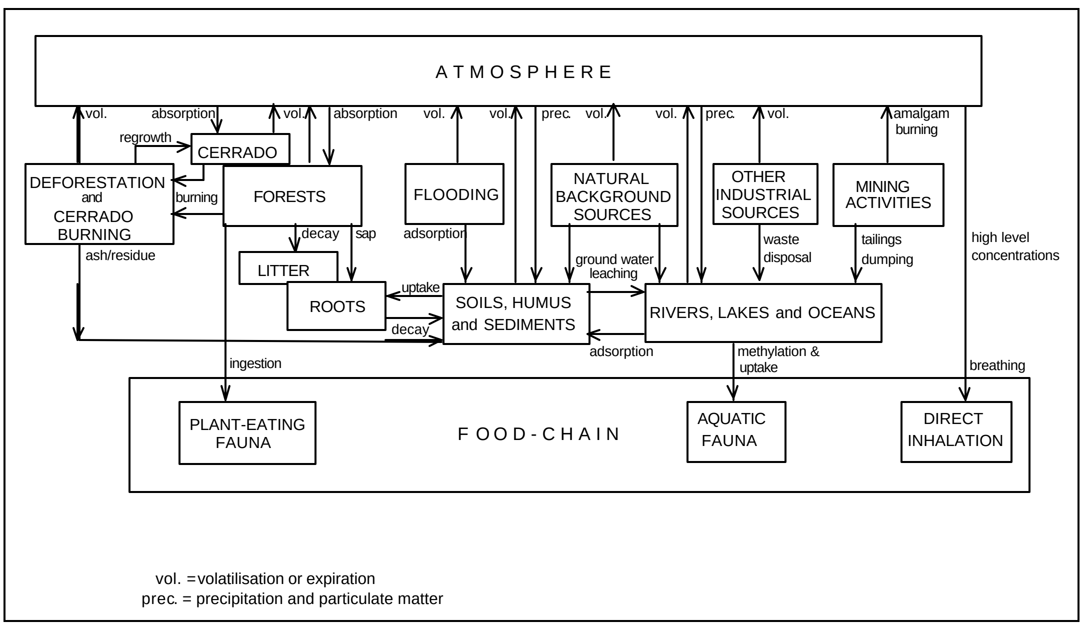


Fig. 2.6 - Mercury biogeochemical cycle indicating different sources of mercury emission

Other Countries

News about gold panners in other Latin American countries has been told by mining engineers, geologists and local citizens but little information is available. The presence of small gold miners is also noticed in Argentina, Cuba, El Salvador, Haiti, Panama and Paraguay where most of them are panners who are involved in this activity for subsistence. A detailed investigation should be carried out to observe how small-scale gold mining is growing in these countries.

3. Proposed Solutions for Mercury Problem

As mercury pollution has multiple implications, a multidisciplinary approach is needed to understand how to address the problem. Legal measures to control informal mining and mercury emission are necessary but to date have been inefficient. Mercury is illegally used in almost all Latin American countries. According to Priester (1995) the situation requires solutions which combine protection for the environment and workers, with the need to elevate the economic result of the overall venture; an illegal miner will not pay out a dollar for a piece of equipment or technique which does not return two dollars.[128]

Solutions for the problem have received little attention from researchers and governments. An integrated approach to mercury problem is necessary. Three main actions are delineated in Fig. 3.1:

1. Search for **alternative processes** to avoid mercury
2. Implement **remedial procedures** to highly polluted sites
3. Apply measures to **reduce mercury emissions**

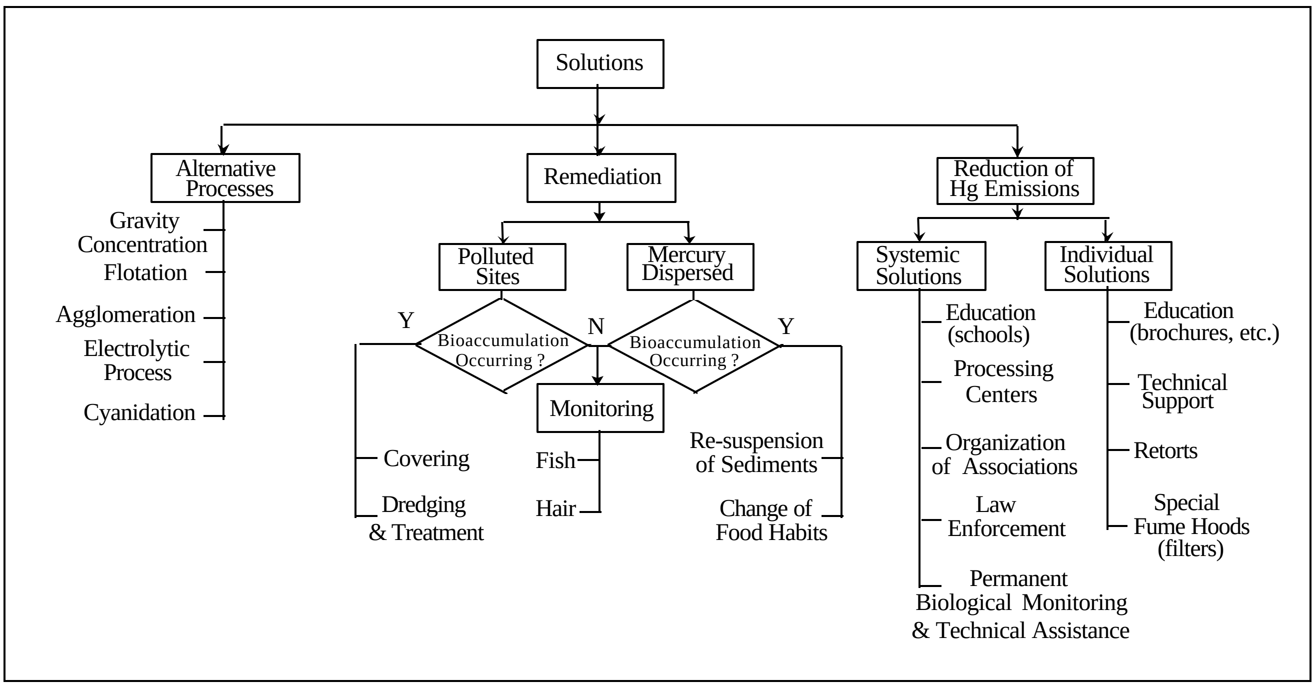


Fig. 3.1 - Solutions for mercury pollution from gold mining

3.1. Alternative Processes

All attempts to introduce **gravity concentration** equipment, such as shaking tables, spirals, automatic panners, etc. to eliminate amalgamation, have not succeeded. In these cases, mercury use was reduced, but never eliminated completely. The principle of these methods is based on using gravity to clean an initial (rougher) concentrate in order to obtain a rich final concentrate for melting. In one Processing Center in Venezuela, Gemini tables have processed concentrates obtained from sluice boxes located on-board barges. Instead of using amalgamation, the tables work as cleaners to produce a concentrate which is melted and sold to the Bank. Unfortunately, a gold-rich middling product is produced which is then amalgamated to extract very fine gold.

Centrifuges, such as Falcon Concentrators, have potential for use for primary gravity concentration as well

[128] Priester, M., 1995. Small-Scale Mining in Latin America. SMI Bull., n.8, p.1.

as for cleaning stages. A new model of the Falcon Concentrator called the Super Bowl uses a fluidized bed spinning-bowl that can reach a production scale up to 60 tonnes of solids/h, applying a centrifugal field of 200 G. Concentrates can reach grades above 20,000 g Au/tonne in two stages (rougher and cleaner) which can be directly melted, avoiding an amalgamation step. Centrifuges have been manufactured in Brazil and are in use by artisanal miners. Despite being rough copies of the Knelson Concentrator, they represent an improvement for gold recovery and reduction of mercury use in artisanal mining.

Froth **flotation** has also been applied in a few artisanal operations in South America as a primary concentration process for fine gold. But even with grades as high as 200 g Au/tonne, the concentrate produced must be submitted to amalgamation or cyanidation. Lins et al. (1994)[129] have studied flotation of gold contained in gravity concentrates. Using xanthates as collectors, concentrates were upgraded from 13 g Au/tonne to 3,000 g Au/tonne with 82% of gold recovery. Unfortunately, it is not trivial to submit concentrates with 2-3 kg/tonne to direct melting. In addition, flotation of coarse gold (above 35mesh ro 0.43mm) is a difficult task requiring control equipment and skilled personnel.

Experiments to replace amalgamation with **coal-oil agglomeration** have indicated promising results· Agglomerates of coal and oil (5 mm) are formed and put in contact of a pulp of gravity concentrate in one or more cycles. Recoveries of 90% were obtained in one step. Envi-Tech Inc.[130] of Edmonton, Canada developed a novel agglomeration process using a proprietary gold adsorbent. Following 5-10 min. of intense agitation, gold loaded adsorbent is separated by froth flotation. In a pilot test, 70% of gold was recovered after 6 hours of operation. The circulating adsorbent contained 350 g Au/tonne. Another selective adsorption technique tried by Lins et al. (1994), used melted paraffin to collect gold in an acidic medium. In spite of encouraging results, none of these methods provide a simple, cheap and quick alternative for unskilled artisanal miners.

An **electrolytic process** to leach gold has also been developed by CETEM[131] - Center of Mineral Technology, Rio de Janeiro and tested in a pilot plant in the Tapajós region, Brazil. This process has the potential to replace amalgamation of gravity concentrates. Material with 1 ppm Au was mixed with sodium chloride (1 Mol/l) which is transformed by electrolysis into a mixture of sodium hypochorite-chlorate. More than 95% of the gold dissolves within 4 hours and is collected on a graphite cathode. The solution is always recycled minimizing effluent discharge. The NaCl and energy consumptions are 100 kg/tonne of ore and 170 kwh/kg of Au respectively. Plastic tanks are used, reducing investment cost. So the process is relatively uncomplicated and inexpensive with the potential for use. The main drawback of course, is the need for trained personnel to control operating variables (pH, current density, etc).

Cyanidation is a process beginning to appear in the artisanal mining communities in Andean countries and, to a lesser extent, in Brazil. Cyanidation of flotation concentrates has been widely adopted by most organized mining companies. The use of amalgamation for all intents and proposes has been banned. As coarse gold requires long retention time for cyanide leaching, when an ore contains coarse gold, it must be removed by a gravity process prior to submitting the material to flotation and/or cyanidation[132]. Cyanidation of the whole ore using techniques of heap leaching or vat leaching implies analytical control.

---

[129] Lins, F.F.; Monte, M.M.; Hamelmann, C.R.; Middea, A., 1994. Amalgamation in Small Gold Operations: Alternatives and Treatment of Hg-Contaminated Soils and Effluents. Proc. International Symposium on Extraction and Processing for the Treatment and Minimization of Wastes, 123rd Congress of TMS, The Mineral, Metals and Materials Society, S. Francisco, CA, Feb. 27-Mar. 3, 1994

[130] Envi-Tech (1997) Field Testing of Envi-Tech Adsorbent Technology for Gold Extraction of Gold. Project Summary. Leaflet of the presentation at CANMET, Ottawa, March 07, 1997.

[131] Data provided by Mr. Ronaldo Santos, CETEM, Rio de Janeiro, Brazil.

[132] A 65# (0.21 mm) gold particle takes over 60 hours to be dissolved in cyanide. Veiga, M.M., 1989. Technological Characterization of Gold Ores. Brasil Mineral, n. 72, p. 124-136 (in Portuguese).

Rain is one of the main problems for such operations in tropical countries. In Brazil, some atisanal miners are using resin or activated charcoal to adsorb gold from cyanide solutions. No elution techniques have been applied. The resin or charcoal is simply burned leaving the gold behind.

Despite high gold recoveries, cyanidation needs much more skill and investment than simple amalgamation. In such cases, artisanal miners need technical support. A small cyanidation plant can be set up for use by a small mining community, but this is not a general solution for all cases of artisanal mining. For a grain size of gold coarser than 0.3 mm cyanide dissolves gold slowly. Hand picking is also impracticable in such cases. The method adopted by organized mining companies uses a sequence of gravity concentrators (cleaners). Another important issue is the environmental and occupational risk for operators. Despite the fact that part of residual cyanide is naturally degraded by sunlight, complete cyanide destruction requires chemical processes. These techniques are not trivial. The environmental impacts of cyanide can be lower than those of mercury, but the consequences of occupational exposure can be rapid and more dramatic than that of mercury.

The possibility to replace amalgamation with other processes is remote, but must be pursued. For an artisanal miner, mercury is an easy and efficient way to extract fine gold. When amalgamation is applied to gravity concentrates, more than 90% of gold is recovered. No sophisticated technology is necessary. Investigation of alternative processes must continue, but no extraordinary breakthrough should be expected.

The only possibility to eliminate wide spread use of amalgamation is to promote Processing Centers, i.e. miners take their gravity concentrates to a central establishment for processing by specialized people using leaching methods in a controlled laboratory environment. Such an approach is viable but will hardly be adopted by all miners spread throughout the jungles. Implementation will demand a very organized measure combining efforts from governments and miners.

3.2. Remedial Procedures

The political and technical decision to apply remedial procedures to a polluted site is usually based on environmental risk assessment. Risk assessment requires an investigation or monitoring of a site to establish the level of present and future pollution. Most countries have mercury guidelines for fish, water and air but not for sediments. The Environmental Agency of Japan established 25 ppm as a provisional minimum standard to remove Hg-contaminated sediments[133] while in British Columbia, Canada[134], the Ministry of Environment uses 10 ppm Hg as the level to restrict all uses of land and application of remedial measures. These are isolated cases of soil guidelines. So, determination of mercury level in a sediment is not enough to support decisions for remedial action.

Remedial procedures are necessary when mercury bioccumulation is evidenced by monitoring programs. In this case, the only indicator or evidence of bioaccumulation is <u>biota</u>, in particular <u>fish</u>, specifically <u>carnivorous fish</u>, preferably those with low mobility (e.g. black piranha). Predictions about risk of bioaccumulation can also be made based on natural variables (sediment type, Hg levels in sediments, water conductivity, Eh, pH, humosity, etc.) but these are not evidence of Hg pollution but rather evidence of environmental conditions that can lead to bioaccumulation.

---

[133] Buffa, L. (1976). Review of Environmental Control of Mercury in Japan. Report EPS 3-WP-76. Environment Canada, Ottawa, Ontario, 81p.

[134] B.C. Ministry of Environment, 1989. British Columbia Standards for Managing Contamination at the Pacific Place Site. Pacific Place Guidelines, Waste Management Program, appendix N, p. 77-82, April 5, 1989.

Based on the nature of emissions, mercury can be concentrated in hot spots or dispersed in the sediments. The different procedures to amend these situations are delineated in Fig. 3.1. Whether hot spots should be dredged or covered is decided by the level of Hg in biota and an evaluation of costs involved with the dredging operation and spoil treatment.

Highly Polluted Sites ("hot spots")

Frequently amalgamation is carried out in small pools excavated at river sides. Even when amalgamation takes place in a water box, tailings are discharged into the water stream creating **"hot spots"** where the Hg concentration can be hundreds of ppm. In a sediment, when mercury droplets are visible after concentration by panning, the sediment has mercury levels above 3 ppm. Whether "hot spots" should be dredged or covered is a decision primarily based on evaluation of bioaccumulation levels, costs involved in the dredging operation and spoil treatment.

The principle of covering procedures is to prevent releasing mercury (in any form) from sediments to the water. The extent of pollution and the hazard potential establish which material should be used as covering. Each case needs evaluation and prior laboratory experiments. Two kinds of materials can be used as covering materials, based on the reaction potential with mercury: inert or reactive (or adsorbents)[135]. Covering is recommended for "hot spots" in enclosed systems. In a river, this technique would be less satisfactory, because erosion during high flows would simply re-expose the contaminated river bottom.

Covering "hot spots" is a technique based on the fact that metallic Hg is stable at the bottom of the aquatic system and any possible oxidation is controlled by adsorption so that the action of methylation agents is hindered. The remedial actions must focus on reducing oxygen access to the water-sediment interface and/or adsorbing all oxidized mercury that might form. This process was used in Minamata Bay to control Me-Hg production in sediments. A series of covering procedures for polluted sediments is suggested for testing. Some of the materials that can be mixed with sand or silt to cover "hot spots" are shown below :

- Laterite crusts : iron oxides adsorb oxidized mercury.
- Pyrite: oxidized mercury can be precipitated as sulfide.
- Fibers: adsorb oxidized mercury released from sediments.
- Rubber scraps (e.g. old tires) : adsorb oxidized mercury.
- Scrap Iron (cementation process): precipitates Hg(II) soluble compounds.

The adsorption capacity of lateritic materials such as hydrous ferric (HFO) and manganese oxides is very well known. Tropical countries are rich in **laterite crusts** as weathering products of iron-yielding minerals. These crusts can be used for covering "hot spots".

Experiments using **pyrite** (FeS_2) overlaying Hg-rich sediments has been performed in laboratory and small-scale field tests in Sweden[136]. Formation of HgS takes place, a compound with very low solubility. An area of 1 ha in Lake Gårlången, Sweden, polluted with Hg from municipal wastewater was covered with a 3 cm-layer of mine tailings (sulfide-rich). Methylmercury released from the sediment and being accumulated in fish was reduced 5-fold in three weeks. Over the years, analyses of Hg in fish from the whole lake have indicated a decrease of pollution levels. Pyrite is a common tailing in some gold mining activities which work with primary quartz vein ores. Tailing from gold gravity circuits with some sulfide

[135] Veiga, M.M. and Meech, J.A., 1995. Gold Mining Activities in the Amazon: Clean-up Techniques and Remedial Procedures for Mercury Pollution, Ambio, v. 24, p. 371-375. Royal Swedish Academy.
[136] Jernelöv, A. and Lann, H., 1973. Studies in Sweden on Feasibility of Some Methods for Restoration of Mercury-Contaminated Bodies of Water. Environmental Science and Technology, v.7, n.8, p.712-718.

should be tested.

A large list of cheap organic **fibers** such as - wool, chicken feather, hair, onion skin, nylon, sugar cane bagasse, have been studied as Hg adsorbents[137,138]. The mechanism of adsorption is not well-understood but sulphur-bearing sites play an important role. Laboratory studies[139] have also demonstrated that waste wool and wool/polyester blend fibers remove 90 to 95% of soluble Hg compounds (organic and inorganic) within 24 hours of contact (Tratnyek 1972). Due to the obvious aesthetic and environmental aggression issues, these fibers can not be applied to large polluted areas. However, since artisanal miners are consumers of carpet for use in gold sluice concentrators, discarded carpets could be a potential source of material to cover "hot spots". Field tests should be attempted.

Over a wide range of pH (2 to 13) ground automotive tires can remove as much as 99% of Hg from water in 15 min. The excellent adsorptivity of **rubber** for Hg compounds is thought to arise from the high sulphur and carbon black content of commercial rubber[140]. The technique should be tested on a small scale study in some highly polluted site in mining areas. Rubber scrap has been tested in Nicaragua by the EHP-USAID team but results have not yet been reported[141].

Laboratory studies have shown that **iron scrap** rapidly and efficiently removes Hg (II) and Me-Hg from water by converting these soluble forms into elemental mercury. When Hg(II) is cemented (reduced and precipitated) with iron, hydrous ferric oxide is formed, which is also an effective coprecipitator for Hg species. Discarded shredded automobile bodies are suggested as an iron source. Reduction of Hg compounds to metallic mercury (Hg°) occurs either under aerobic or anaerobic conditions. Me-Hg reduction is more efficient at acidic pH levels, while the removal of Hg(II) is better at neutral or slightly alkaline pH[142]. This technique has good potential to be tested in highly polluted sites. Iron scrap dumped into "hot spots" or mixed with sand may contribute to an efficient covering of sediments to control mercury entry into the water column.

Dredging procedures remove the source of contamination from the water system. They are expensive measures and are recommended only when the gold content in the spoil can return part of the costs or when mercury bioaccumulation cannot be controlled by covering processes. Usually, mercury "hot spots" have high gold content. A separate processing plant must be implemented to extract gold and mercury from dredged material. Dredging can be a definite measure for highly polluted spots where Hg pollution is well-concentrated, but three main problems regarding environmental impact must be addressed:

- Dispersal of Hg into streams during the dredging operation.
- Treatment and disposal of the contaminated spoil.
- Covering of the dredged site.

---

137 Asai, S.; Konishi, Y.; Tomisaki, H., 1986. Separation of Mercury from Aqueous Mercuric Chloride Solutions by Onion Skins. Separation Science Technology v.21, n.8, p.809-821.

138 Feick, G.; Johanson, E.E.; Yeaple, D.S., 1972. Control of Mercury Contamination in Freshwater Sediments. U.S.Environmental Protection Agency, report EPA-R2-72-077. Washington, D.C. 155p.

139 Tratnyek, J.P., 1972. *Waste Wool as a Scavenger for Mercury Pollution in Waters*. Report prepared by Arthur D. Little Inc. to U.S.Environmental Protection Agency, contract n. 68-01-0090, Cambridge, Massachusetts. 49 p.

140 Beszedits, S., 1979. Mercury Removal from Effluents and Wastwaters. In: The Biogeochemistry of Mercury in the Environment. p.231-276. Ed. J.O. Nriagu. Elsevier/North-Holland Biomedical Press, Amsterdam, 696 p.

141 Edwards, D. and Ault, S., 1996. Nicaragua: Project Start-up Workshop Preparation Visit - Reducing Health Impacts of Gold Mining U.S. Agency for International Development-Environment Health Project, 1996. Report to the File n. 63, Washington, DC.

142 EPA, 1972. Control of Mercury Pollution in Sediments. U.S. Environmental Protection Agency, report EPA-R2-72-043, Contract No. 68-01-0087, Project 16080 HTY, Washington, D.C., 55p.

Aquarium experiments with simulated mechanical dredging have indicated that the amount of mercury dispersed in the water column is of the order of 2 - 10% of that removed. The majority of the Hg dispersed is associated (adsorbed) with suspended particles. An effective method to prevent redistribution of Hg is to use a suction dredge in place of a mechanical one. The major problem of suction dredging is the high percentage of water in the spoil. So, settling ponds and aluminum sulphate are necessary to clarify water before returning to watercourses[143].

In Venezuela, miners concentrating alluvial gold from sediments of the Caroni river have reported that, between 1991 and 1994, they extracted 0.56 g Hg per kg of concentrate produced by sluice boxes placed on board of their barges[144]. Considering that a miner working in Caroni river produces 40 kg of concentrate per 1,400 tonnes of ore processed in sluice boxes, this gives 22g of Hg per 40-hour shift, or 0.02 g Hg/tonne of riverbed sediment. Assuming over 80 dredges are working in the lower Caroni area, processing almost 2,000,000 tonnes of ore annually, over 40 kg of mercury are recovered from the river annually. Since those miners are no longer using mercury on board their dredges these operations are actually contributing to the removal of mercury from the river bottom.

Whenever possible, a sealing treatment is recommended for a dredged spot, such as covering with inert or adsorbent material to guarantee that the remaining mercury is immobilized at the site. Treatment of dredge spoil is an essential procedure.

When placed in a landfill, polluted sediment can lose Hg to the water (when oxidation occurs) or to the atmosphere (evaporation). Mercury losses can be prevented by dispersing adsorbents or complexing agents, such as a long chain thiol or sulfide on the surface of dredged material disposed in a landfill.

Mercury removal from the dredged material is also possible. The only process which provides complete Hg extraction is retorting all contaminated spoil, but this is clearly impractical. In the case of gold mining operations, there is interest in recovering mercury from polluted sediments to recover the high associated gold content.

Experiments with 80 tonnes of polluted sediments (6.5 ppm Hg) dredged from hot spots have been performed in Poconé, Brazil[145]. Centrifuges recovered 70 to 80% of Hg reaching a grade of 1% Hg (10,000 ppm Hg) in the concentrate. Better recovery is difficult since fine dispersed droplets of metallic Hg as well as Hg bound to fine hydrous ferric oxides are not recovered. Gold associated with the spoil was also concentrated in the centrifuges with a recovery around 60%. Gravity methods can reduce Hg levels significantly in the dredged material but since the tailings are still highly contaminated, disposal must follow safety procedures, such as covering with adsorbents.

A new technology has recently been developed in Brazil to remove mercury from contaminated sediments. Manufactured by a Brazilian company, Rio-Sul, special-amalgamating plates can be used to amalgamate gold avoiding mercury emissions. The plates possess a thin coating of mercury and silver electrolytically deposited onto a copper alloy plate. Between 8 to 16 plates are placed in a sluice box in such a way that a cascade effect is obtained when a pulp of gravity concentrate is processed. When gold specks or fine particles (as fine as 400 mesh, 0.037 mm) contact the plates, gold is captured and firmly

---

[143] Feick, G.; Johanson, E.E.; Yeaple, D.S.,1972. Control of Mercury Contamination in Freshwater Sediments. U.S. Env. Protection Agency, report EPA-R2-72-077. Washington, D.C. 155p.

[144] UNEG - Universidad Experimental de Guayana - Venezuela, 1995. Advisory Assistance on Introduction of Alternative Gold Mining and Extraction Techniques Avoiding Mercury Pollution. Report prepared by Bermudez, D.; Rodriguez, J.; Espinoza, J for UNIDO. Contract SI/VEN/94/801. 40p.

[145] Farid et al., 1991 - op. cit.

fixed to the plate surface. No mercury loss from the plates has been observed when gravity concentrates are amalgamated. When the plates are loaded, amalgam is removed by washing with a plastic scraper. These plates have been successfully tested in Brazil to remove Hg from contaminated tailing[146]. Amalgamation tailings from 35 dredges operating in the Piranga river, State of Minas Gerais, Brazil were treated with these special plates. About 145 kg of mercury and 880 grams of gold were extracted from 91 tonnes of tailing treated in 13 days. About 90% of the mercury was recovered in two operating cycles and tailings were disposed safely (lined pool and cemented). This technology also has the potential to replace the common amalgamated copper plates used in many artisanal operations.

Currently, the Rio-Sul Ltd.[147] is the only available manufacturer of these plates in Brazil. In Bambuzal, State of Para, Brazil, 200 tonnes of contaminated tailing were processed. The plates recovered 7.6 kg of mercury and 1.6 kg of residual gold. In Pontes e Lacerda, State of Mato Grosso, Brazil, the Rio-Sul system recovered 4.1 kg of mercury and 1 kg of gold by reprocessing 260 tonnes of contaminated tailings. Many other case studies are reported by Rio-Sul. The system is also being applied to decontaminate tailings in Venezuela.

Hydrometallurgical processes for treating dredged material are also being studied. The electrolytic method developed by CETEM that was previously described as an alternative method to recover gold, can also be applied to treat Hg-contaminated sediments. The process was tested in two pilot plants in Poconé and Tapajós regions, Brazil[148,149]. This method uses a pulp of 30 to 40% solids and a salt concentration between 5 to 20%. All mercury compounds are oxidized within 3 hours by hypochlorite solution generated by electrolysis and metallic mercury is then deposited onto the cathode. Power consumption is extremely low, around 100 to 200 kWh/kg Hg extracted. In Tapajós, the mercury extraction was above 99% and the final solids showed 60 to 300 ppb Hg[150].

Flotation to remove mercury from dredged sediments has also been studied. With synthetic samples, mercury recovery by flotation is as high as 95%[151], but with contaminated material, only 30 to 68% of mercury is recovered[152]. The presence of superfine mercury or mercury adsorbed onto other minerals, such as HFO, can be reasons for low recoveries.

Mercury Dispersed on Sediments

Procedures to minimize mercury bioaccumulation have been applied in Canada and Sweden where fish from natural and man-made reservoirs show increasing mercury levels over time[153,154]. Mercury sources in

---

146 Veiga, M.M.; Veiga,A.T.; Franco, L.L.; Bonagamba, M.; Meech, J.A., 1995b. An Integrated Approach to Mercury-Contaminated Sites. Proc. Eco Urbs' 95, p.51-53. Rio de Janeiro, Jun. 19-23, 1995.

147 Mr. Claudio Nunes' e-mail is snunes@wceterp.ceterp.com.br.

148 Souza, V.P., 1991. Tailing Decontamination by Electrolytic Process. In: Poconé, um Campo de Estudos do Impacto Ambiental do Garimpo, p.95-113. Ed. M.M. Veiga e F.C.R. Fernandes. Rio de Janeiro, CETEM/CNPq. (in Portuguese).

149 Sobral, L.G.S.; Santos, R.L.C.; Hempel, M.; Thöming, J., 1996. The Electroleaching of Residues Containing Mercury. Part I: Kinetics Aspects. Paper presented at Clean Technology for the Mining Industry, Univ. Concepción, Chile.

150 Personal communication from Mr. Ronaldo Santos, CETEM, Rio de Janeiro.

151 Lima, H.M. and Araújo, A.C., 1994. Flotation Study of Metallic Mercury. Rev. Escola Minas de Ouro Preto, v.47, n. 4, p.289-292, (in Portuguese).

152 Lins, F.F. et al.; 1994 - op. cit.

153 Lindqvist,O.; Johansson, K.; Aastrup, M.; Andersson, A.; Bringmark, L.; Hovsenius, G.; Hakanson, L.; Iverfeldt, A.; Meili, M.; Timm, B., 1991. Mercury in the Swedish Environment - Recent Research on Cause, Consequence and Corrective Methods. Water, Air and Soil Pollution, v.55, p.1-261.

154 Rudd, J.W.M. and Turner, M.A., 1984. Mercury and Selenium Bioaccumulation as a function of Aquatic Primary Productivity. In: Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario, and Possible Remedial

these countries are industrial emissions from coal combustion, pulp and paper or chlor-alkali effluents. Sometimes the source is unknown. Procedures such as selenium, liming or intensive fishing are applicable for enclosed environments such as lakes, lagoons and reservoirs but no short term result has been observed. Some of these techniques could be tested in Hg-polluted mining areas, but the cost is a major impediment for these methods.

Re-suspension of sediments is a method studied in Canadians impoundments[155]. Clayey ferruginous sediments have an enormous capacity to absorb heavy metals in solution, inhibiting Hg uptake by fish[156]. Some sediments are ineffective adsorbents and so field trials are necessary to confirm the technical feasibility of this remedial activity. Application of a procedure is not trivial as water turbidity is increased affecting the aquatic life drastically. In addition, mercury adsorbed onto suspended particle may be released in the presence of salts or organic acids in the water column. This procedure must be examined carefully prior to selection.

Change of food habits of riparian people is unfortunately, the only practical and immediately applicable option for regions where mercury is dispersed and bioaccumulation is occurring. A massive educational campaign is needed. This has been applied in many developed countries impacted with mercury. In James Bay, Canada, most fish from La Grande hydroelectric dam are Hg-contaminated. A brochure informing the general public has been issued for First-Nations people describing mercury sources, biotransformation, mercury in the human body, dietary recommendations, etc. The booklet also includes a list of recipes in which fish is diluted with vegetables reducing the amount of methylmercury ingested. Of course, this is not an easy measure for many Latin American communities in which have fish is the main or only source of food. However, projects are starting in the Brazilian Amazon to introduce concepts of sustainability based on fish and chicken farming. This is definitely an interesting approach as it also encourages other economic activities besides mining.
Eating fish that are not carnivorous is a useful measure to as well. Unfortunately, for most riparians, carnivorous fish taste better than other species. Cooking recipes must promote consumption of herbivorous or detritivorous species. But one can be contaminated with mercury even from non-carnivorous fish. For example, if a person consumes 200 g of fish daily (usual for riparians) containing 0.2 µg/g (ppm) of mercury (which is well below the 0.5 ppm Hg established by the World Health Organization (WHO) as the limit for human consumption) approximately 40 µg of methylmercury is being ingested daily. This is well above the ADI (Allowable Daily Intake) for both Canada and WHO. The Canadian[157] ADI guideline, exclusive for diets based on fish, is 13 µg per person. WHO adopted an ADI level of 30 µg Me-Hg as a safe level. Such concepts are difficult to understand by ordinary people.

The effect of impoundment in increasing methylmercury in aquatic biota has been a huge problem around the world which has forced fish-eating people to change their food habits. This phenomenon is associated mainly with the amount and quality of organic matter in flooded sediments which affect microbial activity and increase methylation rates[158,159]. This effect was recently identified in the Guri hydroelectric reservoir,

---

Measures. p.474-490.Ed. R.J.Allan and T.Brydges. Toronto, Ontario Ministry of the Environment.

155 Parks, J.W.; Sutton, J.A.; Hollinger, J.D., 1984. Mercury Contamination in the Wabigoon/English/Winippeg River System - Causes, Effects and Possible Remedial Measures. In: Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario, and Possible Remedial Measures. p.3-352.Ed. R.J.Allan and T.Brydges. Toronto, Ontario Ministry of the Environment.

156 Ferreira, N.S. and Veiga, M.M., 1995. Control of mercury bioavailability by sediment adsorption. Proc. Eco Urbs' 95, p.53-55. Rio de Janeiro, Jun. 19-23, 1995.

157 Canadian Water Quality Guidelines, 1987. Guidelines for Mercury by Task Force on Water Quality Guidelines of Canadian Council of Resource and Environment Ministers. Environment Canada, Water Quality Branch, Ottawa, Ontario, chapter 1, p.9.

158 Lucotte, M.; Mucci, A.; Hillaire-Marcel, C.; Pichet, P.; Grondin, A. 1995. Anthropogenic Mercury Enrichment in Remote Lakes of Northern Quebec (Canada). Water, Air and Soil Pollution, v.80. p.467-476.

Venezuela[160]. From 219 fish samples, 93 specimens (or 42.4%) showed levels above 0.5 ppm Hg. About 90% of the most appreciated carnivorous fish in the region (*Raphiodon vulpinus*), showed average Hg levels of 2.7 ppm (0.17 to 8.25 ppm; 31 samples). The government of Bolivar State and La Salle Foundation have distributed leaflets to the affected communities showing how much fish can be consumed safely each week. Children and pregnant women are the main target of the campaign. An ADI of 15 µg of Me-Hg for children and pregnant women was adopted.

3.3. Reduction of Mercury Emission

Mercury is a very cheap reagent to extract gold in Latin America.(US$ 230/flask of 76 lb, in NY - April 1997). If more control on mercury sales is exerted, the price would increase (even with smuggling) and the miners would stop using Hg in riffled sluices to amalgamate the whole ore. This is inefficient and not environmentally acceptable. Amalgamation use should focus on treating concentrates.

Sometimes, in hydraulic monitor operations, mercury is spread on the ground. Some miners still believe that mercury moves through the ground to trap all the gold that comes into contact with. Sometimes, mercury is introduced in riffled sluices. In these cases, mercury loss can be as high as 70% and gold recovery is actually quite low. Mercury flouring[161] occurs and amalgamation is ineffective. Amalgamation occurs when mercury droplets and gold specks pumped with the ore are retained by the riffled sluices. This gives the illusion that gold is amalgamated on the ground. So, an important improvement is to convince miners to adopt an initial gravity operation without using mercury. Amalgamation is efficient for particles coarser than 200 mesh (0.074 mm) and for free or partially liberated gold[162]. The efficiency of the process depends on the contact of mercury with gold particles. Amalgamation can be properly conducted with negligible levels of emission and occupational exposure for miners.

Reduction of mercury emission is a feasible and practical way to cope with the problem. There are two approaches to be followed (Fig. 3.1).

1. Systemic Solutions are those which consist of measures dependent on institutions, agencies and even private companies for implementation.
2. Individual Solutions are brought to miners by various sources but their use depends on each individual to adopt the suggested measures.

In both approaches, education is a pre-requisite for long-term solution to reduce mercury emission. Educational measures can be seen as an assembly of recommendations addressed at people involved with mining in order to convince them to adopt safe methods for the environment and themselves. These measures may not necessarily reach the informal miners directly, but through other skilled people who are frequently in contact with them (e.g. priests, equipment suppliers, social assistants, mining inspectors, environmentalists, health care people, etc.). Miners must be convinced that they are being affected by mercury vapors and causing health problems for their neighbors, friends and family members. A few brochures explaining the danger of mercury vapor are being distributed by international institutions and association of miners in Latin America. Disorganized and incorrect information on hazardous problems with mercury, usually increases the gap between artisanal miners and different sectors of society.

---

[159] Stokes, P.M. and Wren, C.D., 1987. Bioaccumulation of Mercury by Aquatic Biota in Hydroelectric Reservoirs. Chapter 16, SCOPE 31. John Wiley, New York, p.255-277

[160] UNIDO, 1996. Advisory Assistance on Avoidance Mercury Pollution from Artisanal Gold Mining Operations in State of Bolivar, Venezuela. Prepared by M.M. Veiga, contract SI/VEN/94/801/11-51. 147 p.

[161] Mercury loses coalescence and small droplets are formed. This hinders Hg recovery after amalgamation.

[162] Wenqian,W. and Poling, G.W., 1983. Methods for Recovering Fine Placer Gold. CIM - Canadian Inst. Mining and Metallurgy Bulletin, v.76, n.860, p.47-56.

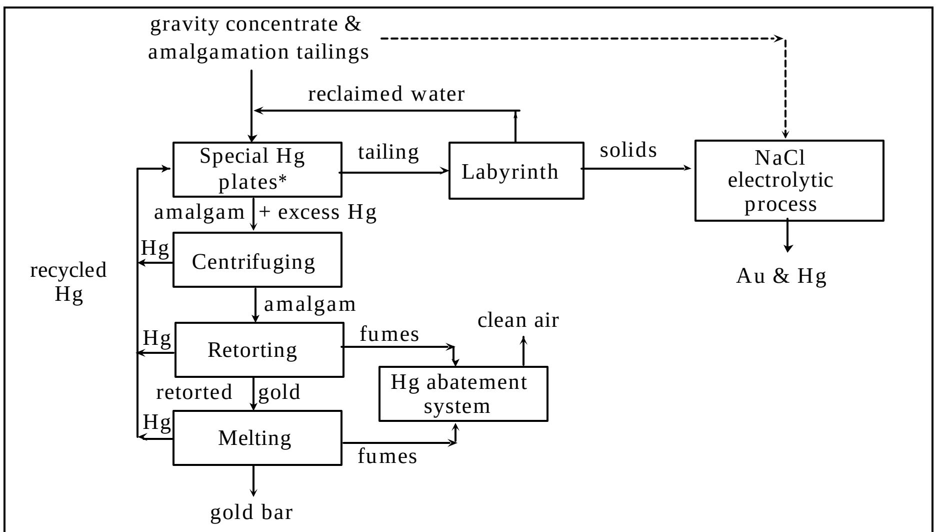
Systemic Solutions

A durable systemic measure is the introduction of environmental issues in the formal education (schools). A Miner's child can play a positive role in changing the attitudes of their parents with respect to poor amalgamation practices.

A very creative solution has been implemented in Venezuela: Amalgamation Centers. This solution can be easily reproduced in other Latin American countries. Miners take their gravity concentrates to these Centers to be safely amalgamated by technical operators. In the Amalgamation Centers in Venezuela operated by the government, the service is free. In private Centers, miners pay US$ 0.7 per kg of concentrate to be amalgamated.

Based on the Carhuachi Center, a remarkable Amalgamation Center in Caroni River, UNIDO and a Venezuelan Non-Governmental Organization, named PARECA, have designed a new **Processing Center - UNECA - UN**it of gold **E**xtraction and **C**ontrolled **A**malgamation. Gold is extracted by trained operators using special-amalgamating plates or leaching using the NaCl electrolytic process. Both methods reduce the use of mercury. The electrolytic process actually eliminates amalgamation. Special retorts and melting furnaces working under fume hoods with charcoal filters impregnated with iodine are used (Fig. 3.2).

The UNECA-type Processing Center is suitable for installation in mining villages or in any central area to facilitate transportation of gravity concentrates. Gold recovery is actually improved and mercury exposure to the operators is insignificant. For a miner who takes his concentrate to a Processing Center, there is the additional benefit of reducing costs in his own processing plant. These Centers play an important role in bringing information about mercurialism caused by Hg vapor and contaminated fish ingestion. Miners can be given brochures and additional instructions while they wait for the processing of their concentrates. The Centers can provide advice for miners on how to improve their production and can provide a meeting place for other purposes of education and organization. Further details about the UNECA Centers are described in the Chapter 4 of this document.



NOTE: * amalgamation can be replaced with NaCl electrolytic process or other leaching process

Fig. 3.2 - Steps in a UNECA Processing Center

The concept of the UNECA Processing Center is similar to the Mining Center set up in Zimbabwe

(Shamva Mining Center established by IT[163]) in 1989. This facility provided a means for about 200 miners to a central place for milling. Although successful, this method is not as flexible as the Venezuelan Processing Centers. In the UNECA Centers, miners can continue their mining and processing activities on their own without interference. Only the concentrates are processed in a central place. This means that changes in the legal and economic organization of the miners are not necessary and the Centers can be immediately implemented with full support of environmental agencies and Mining Departments. Even Small-Miner Associations can be allowed to open their own Processing Centers.

Another important systemic measure comprises **organization** of the artisanal mining activities. Creation of Miners' Association has been seen as an important step in organizing the mining activities as well as an effective channel for introduction of clean techniques.

Law enforcement is an important element in controlling mercury sales but there are other inspection requirements as well. Miners must stop using mercury in their sluices or spreading Hg on the ground in hydraulic monitoring operations. The aim must be to force miners to think about amalgamating only concentrates. This reduces emissions and gives an opportunity to introduce new techniques in the future, such as the Processing Centers.

The same police action must be applied to the large majority of gold dealers who melt gold and release mercury into the urban atmosphere. Solutions such as small scrubbers or filters must be enforced. These dealers are usually rich companies that can easily afford to introduce safety equipment. Legal control on miners burning mercury in open pans is more difficult since this operation is rapidly done and miners are often moving about from area to area.

It is also noteworthy to highlight the importance of permanent biological monitoring and technical assistance. Monitoring programs have been the focus of environmental agencies and researchers. They are important to establish the bioaccumulation levels in a region. In this case, fish and human samples, such as hair, are important pieces of evidence[164].. **Biological monitoring** consists of analyzing aquatic biota and individuals to control the occupational poisoning and mercury bioaccumulation level. This is usually an expensive task since chemical labs and specialized personnel are needed to analyze mercury levels in biological samples.

A computer program (HgEx)[165,166] has been developed to transfer knowledge and to allow rapid diagnosis of bioaccumulation risk even when biota sample is not available. Non-technical users, who might include health workers, environmental and mining inspectors, miners, biologists and local people may also have a picture of the intoxication level of individuals subjected to mercury exposure or those who have fish as their main diet. This software does not exclude the need for permanent control of bioccumulation levels, particularly in humans, but also provides a preliminary indication of the magnitude of the problem mainly at its initial stages.

---

[163] Intermediate Technology (IT) is an UK-based international development agency founded in the 1960s to enable poor people in three continents to develop and use skills and technologies which give them more control over their lives and to contribute to the sustainable development of their communities.

[164] Veiga, M.M. and Meech, J.A., 1994. Application of Fuzzy Logic to Environmental Risk Assessment. In: Proc. 4th Meeting of the Southern Hemisphere on Mineral Technology, p. 355-370. Concepcion, Chile, Nov. 20-23, 1994.

[165] Veiga, M.M. and Meech, J.A. 1992. Expert System for Risk Assessment of Mercury Discharge from Gold Mining Operations. Proc. Int. Symp. on AI in Material Process. 31st Annual Conf. of Metallurgists. of CIM, p. 107-118. Aug. 23-27, 1992. Edmonton, Canada.

[166] Veiga,M.M. and Meech,J.A., 1995. HgEx - A heuristic system on mercury pollution in the Amazon. Water, Air & Soil Pollution , v.80, p. 123-132.

Technical assistance comprises actions to bring practical solutions for miners to improve their productivity and reduce mercury emission. In Latin America this has been approached by NGOs and, to a lesser extent, by governmental agencies. This must also be part of a permanent policy of Mining Departments which need trained people to deal with artisanal miners in a trustworthy manner. Miners are usually suspicious about government representatives, even when they bring profitable solutions. Engineers, technicians or consultants give suggestions but they never stay around to see the outcome of their ideas. This has brought an uncomfortable feeling to the small miners who usually bad-mouth technical people. In 1991, Ivo Lubrina, president of the Amazonian Union of "Garimpeiros" - USAGAL declared in an interview: *Thanks to radio and TV, "garimpeiros" are concerned now about mercury, but they don't know exactly why. As there is no orientation from government or technical people, everything continues as before. I would say that the transfer of news among "garimpeiros" is happening like a rotten onion: it is going from one hand to another*.

Most Latin American countries have Mining and Environmental Agencies, usually with low budgets and unmotivated personnel. This further increases the distance between technical solutions and artisanal miners. Miners are very proud of their simple technologies even though they know that they could make it better with some help. An intelligent approach must be devised to train government personnel to guarantee that they will provide continued and durable technical assistance.

Individual Solutions

This group of solutions is focused directly at the individual artisanal miner to reduce his/her emission of mercury. Retorts can be used to capture volatilized mercury, condensing it with recovery above 95%, allowing the mercury to be recycled and resulting in substantial reduction in air pollution and occupational exposure. There are many types of retorts. Some are made with stainless steel while others use inexpensive cast iron. Hg losses during retorting depend on the type of connections or clamps used.

A home-made retort built with standard plumbing water pipes can be easily assembled to reduce mercury emission. The RHYP retort can be made with ordinary water plumbing connections (Fig. 3.3). The distillation chamber is made by connecting an end plug into which the amalgam is placed. The size of the retort can vary from 5 to 20 cm. An iron tube is connected to the elbow bend by a thread, bushing, or welding. The condensation tube should be at least 50 cm long and should curve downwards to permit good condensation of gaseous mercury without using coolant. For better performance, the retort can be immersed in a charcoal bed in order to heat it as a whole and avoid mercury leakage[167].

A hole in the ground or an iron bucket with charcoal can be used. When the fire is turned on (like a barbecue), after 1 hour all mercury should be retorted off. Use of this type of retort is easily understood and accepted by miners[168]. All materials are inexpensive, familiar and accessible to the miners.

---

[167] Veiga, M.M.; Meech, J.A.; Hypolito, R. 1995 - op. cit.
[168] This retort was built in Ciudad Guayana, Venezuela at a price of Bs 2000 (US$ 12 or 1 gram of gold).

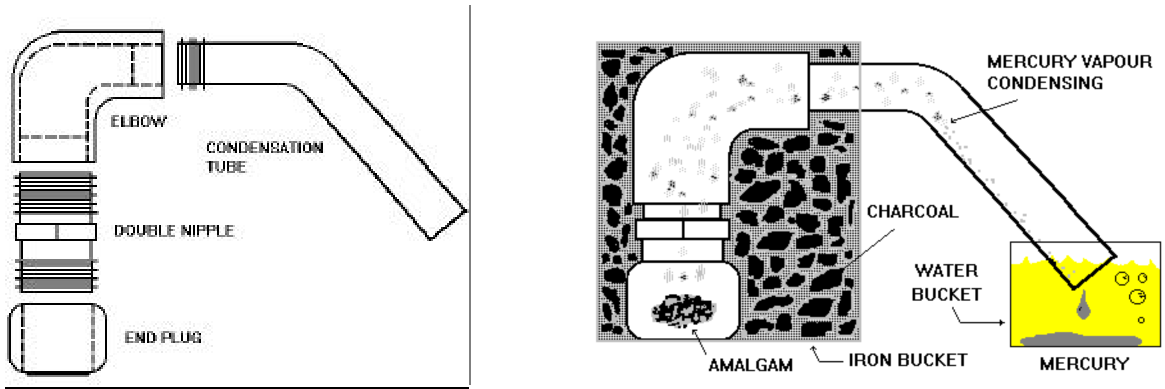


Fig. 3.3 - Home made retort (RHYP retort)

Methods for mercury abatement from fumes released when gold bullion is melted are available and can be easily implemented. In 1989, a Brazilian company developed a mercury condensing fume-hood. The prototype had a series of condensing plates coupled with activated charcoal filters impregnated with iodine solution (Fig. 3.4). This equipment reduces mercury emission drastically[169]. More than 99.9% of mercury from the fumes is retained by this special fume-hood. Less than 40 µg/m^3 of mercury was detected in the interior of the shop during a gold melting operation compared with other measurements as high as 300 µg/m^3 in unprotected shops[170,171]. Similar idea was devised by the Amalgamation Center of Carhuachi in Venezuela. This simple solution must be applied to all gold dealers in Latin America, which will result in a significant reduction of poisoning for urban citizens.

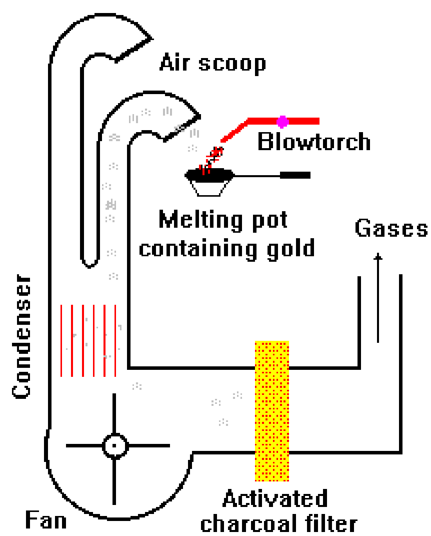


Fig. 3.4 - Special fume-hood with condenser and filter

[169] Veiga, M.M. and Fernandes, F.R.C., 1990 - op. cit.
[170] Malm et al. (1990) - op. cit.
[171] background in cities is 0.01 µg Hg/m^3, limit for public exposure is 1 µg Hg/m^3 and limit for industrial exposure is 50 µg Hg/m^3.

4. Benefits and Costs to Implement UNECA Centers

4.1. Benefits of UNECA

With the UNECA Processing Centers, miners who take their concentrates to the Centers will have the following benefits:

- Gold recovery from gravity concentrates is improved.
- Cost reduction in the processing plant.
- Better price of gold sold to banks or dealers (gold is already melted in the Centers).
- No mercury vapor exposure.
- No need to buy mercury illegally.
- Access to information about improving mining and mineral process techniques.
- Access to information about obtaining legal mineral titles.
- Access to information about obtaining financial support.

For the general public, the UNECA Centers bring the following benefits:

- No mercury emission from amalgamation and gold melting operations.
- Information about the danger of mercury vapor exposure.
- Information about mercurialism caused by fish ingestion.
- Advice about fish consumption.
- Advice for pregnant women and children.
- Preliminary diagnostic of mercurialism.
- Medical orientation.
- Advice for those who want to start an artisanal mining operation.

All criteria and arrangements to install a UNECA Processing Center must be previously discussed with governments and the local Association of Miners. The efficiency of the measure depends on the **miners commitment** to take their concentrates to the Center. A strong educational campaign must precede the Center installation. This consists of a series of meetings with miner leaders to convince them about the risk of the poor amalgamation practices and the benefits brought by UNECA Centers. As well, governments must be assisted to find ways to legalize this Centers and enforce the law in mining regions where the Center will be set up to guarantee that miners will stop their own amalgamation.

4.2. Time Table to Install a UNECA Center

Activity **months**	**1**	**2**	**3**	**4**	**5**	**6**
Educational Campaign						
Government Assistance						
Lay out of the UNECA center						
Construction of the UNECA Center						
Field test (start-up) and training						

NOTE: The lay-out is developed based on the existing facilities and infrastructure of the site.

4.3. Costs of a UNECA Center

The price of a UNECA-type Center depends on the process to be adopted (amalgamation with special plates and/or NaCl electrolytic leaching process), infrastructure, power supply, civil construction, material cost, transportation and labor costs of the country and mining region. A preliminary generic investment is shown as follows:

Table 4.1 - Estimated fixed capital costs (equipment) of a UNECA Center

Item	US$
- Special amalgamation-plates (2 sluices of eight 30x40 cm plates each in metallic frame)	20,000
- Fume hoods, air filters and scrubbers	15,000
- Retorts (3 units with gas blow-torches + gas tanks)	9,000
- Sealed melting furnace with condenser (1 unit working with gas)	15,000
- Electrolytic leaching system (tanks + stirrer + current source + pumps + filters + activated charcoal column)	60,000
- Ancillaries & Contingency	10,000
TOTAL	**129,000**

Table 4.2 - Estimated variable capital costs of a UNECA Center

Item	US$
- Civil construction + water supply equipment + water treatment tanks + security devices.	20,000
- Mechanical + electrical work	10,000
- Engineering + consulting fees (3 eng. - 2 months each on the site)	48,000
- Travel and living expenses for engineers and laborers (6 months)	30,000
- Start-up assistance and operators training	10,000
TOTAL	**118,000**

The cost obtained in Table 4.1 do not include equipment for power supply, such as generators, transformers and power lines. Electric power must be available on the site. The price of the land to be installed the Center is not included either. The total investment of almost US$ 250,000 can be drastically reduced after the installation of the first Center as many local manufacturers can be trained. The variable costs such as engineering and consulting fees can also be reduced as the technology is transferred to local technical people who can be in charge of building other Centers.

The operating costs for a UNECA Processing Center are also dependent on local costs. The Center works with 5 people (or less): 2 technicians + 3 helpers in just one shift (8 hours, for 5 days/week). One technician is also in charge of administration. Three armed people in charge of security are considered in the estimated operating cost depicted in Table 4.3.

Water must be supplied by a local waterstream or impoundment. Water reclamation must be also taken into consideration. Frequent monitoring (Hg analysis) of liquid effluents, air and urine of workers is strongly advised.

The reagent consumption can be reduced after the start-up. Transportation of reagents to the Center is an item difficult to estimate as these Center can be located in remote regions. After a decontamination step with NaCl electrolytic leaching, solids must be transported, buried, covered with a laterite layer and a simple revegetation provides an adequate end for solids. A generic operating cost is listed as follows:

Table 4.3 - Estimated operating costs for a UNECA Center

Item	**US$/month**
- Labor	2,500
- Security (personnel)	2,400
- Electric power	1,000
- Gas (for retorts and melting furnace)	500
- Reagents (NaCl, NaOH, KI, Hg, activated charcoal, etc.)	3,000
- Transportation of reagents and decontaminated solids	1,000
- Repair parts + Maintenance	2,000
- Disposal of decontaminated solids + revegetation	1,000
- Mercury monitoring	500
- Contingency	1,000
TOTAL	**14,900**

As in Venezuela, the UNECA Center can charge US$ 1/kg of concentrate processed. Assuming the concentrates weigh between 30 and 60 kg with grades ranging from 2,000 to 5,000 g/tonne, the cost of US$ 30 to 60 charged by the Center represents 2 to 5% of the gold content in the concentrates. Processing 500 kg of concentrates daily, which is approximately the amount treated by a Venezuelan Center, the income of US$ 10,000/month will be derived. This almost covers the operating cost.

The UNECA Centers are also decontamination centers. Using the electrolytic process, residual mercury and gold can be extracted from dredged “hot spots”. Tailings produced by individual miners who insist on amalgamating their concentrates can also be treated in the Center. As gold content in amalgamation tailings is high, the decontamination step, as observed in Venezuela, is a profitable operation conducted by private companies. The Center gives a safe end (landfill) to the decontaminated residues.

Governments must set up a mechanism to guarantee that the Processing Centers will receive gravity concentrates and amalgamation tailings from miners. This can be done by decrees, contracts and agreements.

UNIDO is prepared to assist the development and implementation of these Processing Centers in any country.

5. Final Remarks

It is clear that artisanal mining in Latin America is a temporary activity. This will persist up to exhaustion of the easily extractable gold. Artisanal activities on primary ore deposits are inefficient and expensive. In all regions where miners insist on applying rudimentary methods to extract and process primary ores, the results are not encouraging. This actually is creating social and economic problems in municipalities where mining was the main economic activity, due to the migratory nature of miners. It is clear that gold panners who conduct a very small-scale mining for their subsistence will exist for many decades, as long as they discover alluvial gold in remote regions, but artisanal mechanized operations tend to disappear or evolve into the organized mining sector. For this, artisanal miners need technical and legal support to meet the mining and environmental regulations. Legal titles are essential to organize and transform this informal industry.

Mercury pollution in the Latin America has been used by different segments of the society as a useful villain. Fantasies, panic and political interests have been derived and affected communities (miners and fish-eating people) have been ignored. The number of academic research and monitoring programs are far higher than the number of solutions suggested or effectively implemented in the field. The trait of the Latin American artisanal miners must be understood as a pre-requisite to change their behavior. The political will of governments is an important clutch to transform a squad of unprivileged people into citizens. The old “garimpeiro” saying - *it is easier a man becomes a “garimpeiro” than a “garimpeiro” becomes a man* - must be changed.

Mercury pollution is one of the most serious environmental problems related to the mining sector, but it is just the tip of the iceberg of the environmental, social and economic problems associated with artisanal gold mining activities. The creation of Processing Centers to amalgamate or leach gravity concentrates is perhaps the most concrete systemic solution to reduce emissions or eliminate mercury use. Since miners will agree to bring their gravity concentrates to these Centers, as observed in Venezuela, amalgamation can be conducted safely and without Hg emission. Leaching processes, such as an electrolytic process using salt table is a practical and environmental friendly alternative to dissolve gold from concentrates.

UNIDO is prepared to assist and implement all steps needed to introduce safe technologies into artisanal gold mining activities respecting the principles of the miners and the integrity of the mining and environmental laws.