An Assessment of Primary and Secondary Mercury Supplies in Mexico

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ACRONYMS AND ABBREVIATIONS

ASGM	Artisanal and small-scale gold mining
Camimex	*Cámara Minera de México* (Mining Association of Mexico)
Canacero	*Cámara Nacional de la Industria del Hierro y Acero* (National Iron and Steel Industries Chamber)
CEC	Commission for Environmental Cooperation
COA	*Cédula de Operación Anual* (Annual Certificate of Operation)
CRM	*Consejo de Recursos Minerales* (Council of Mineral Resources, now *Servicio Geológico Mexicano*—SGM)
EPA	Environmental Protection Agency (US)
g/t	grams per metric ton
Hg	mercury
INE	*Instituto Nacional de Ecología* (National Institute of Ecology)
INEGI	*Instituto Nacional de Estadística y Geografía* (National Institute of Statistics and Geography)
LBI	UNEP Global Legally Binding Instrument on Mercury
LGPGIR	*Ley General para la Prevención y Gestión Integral de Residuos* (General Law for Waste Prevention and Comprehensive Management)
LGEEPA	*Ley General del Equilibrio Ecológico y la Protección al Ambiente* (General Law of Ecological Balance and Environmental Protection)
NAAEC	North American Agreement on Environmental Cooperation
NAFTA	North American Free Trade Agreement
NARAP	North American Regional Action Plan
ppm	parts per million
Profepa	*Procuraduría Federal de Protección Ambiental* (Federal Attorney for Environmental Protection)
RETC	*Registro de Emisiones y Transferencia de Contaminantes* (Pollutant Release and Transfer Register)
SE	*Secretaría de Economía* (Secretariat of Economy)
SGM	*Servicio Geológico Mexicano* (Mexican Geological Service)
SIAVI	*Sistema de Información Arancelaria vía Internet* (Tariff Information System via the Internet)
SIEM	*Sistema de Información Empresarial Mexicano* (Mexican Business

	Information System)
Semarnat	*Secretaría de Medio Ambiente y Recursos Naturales* (Secretariat of Environment and Natural Resources)
SMOC	Sound Management of Chemicals (CEC initiative)
UNEP	United Nations Environment Programme
USGS	United States Geological Survey

DEFINITIONS AND EQUIVALENCES

Artisanal: small-scale, individual-based mining or working of precious metals (applied chiefly to gold in this report).

By-product mercury: mercury generated from other metals production processes, when mercury is found as trace metal in the ore of these metals.

Formal primary production: production carried out by the owner of the concession (grant) of the mine; generally, this production is performed on a medium or large scale.

Informal primary production: production carried out by miners with or without a permit from the grant holder, or in abandoned mines, usually by artisanal methods. Informal production of mercury is not recorded officially; however, where this production occurs, the quantity of mercury produced and not reported should be considered as part of the surplus mercury.

Mark: unit of weight = 8 ounces = 230 grams.

Primary mercury: mined, virgin mercury.

Quintal: unit of weight = 46 kilograms.

Secondary mercury: mercury recovered from mercury-containing end-of-life products, from tailings generated by previous preciou metals mining activities, or from other industrial processes that generate mercury-containing wastes. Such mercury-containing sources are termed “secondary reserves.”

Ton: = unit of weight = 1000 kilograms.
Throughout this report the term *ton* refers to metric ton, whether so specified or not.

ORGANIZATION OF THIS REPORT

Six chapters comprise this report, as outlined below.

Chapter 1 explains the objectives and scope of this report. It also presents a succinct overview of the current international situation concerning mercury emissions, consumption and supply, and provides an outlook on the mercury reduction and ban policies at the international level.

Chapter 2 gives a history of primary mercury mining (production) in Mexico to its present-day status—it officially stopped occurring in 1994, but probably is being carried on informally and not reported. The information that is available on Mexico's mines, including location, size, condition, production methods, and costs, is surveyed and used to build a prospective on the potential reserves of mercury available for mining. A brief description of the domestic regulations pertaining to mercury mining is included. The conditions that may enable the resumption of primary mercury production are listed.

Chapter 3 is dedicated to estimating the potential reserves of secondary mercury that could be recycled, using the lixiviation process, from the wastes (tailings) of Colonial and Postcolonial silver mining. In this chapter the results of a parallel study are also presented to quantify secondary mercury reserves, based on sampling and analytical methods performed in Zacatecas City and the surrounding area. A description is given of how historical silver-mining activities introduced this large amount of mercury in Mexican territory.

Chapter 4 describes other potential sources of secondary mercury supply in Mexico, including chlor-alkali plant conversions to non-mercury-cell technology. In addition, hypothetical estimates are given on by-product mercury that can be recovered from mining and metal-processing operations, and on mercury generated from possible future collection programs of mercury-containing instruments and devices.

Chapter 5 assesses possible future trends in the supply of and demand for mercury in Mexico. The impending restrictions in trade of mercury internationally and other policies restricting its use are considered, in the context of their repercussions on Mexico which include motivating informal mining or resuming formal mercury mining. A discussion related to informal primary production in Mexico is also presented.

Chapter 6 summarizes the findings and offers recommendations.

DISCLAIMER

The material in this report was based on information taken from different official and non-official sources. In some cases, due to gaps in the available information, the data generated in this document had to be derived from indirect or informal sources. Because of this, the author considered it necessary to establish a rating system (see the Confidence-rating Criteria, below) to be applied, when necessary, to some results and figures in this report. A ranking level has been inserted in each data table throughout the document indicating the level of confidence for each data point included in this report.

Confidence-rating Criteria
(applied to certain generated information in this report)

Rating Level	Criteria
High	Based on available public or official information or validated data
Medium	Based on limited data or data not yet validated
Low	Based on inadequate data and must be considered as preliminary estimate

The recommendations included in this report are proposals of the consultant and have not necessarily been endorsed by the Commission for Environmental Cooperation, the CEC Mercury Task Force, or the governments of the individual countries.

EXECUTIVE SUMMARY

The objectives of this report are to estimate the supplies of primary and secondary mercury in Mexico that could be generated from different sources; to assess if extraction of identified mercury reserves would be both economically and technologically feasible; and to analyze the potential for Mexico to become an unintended but significant source of global mercury supply following the implementation of elemental mercury bans in the United States in 2013 and in the European Union in 2011.

This information can also be helpful in orienting governmental decisions related to the United Nations Environment Programme (UNEP) Legally Binding Instrument on Mercury.

Primary production

There is significant natural occurrence of minerals containing mercury in Mexico. The average mercury content found in Mexican ore deposits has ranged from 0.33 to 10 percent. The most important such reserves are located in the states of Zacatecas, Querétaro, San Luis Potosí, Durango, and Guerrero.

According to information provided by the Secretariat of Economy (SE—*Secretaría de Economía*), 314 mercury mines were reported in 2010. In 1968, the Commission for Mining Promotion (CFM—*Comisión de Fomento Minero*) reported the existence of 1,119 mercury mining projects. These two sources have been consulted in determining the physical and legal status of each mine, its current condition (exhausted or productive), and the identity of its operator.

Formal primary production of mercury in Mexico began in the 1840s. According to historic and official information, from 1840 to 1994 Mexico produced an estimated 35,555 metric tons of mercury, with a yearly average of 229 tons. The peak years of production were 1942, with 1,117 metric tons, and 1955, with 1,030 metric tons, while 1994 was the final year of primary production and had the least production, estimated at 11 tons.

An inventory of approximate mercury reserves throughout Mexico does not exist. The poor record-keeping may be explained in part by the lack of importance credited to mercury mining because of the greater interest in other metals, such as gold, silver and copper, and because the demand for mercury has fluctuated a great deal (especially over the last thirty years), often resulting in prices too low to warrant costly investment for exploration that would be more profitable if applied to producing more valuable metals. However, it is known that the richest mercury deposits in Mexico are found in locations in central states, such as Nuevo Mercurio in Zacatecas, Sierra Gorda in Querétaro, and the High Plateau in San Luis Potosí.

Official information reviewed here indicates that there is a potential reserve of 42,000 metric tons of mercury in four mines located in Zacatecas, Querétaro, and Estado de México (see **Table 2-6**). However, since there are more than 300 reported mines, a more comprehensive estimate would be required to obtain a total estimate of Mexico's mercury reserves.

Informal primary production

Although there is no official information on formal or informal mercury production[1] since 1994 (when official production ceased), a provisional estimate of around 38 tons of informally produced mercury for the period of 2007–2009 can be given by considering the following sources:

- Customs statistics indicating that Mexico exported more mercury than official statistics substantiate for the amount of mercury produced and imported;
- Reports by journalists referring to informal mercury production in Querétaro and Zacatecas; and
- Commercial advertisements on the Web offering supplies of mercury for sale (see **Section 5.2**).

Secondary production from wastes (tailings) generated by previous mining activities

Mexico has significant secondary mercury reserves as a consequence of the inefficiency of the silver amalgamation method used in silver production during the Colonial and Postcolonial Periods (1545–1900). It is estimated that roughly 73,000 tons of mercury were released to soils and water bodies. In addition, significant quantities of silver and mercury, as well as small amounts of gold, remain in wastes (tailings) generated from these mining activities.

In addition, it is estimated that around 196,000 tons of mercury (Hg) were released to the atmosphere during the aforementioned periods. This figure has been derived by calculating that approximately 93,000 tons of silver were produced (see **Table 3-5**) and that about 2.1 kilogram (kg) of mercury is required to produce one kg of silver with the amalgamation method. Amalgamation was replaced by the cyanidation technique for silver production between 1900 and 1920.[2]

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[1] "Informal" mining or mining-related activities denotes those undertaken without official governmental recognition. They may or may not be illegal but are likely "off the books." "Informal" is not the same as "artisanal," which is characterized solely by being small in scale.

[2] Also known as the MacArthur-Forrest process, this technique involves using aqueous solutions of sodium

During the last 100 years, secondary production of silver and mercury from tailings has been documented in Hidalgo, San Luis Potosí, and especially Zacatecas, where it is estimated that around 2,000 tons of mercury were recycled by using the lixiviation method (see **Section 3.4**).

Present day secondary production at the two existing recycling plants in Zacatecas amounts to approximately 24 tons/year. However, any increase in the current level of production at these plants depends on the availability of tailings containing silver and mercury, the mercury content in these tailings, and silver and mercury prices and demand. The potential combined mercury-production capacity of these two plants is estimated to be approximately 45 tons/year.

It is difficult to estimate how much of the estimated 73,000 tons of mercury in Mexican soils (in tailings dating from the Colonial and Postcolonial Periods) can still be recovered, due to the following factors:

- In many locations, tailings are now covered by urban development;
- The geographical and physical location of tailings and their distance from recycling plants may constrain the economic viability of recovering the precious metals and mercury;
- Tailings erode and disperse through the years, decreasing the amounts of silver and mercury per ton and eroding the profitability of recuperation efforts; and
- International prices of silver, gold and mercury also determine if the recycling activity is feasible and remunerative.

However, estimated reserves of mercury in Zacatecas alone (the state that has produced around one-third of all Mexican silver and which has a tradition of recycling tailings) range from 7,000 to 14,000 tons (see **Table 3-7**).

For all the above reasons, it is difficult to determine how long tailing-recycling activities will occur in Zacatecas or if they will be extended to other states where the amalgamation method was used, such as Hidalgo, Guanajuato or Chihuahua.

Chlor-alkali mercury reserves

Approximately 265 tons of mercury reserves will be available when the two remaining chlor-alkali plants producing chlorine and caustic soda (sodium hydroxide) change to non-mercury technology (see **Table 4-1**).

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cyanide in the presence of oxygen to dissolve the gold for separation and recovery.

By-product mercury from the metal production sector

There is no available information on the amount of mercury recovered in the different metal production processes. However, the amount of recovered by-product mercury that hypothetically may be available to the market from this sector is estimated to be about eight tons. This quantity was calculated using the methodology prescribed by the UNEP Mercury Inventory Toolkit, and based on 2004 information on national emissions from the National Inventory of Mercury Releases (see **Table 4-2**).

Prospective on secondary production from collection-recycling programs

Secondary mercury production from discarded mercury-containing products is not currently occurring in Mexico. Assuming hypothetically that collection and recycling-recovery programs are successful and achieve a 50-percent recycling level in the health and the electric sectors, a preliminary estimate of the potential quantity of mercury that may be available from recycling activities during 2012–2013 is about seven tons per year (see **Table 4-3**).

It is important to note that future recycling activities in Mexico are framed by factors that differ from those in developed countries such as the United States, where in the last decade recycling mercury has offered two ways of making a profit:

- By the generators of spent mercury-containing products paying the cost of recycling; and
- Through the possibility of selling the recovered mercury on the international market.

Recycling of waste mercury-containing products faces the following challenges in Mexico:

- The supply of mercury recycling services may be affected by the lack of investors interested in affording the high cost of the mercury-recycling business; and
- Recyclers will not have an easy job selling the recovered mercury in the future if new international restrictions on use and export come into effect; instead, recyclers (or customers) will have to pay for the final confinement or stabilization costs.

Possible future scenario

The information generated in this report suggests that Mexico meets latent conditions to become a substitute for the US's historic export supply of mercury[3] (at least in the Latin American region) when the US export ban becomes effective in 2013. Namely:

- Based on its history in previous productive decades, Mexico's primary and secondary production could increase from an estimated 24 tons to 450 tons per year, with the possibility of doubling in the near future; and
- In the global context, it is important to consider that two kilograms of mercury, at an international market price of US$84.13,[4] can amalgamate one kilogram of gold, which will fetch US$43,564.00.[5] The rising price of gold increases demand for mercury from countries where artisanal and small-scale gold mining takes place, which in turn could drive Mexico to exploit its capacity as a mercury producer and exporter. This is a complex issue that should be analyzed by all the sectors and individuals involved.

Potential Primary and Secondary Mercury (Hg) Supply in Mexico

	Metric tons	Confidence rating*
Probable primary Hg reserves	42,000	Medium
Secondary Hg reserves from mining wastes	7,000–14,000	Medium
Chlor-alkali mercury reserves	265	High
By-product mercury from the metal production sector	8	Low
Secondary production from recycling programs of products	14	Low
Total	49,287–56,287	

Note: Whether these quantities become available to the international market will greatly depend on Hg global mercury market conditions compared to extraction costs and technological feasibility.
*See the disclaimer in the previous section of this report.

[3] According to the USGS 2010 *Minerals Yearbook* (advance release), the US exports during 2007, 2008, 2009 and 2010 were 84, 732, 753 and 500 tons, respectively, which results in a yearly average of 517 tons (USGS 2010, p. 102, available at: <http://minerals.usgs.gov/minerals/pubs/commodity/mercury/myb1-2010-mercu.pdf>); while Mexican production for the period 1988, 1989, 1990 and 1991 (when mercury demand started to decline) was 345, 651, 735, and 340 tons, respectively, which results in a yearly average of 518 tons (see **Table 2-4** in this report).

[4] Based on 2011 prices, one flask = US$1,450.00/34.47 kilogram/flask = US$42.065/kilogram. Source: <http://minerals.usgs.gov/minerals/pubs/commodity/mercury/mcs-2011-mercu.pdf>.

[5] Based on 4 February 2011 prices, one troy ounce (31.106 grams) = US$1,355.00 = US$43.564/gram x 1000 grams = US$43,564/kilogram. Source: <http://www.gold.org/investment/statistics/prices/>.

Recommendations presented in this report

- Develop and propose a strategy in a joint effort with other relevant entities, such as the Secretariat of Economy, Semarnat, and other governmental and industrial sectors, focusing on assessing the current and future prospects for mercury production. Among other issues, it should include a socio-economic study of informal mining communities in Querétaro and Zacatecas.
- Based on current environmental, health and economic regulations, develop a specific, proposed regulatory framework for mercury. This framework must take into consideration the following issues: the ban on primary mercury production; the promotion of initiatives for recovering mercury-containing products; by-product mercury generation control; and long-term storage for elemental mercury and mercury-containing wastes.
- Find the financial resources (from national and possibly international sources) to implement an adequate national mercury collection and retirement program, including long-term storage and mercury-stabilization technologies.
- Considering that the implementation of recycling programs will take an unknown period of time, develop and implement a strategy for the continuing elimination of mercury in products and processes.
- In a joint effort with national customs authorities, implement a mechanism to monitor the actual imports and exports of mercury and mercury-containing products, including mercury compounds.
- Promote a national meeting(s) with all key sectors and interested stakeholders. Have as initial objectives to disseminate information on the issues related to mercury; to facilitate communication; to dedicate joint efforts and resources to avoiding mercury uses and releases; and to elaborate and submit a draft for a national mercury action plan.
- In order to move forward with Mexican commitments to international initiatives, such as the UNEP Mercury Programme and the North American Regional Action Plan for mercury (see **Section 1.5.1**) of the Commission for Environmental Cooperation (CEC), promote a multinational workshop with the support of the CEC and UNEP, having among its objectives the preparation and submission of a proposal for a multilateral plan designing an environmentally sound transition period, in order to avoid movement of mercury between countries.
- Assess if artisanal gold mining is occurring in Mexico, to what extent, and the amounts of mercury used by this activity.

Update to 2012

Since this report was initially prepared, demand for mercury from artisanal gold-producing countries (Colombia, Peru, among others) has increased, as have gold prices. As well, Mexican production of mercury increased from 12 tons in 2010 to around 121.5 tons in 2011, to about 96.7 tons during the first six months of 2012. On the other hand, imports of mercury into Mexico from mercury-producing countries began in 2011 and 2012 (Kyrgyzstan, with 10.35 tons in 2011, and China, with 5 tons during the first six months of 2012). In each case it has been the first time Mexico has imported mercury from those countries.

Trends in supply and demand for mercury in Mexico:
Imports into Mexico in 2009, 2010, 2011, and through the first six months of 2012 totaled 26.09; 14.54; 13.89 and 5.03 tons, respectively; while Mexican mercury exports during the same period totaled: 36.69; 25.51; 134.30 and 100.89 tons, respectively *(Source:* <http://www.economia-snci.gob.mx/siavi4/fraccion.php>, at Tariff number 2805 4001).

CHAPTER 1 INTRODUCTION

1.1 Overview

Mercury is a highly toxic substance that has aroused increasing concern in developed countries since 1956, when an organic mercury compound caused massive, deadly intoxication in Japan.[6] Other properties of mercury have been described as follows: "[I]n its gaseous elemental form, mercury has a long atmospheric lifetime (6–18 months), which means it can be transported around the globe, hence its characterization as a 'global pollutant'. Atmospheric mercury is deposited in various ways to the ground and water. After deposition, some of the mercury can be transformed, primarily by microbial action, into methylmercury. Methylmercury bio-accumulates and bio-magnifies in food webs, resulting in increased concentrations in organisms higher in the food web" (WHO 2008).

Mercury is a naturally occurring element in the earth's crust and is found in air, water and soil. It is distributed throughout the environment by both natural and anthropogenic processes. It is also found in various inorganic and organic forms and is persistent in the environment. The three predominant forms are:

- Elemental mercury (Hg^0);
- Ionic mercury, also known as inorganic mercury—Hg (II) or Hg^{+2}—which in nature exists as Hg (II) mercuric compounds or as complexes in solution; and
- Organic mercury, with methylmercury (CH_3Hg) being the most important (WHO 2008).

Because of its unique characteristic of amalgamating with some other metals, such as gold and silver, the demand for mercury is high for artisanal and small-scale gold mining (ASGM). This demand was estimated to be around 650 to 1000 tons a year in 2005 (UNEP 2006). In countries where ASGM occurs (such as Peru, Brazil, Colombia, and some countries in Asia and Africa), this activity offers a livelihood for several million people. The artisanal gold sector produces 20 to 30 percent of the world's mined gold, approximately 500–800 tons in 2005 (UNEP 2008). In fact,

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[6] Japanese Ministry of the Environment. 2002. Minamata Disease the History and Measures. Available at: <http://www.env.go.jp/en/chemi/hs/minamata2002/>. Further information on health effects of mercury (Minamata disease in Japan) is available at the Agency for Toxic Substances and Disease Registry, Toxicological profile for mercury, at: <http://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=115&tid=24>. See also: WHO (World Health Organization). 2008. Guidance for Identifying Populations at Risk from Mercury Exposure. Issued by UNEP DTIE Chemicals Branch and WHO Department of Food Safety and Zoonoses. Geneva, Switzerland. August 2008. Online at: <http://www.who.int/foodsafety/publications/chem/mercuryexposure.pdf>.

this sector is the principal mercury consumer in the world today, and also a source of substantial mercury emissions.

Other mercury consumption sectors, in order of importance are vinyl-chloride-monomer production using mercury, chlor-alkali production, dentistry, measuring and control devices, electrical and electronic devices, lighting, cultural-traditional uses, and other more minor uses.

Mercury compounds are used in some batteries, pharmaceuticals, paints, and as laboratory reagents. Mercury can be released to air, water, and soils during production and use or after the disposal of mercury-containing products and wastes. The global mercury demand of the above-mentioned sectors in 2005 was estimated as between 2,670 and 3,900 metric tons (UNEP 2006).

This is approximately equal to the global mercury supply, which is estimated to be around 3,000 to 3,800 tons (UNEP 2006). The two main mercury-producer sectors are primary mercury mining and other metal-production activities that generate mercury as a by-product. The estimated total production from both sectors is approximately 1,800–2,200 tons. Another important source of mercury is generated by decommissioning chlor-alkali cells, estimated to yield 600–800 tons. Recycling activities of mercury-containing products and wastes contribute another 540–660 tons.

Mercury is also released to the environment by various industrial sources that mobilize and emit mercury impurities from input materials (such as fuels and feedstock). These include coal-fired power plants, non-ferrous-metals smelters, and cement production plants, all of which are among the sources with the highest mercury emissions. These emissions lead to environmental contamination and human exposures. The degree of emissions and levels of exposures from any one facility depend on various factors, including the mercury levels in the fuel and the feedstock, the emissions-control devices present, the stack heights, the size of the operation, and other factors (WHO 2008).

According to *The Global Atmospheric Mercury Assessment* (UNEP-Chemicals 2008), the temporal trends in mercury emissions to air in 1990 were estimated to be about 1910 tons. In 1995, estimated emissions rose to about 2050 tons, but fell to about 1930 tons by 2000–2005. The greatest decreases were in Europe, with considerable declines also in North America, reflecting the introduction and wider use of emission-control technologies. Emissions in Asia, South America, Africa and Oceania increased modestly over this period, attributed to economic expansion in some countries, with the largest increases seen in Asia.

Comparing the earlier global inventories with the new 2005 figures is complicated by changes in methods and assumptions and by the addition of new sectors of activity. Using data for only those sectors included in both the 2000 and 2005 global emissions inventories, the estimated total emissions from these sectors fell by about 450 tons. Some of this decrease is real, but some is likely due to improved quality of information, data and estimation (UNEP 2008).

1.2 Objectives of This Report

The objectives of this report are to give an estimate of primary and secondary mercury supplies generated from different sources and wastes; provide elements to assess if identified mercury reserves would be both economically and technologically feasible to extract; and give an analysis of the potential for Mexico to become an unintended but significant source of global mercury supply following the implementation of elemental mercury bans in the US in 2013 and in the European Union in 2011.

This information will be helpful in orienting Mexican governmental decisions related to the United Nations Environment Programme (UNEP) Legally Binding Instrument on Mercury.

The idea for this study emerged from the Commission for Environmental Cooperation's [7] North American Regional Action Plan on Mercury (mercury NARAP), which provides a strategic framework for Canada, Mexico and the United States to implement actions aimed at reducing and eliminating anthropogenic mercury sources (CEC 2000).

The work in this report is a follow-on study to a previous report, the *Mexican Mercury Market Report*, released by the Commission for Environmental Cooperation (CEC) in 2008, whose purpose was to collect and analyze available information from Mexico on the supply, demand, trade, market characteristics, and trends in elemental mercury and mercury-containing products in commerce. That report also identified market actors, consumers, producers and institutions, along with data on mercury production, imports, exports, supply and demand. One of the recommendations presented in the report was to assess the impact on the global market if potential Mexican primary and secondary mercury sources of supply became available (CEC 2008).

1.3 Historical Context

Since ancient times, humans have made use of mercury as a raw material for decorative painting or religious purposes. However, since the start of the industrial age, mercury applications have expanded to other manufacturing and scientific uses.

Mercury is mined as cinnabar ore, which contains mercuric sulfide. The metallic form is refined by heating the ore to temperatures above 1,000ºF (538ºC). This vaporizes the mercury in the ore, and the vapors are condensed to yield liquid metal mercury. As a naturally occurring metal, mercury is found throughout the environment, released as the result of volcanic activity and of the normal breakdown of minerals in rocks and soil from exposure to wind and water (ATSDR 1999).

[7] The CEC was established by the North American Agreement on Environmental Cooperation (NAAEC).

Mercury is present in fossil fuels and in association with other metals; thus it is also released to the environment when fuels are combusted and through mining activities.

Mercury has many other applications in different sectors of the chemical industry, such as in the production of chlorine, vinyl chloride monomer, and fungicides that contain inorganic mercury. Its chemical and physical properties make it useful in dental amalgams, measuring and control devices, lighting, electrical and electronic devices, and explosives, among other applications.

Since 1555–1556, when the amalgamation method of extracting precious metals from ore was developed at the Pachuca mines in New Spain (Mexico), the consumption of mercury in silver and gold production began to cause environmental impacts on a global scale. It is estimated that during the Colonial Period, 1556–1810, between 100,000 and 126,000 tons of mercury were released into the atmosphere as a consequence of the silver production in Spanish colonies in the Americas (Camargo 2002).

1.4 Economic and Social Context

The current environmental trend in developed countries has led to European and US regulations that have banned or will ban the export of mercury from these regions in 2011 and 2013, respectively, resulting in a potential supply shortage in other countries, including those where artisanal and small-scale gold mining (ASGM) is an important contributor to the economy.

Two kilograms of mercury can amalgamate one kilogram of gold. The cost of two kilograms of mercury on the international market is currently US$84.13.[8] Recently, the demand for gold has soared, raising its price to US$43,564 per kilogram.[9] With the bans on the export of mercury throughout much of the world looming in the near future, the demand for mercury from countries where it is needed for artisanal and small-scale gold mining can be expected to rise, along with its price. This could ultimately lead to higher production of mercury in Mexico.

Artisanal and small-scale gold mining is frequently coupled with extensive environmental degradation and deplorable socio-economic conditions, as has been seen in more than 50 countries. According to Hentschel et al. (2003), deleterious aspects of ASGM are:

- Lack or limited use of mechanization, resulting in dangerous and physically taxing work;
- Low availability of occupational safety and health care;
- Poor qualification of personnel at all operational levels;

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[8] Based on 2011 prices, one flask of mercury = US$1,450.00/34.47 kilograms = US$42.065. Source: USGS, <http://minerals.usgs.gov/minerals/pubs/commodity/mercury/mcs-2011-mercu.pdf>, p. 103.

[9] Based on 4 February 2011 prices, one troy ounce of gold = US$1,355.00/31.106 grams = US$43.564 per gram x1000 grams = US$43,564/kilogram. Source: <http://www.gold.org/investment/statistics/prices/>.

- Exploitation of marginal and/or very small deposits, which are not economically exploitable by mechanized mining;
- Low productivity;
- Low salaries and income; and
- Chronic lack of working and investment capital.

Considering Mexico's capacity, due to its significant reserves, as a potential mercury producer, the current mercury demand of ASGM countries, and the mercury export ban policy proposed by some developed countries, it is important to estimate the extent to which informal (unreported) production of mercury will occur, in order to assess the occupational, environmental, legal and economic aspects involved.

1.5 Regional and International Perspectives

Throughout the world, important initiatives have been devised to reduce anthropogenic mercury emissions. Actions taken have been significant, expressed in national, regional and international initiatives, protocols and plans, promoted by regional and international organizations.

Regional perspective

At the North American level, Mexico has participated with Canada and the United States since 1997 in a joint effort dedicated to reducing anthropogenic releases of mercury through a North American Regional Action Plan (NARAP) on mercury, and managed by the trinational Sound Management of Chemicals Working Group directing a Task Force on Mercury.

The coordinated trilateral implementation of the NARAP was not envisioned as a long-term effort. The Task Force on Mercury chose the year 2010 as the final year of action under the mercury NARAP framework and has developed a close-out report on its accomplishments.[10]

International perspective

In February 2009, the Governing Council of the United Nations Environment Programme mandated an Intergovernmental Negotiating Committee to prepare a Global Legally Binding Instrument on mercury (LBI). Negotiations are taking place between 2010 and 2013. The negotiations include discussion of a draft provision, among others, to reduce the supply of mercury and enhance the capacity for its environmentally sound storage or disposal.

The following actions will also influence the global supply of mercury:

[10] In publication as of this writing; the report will be available in 2012 on the CEC website.

- Regulation No. (EC) 1102/2008 of the European Parliament and the European Council on the banning of exports of metallic mercury and certain mercury compounds and mixtures and on the safe storage of metallic mercury. Issued on 22 October 2008.[11]
- *An Act to Prohibit the Sale, Distribution, Transfer, and Export of Elemental Mercury, and for Other Purposes*. Also known by its short title: The Mercury Export Ban Act of 2008. Enacted by the Senate and House of Representatives of the United States of America, in Congress. Approved on 14 October 2008.[12]

In view of these pending restrictions on exports in Europe and in the United States, Mexico may pursue development of a mercury production policy that considers the outcome of the UNEP LBI. The information presented in this report should provide information for better understanding the current and potential Mexican supply of mercury.

CHAPTER 2 PRIMARY MERCURY MINING IN MEXICO

This chapter will present a survey of past primary mercury production and offer insight on present and future mercury production based on information gathered on the mines in Mexico, including their location, size, production methods and production costs, and on the status of mercury mining in Mexico. The period of mining for which there are data stretches from 1840 to 1994, when formal mercury mining ceased, according to official information. Informal primary mercury production is addressed in **Chapter 5**.

2.1 Characteristics of Mercury Mines in Mexico

Natural deposits of minerals containing mercury are found in 21 Mexican states, particularly in the northwestern and central western regions of Mexico (see **Figure 2-1**). Among these deposits are found the following: metacinnabar, onofrite, cinnabar, amalgam, livingstonite, guadalcazarite (metacinnabar with four percent zinc), montroydite, terlinguaite, eglestonite, and native mercury, which occurs in minor amounts as small liquid blobs lodged atop the crevices or in pores of mercury ores (Secofi 1996).

[11] European Union, <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:304:0075:0079:EN:PDF>.

[12] See <http://www.gpo.gov/fdsys/pkg/PLAW-110publ414/pdf/PLAW-110publ414.pdf>.

Figure 2-1: Main Natural Deposits of Mercury in Mexico

Source: Derived from the Geological-mining Monograph of the states of Chihuahua, Durango, Zacatecas, San Luis Potosí, Querétaro, Hidalgo and Guerrero. The collection of these monographs is available online in English and Spanish at: <http://portal.sgm.gob.mx/publicaciones_sgm/Municipio_b.jsp?wparam=7#>.

Historically, the average mercury contents in Mexican mining ores have ranged from 0.33 to 10 percent (González-Reyna 1947). This percentage range, together with international mercury prices, has determined the quantity of Mexican production. When the amount of mercury in ore is 0.5 percent or less, its production is not economically viable unless the price of mercury is high.

The most important mercury reserves are located in the states of Zacatecas, Querétaro, Guerrero, San Luis Potosí, and Durango (see **Table 2-1**). Other producer states are Chihuahua, Guanajuato, Hidalgo, Jalisco, México Michoacán, Morelos, Nayarit, Oaxaca, Puebla, Sonora and Tlaxcala (González-Reyna 1947).

There is no complete historic registry of mercury mines and mines which produce mercury associated with other metals. However, the following sources provide a valuable reference point from which to begin a comprehensive survey of mining activities in Mexico.

Information on the status of each mercury mine and of mercury mines associated with other metals is available on the Mexican Secretariat of Economy (SE—*Secretaría de Economía*) website: <http://www.economia-dgm.gob.mx/>. Information on the status of mines is also available in

Physical Inventories of Mineral Resources, edited by the Mexican Geological Service (SGM—*Servicio Geológico Mexicano*), and in the Geological-mining Monographs, edited by the Mineral Resources Council (CRM—*Consejo de Recursos Minerales*), both available at <http://www.coremisgm.gob.mx/>.

An important source of information is the 1968 list compiled by the Commission for Mining Promotion (*Comisión de Fomento Minero* 1968), which provides the cumulative number of mining concessions and indicates the names of the towns where they are located.

An up-to-date resource is the 2010 list of 314 mines provided by the Secretariat of Economy (SE—*Secretaría de Economía* 2010). This compilation includes the status of each of these mines (most of them abandoned). For a numerical summary by state (see **Table 2-1**).[13]

Yet another source of information for some states is the collection of geologic and mining monographs published by the Mexican Geological Service (SGM)[14] during the 1990s. This source is especially valuable for providing the locations of the mines[15] (see maps in **Figures 2-1** and **2-2**).

Despite the fact that there is adequate information about the number of mercury mines and their locations, there are not enough data to compile a thorough inventory to estimate the potential national mercury reserves. Information is not available on each mine's history of exploration, its condition, or its productive capacity. As well, more research would need to be done to determine the physical and legal status of each mine, its operator, and its current condition.

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[13] The complete list is given in **Appendix 1: Lists of Mercury and Mercury-associated Metals Mines**.

[14] Available at: <http://portal.sgm.gob.mx/publicaciones_sgm/Municipio_b.jsp?wparam=7#>

[15] See the second list in **Appendix 1**.

Table 2-1: Inactive Mercury Mines in Mexico (Data confidence rating level: Medium)		
State	Number of mines recorded in 1968*	Number of mines recorded in 2010**
Aguascalientes	1	–
Coahuila	16	1
Chihuahua	58	1
Durango	214	46
Guanajuato	49	28
Guerrero	73	23
Hidalgo	4	2
Jalisco	20	–
México	19	5
Michoacán	10	1
Morelos	5	–
Nayarit	2	2
Nuevo León	6	–
Oaxaca	–	3
Puebla	1	–
Querétaro	322	75
San Luis Potosí	100	56
Sinaloa	1	–
Tamaulipas	4	–
Veracruz	2	–
Zacatecas	212	71
Total	1,119	314

Sources:
* *Comisión de Fomento Minero* 1968. Mercurio. *Departamento de Estudios Económicos*. November.
** *Secretaría de Economía* 2010.

2.2 Historic and Current Levels of Primary Mercury Production

The consumption of mercury throughout the Colonial and Postcolonial Periods was dedicated to silver production. During the Colonial Period, mercury was imported from Spain. Formal primary mercury production in Mexico began in the 1840s (the beginning of the Postcolonial Period).

There are different explanations as to why New Spain (Mexico) did not produce mercury during Colonial times, considering that mercury was an essential commodity for the silver refining carried on there and that demand for mercury in the silver mines of the West Indies was not met by Spain's Almaden mercury mine (the richest in the world), while significant mercury reserves existed in Mexico.

The Spanish Crown issued several royal documents (*Cedulas Reales*) in 1728 and 1730, ordering the closure of mercury mines (in Cuernavaca and Zacatecas) in order to have control over silver production. It is probable that Spain, aware that Mexican mines produced lower yields than in Peru and at the Spanish Almaden mines, preferred to promote its exploration elsewhere and not invest in exploration and better technology for mining mercury in New Spain (Lang 1969; Lang 1977; Segura 1941).

Mexico achieved independence from Spain in 1821 and this independence from foreign sources began to encourage the development of domestic mercury mining. By 1843, mercury was being mined formally in Mexico, when production started as a result of governmental decrees and initiatives such as tax elimination and rewards to miners who produced 2,000 quintals (92 metric tons) of mercury. This amount was produced for the first time in Guadalcazar, San Luis Potosí. However, by then the large-scale exploration of mercury deposits was of less interest to the miners, in contrast to the more lucrative mining and exploitation of silver and gold reserves (González-Reyna 1947).

Comprehensive data on early primary mercury production are not available. However, Segura (1941) compiled data from various authors and sources of information, on mercury production in individual mines for the period 1840–1895, and on national production for the period 1896–1921 (see **Table 2-2**).

Table 2-2: Historic Mercury Production, 1840–1921
(Data confidence rating level: Low for 1840-1895 data, Medium for 1896-1921)

	Year(s)	Mine	State	Metric tons
Individual mines	1840–1844	El Pedernal and El Durazno	San Luis Potosí	96
	1844–1895	Other Guadalcazar mines	San Luis Potosí	3,402
	1890	El Durazno	San Luis Potosí	31
	1843	Chiquilistlan	Jalisco	361
	1869–1895	Huitzuco Mines*	Guerrero	1,021
			Total (1840-1895)	4,911
National	1896–1921	All mines	Total (1896-1921)	4,374
Total historic mercury production (1840-1921)				**9,285**

Source: Derived from David Segura, 1941. El mercurio en México. *Secretaría de la Economía Nacional, Dirección General de Minas y Petroleo*. México DF. January.
Note: *The most important mine was La Cruz—as quoted in Hernández-Ortíz and McAllister 1945.

Mercury production during the peak period of 1896–1921 amounted to 4,374 metric tons, with an annual average of 168.2 metric tons. According to Segura, the peak year was 1898, with 353 metric tons, while only 33 metric tons were produced in 1917.

Segura reports that the Mexican participation in the international market in 1925 represented 1.08 percent (39 metric tons) of the global production, while Italy produced 50 percent (1,833 metric tons), Spain 35.2 percent (1,277 metric tons), and the US 8.6 percent, or 312 metric tons (Segura 1941).

The most important mines during 1840–1859 were located in San Luis Potosí: El Durazno, el Pedernal and other mines, in the District of Guadalcazar. The second-most important mercury-producing state during this period was Guerrero, particularly its mines in Huitzuco, whose minerals contained mercury content ranging from 1.5 to 12 percent; from 1886 to 1940, approximately 1,020 metric tons of mercury were produced at this mine (Segura 1941).

Official information on the primary mercury production during the period of 1922–1967 is shown in **Table 2-3**. Annual average mercury production during this 46-year period was 403 metric tons per year, with 1,117 and 1,030 metric tons produced during the peak years of 1942 and 1955, respectively.

Before 1942, Japan was the most important importer of Mexico's mercury; however, after the United States declared war against Japan that year, almost all mercury produced in Mexico was exported to the US (González-Reyna 1947). Mercury was used in the manufacture of explosives, which explains the increase in its demand during the Second World War.

According to the Commission for Mining Promotion (CFM—*Comisión de Fomento Minero*), an agreement between Mexico and the United States was concluded by which the Mexican mercury market was to be maintained in the Western Hemisphere: excess mercury not sold by Mexico would be bought by the US Government. In fact, when mercury demand fell in 1943, the US Government agreed to buy the excess mercury through the Metals Reserve Company, at the price of US$192 /flask (CFM 1968).

The other peak year was 1955, when Mexico produced 1,030 metric tons, and in the following years high mercury production was maintained. This was due to the high industrial demand internationally due to new uses of mercury in products such as mercury oxide batteries.

Table 2-3: National Primary Mercury Production, 1922–1967
(metric tons)
(Data confidence rating level: High)

Year	Production	Year	Production	Year	Production
1922	42	1938	294	1954	509
1923	45	1939	253	1955	1030
1924	37	1940	402	1956	673
1925	39	1941	798	1957	726
1926	45	1942	1117	1958	782
1927	81	1943	976	1959	566
1928	87	1944	795	1960	693
1929	83	1945	557	1961	629
1930	171	1946	402	1962	650
1931	251	1947	334	1963	593
1932	253	1948	165	1964	433
1933	154	1949	181	1965	662
1934	158	1950	117	1966	762
1935	216	1951	219	1967	497
1936	183	1952	301	Total	18,532
1937	170	1953	401		

Source: *Consejo de Recursos Naturales No Renovables* (CRNNR). 1967. *Sumario estadístico de la minería mexicana.* 1967. *Anuarios del Consejo de Recursos Minerales No. 2.* As quoted in *Comisión de Fomento Minero* 1968.

The reported production for the period 1968 to 1994 appears to drop somewhat, totaling approximately 7,738 tons (see **Table 2-4**), but this is due to an information gap in the official statistics on mercury production for the span from 1968 to 1984 (17 years), for which the only data found were for the State of Querétaro. The production in Querétaro during these years is estimated to be about 2,321 metric tons. The probable production in the other states cannot be included in **Table 2-4**, nor in the summary in **Table 2-5**, until after 1984, when information on the national level was obtained.

Nevertheless, in the 1968–1994 period, there were remarkable years (taking into account that only information from Querétaro was available): 1974, with 537 tons produced, and 1989 and 1990 were also important peak years, with 651 and 735 tons produced, respectively. The reason why demand increased so dramatically during these years is not known.

Table 2-4: National Primary Mercury Production, 1968–1994
(in metric tons)
(Data confidence rating level: Medium)

Year	Production	Year	Production	Year	Production
**1968	56	**1978	70	*1988	345
*1969	776	**1979	68	*1989	651
**1970	264	*1980	145	*1990	735
**1971	261	*1981	240	*1991	340
*1972	776	*1982	295	*1992	21
*1973	197	*1983	221	*1993	12
**1974	537	*1984	384	*1994	11
*1975	490	*1985	394		
**1976	70	*1986	185	Total	7,738
**1977	70	*1987	124		

Sources: **Anuarios Estadísticos de la Minería Mexicana*: 1969, 1972, 1973. Published by: *Consejo de Recursos Naturales No Renovables*. 1975 1980, 1981, 1982, 1983, 1987, 1988, 1989, 1990, 1991, 1992, 1993 and 1994. Published by *Consejo de Recursos Minerales.* Collection available at: <http://www.sgm.gob.mx/index.php?option=com_content&task=view&id=157&Itemid=44&seccion=Productos>.
**Information on Hg production for these years is provided only for Querétaro (CRM 1992c, *Monografía Geológico-Minera del Estado de Querétaro*, pp. 62 and 70).

According to information from the Mexican Council of Mineral Resources (CRM—*Consejo de Recursos Minerales*),[16] there has been no official primary mining of mercury reported in Mexico since 1994 (Inegi 1999). The operations stopped due to a decline in the price of mercury, resulting from a decrease in the demand for this metal.

It is not definitely known if any small-scale or informal mercury mining has occurred after 1994, because if it occurred it was not reported.

[16] In 2005, the Council of Mineral Resources (CRM—*Consejo de Recursos Minerales*) changed its name to the Mexican Geological Service (SGM—*Servicio Geológico Mexicano*).

Table 2-5: Summary of Historic Mercury Production, 1840–1994			
Period	Number of years	Mercury production (in metric tons)	Yearly average (in metric tons)
1840–1921	82	9,285	113
1922–1967	46	18,532	403
1968–1994	27	7,738	287
Total	155	35,555	229

Source: Derived from **Tables 2-2**, **2-3** and **2-4**.

Summary

According to historic and official information, during the 155-year period from 1840–1994, Mexico produced an estimated 35,555 metric tons of mercury.

2.3 Methods and Cost of Primary Production

Cinnabar ore, a source of mercury, has been commonly mined in Mexico using underground or open-pit methods, at depths of less than 100 meters—with some exceptions, such as at the Huitzuco mines in Guerrero State and the Mineral Mercurio mines in Zacatecas State, where operations were conducted at depths of more than 230 and 130 meters, respectively (González-Reyna 1947). After the ore is collected from the mines, it is crushed, screened and then heated in a retort or furnace. Mercury is obtained once the vapors generated in the retort or furnace are cooled.

Another method, used for mercury production in Huitzuco, Guerrero, and in Sain Alto, Zacatecas, entailed flotation plants in which the concentrated product is burned to obtain the metal (González-Reyna 1947).

Yields from Mexican mercury ores range from 0.33 to more than 10 percent mercury content. The higher the mercury content of the ore, the lower the cost of production. During the 1940s to 1960s, when market demand and prices for mercury were high, significant investments were made in costly machinery for mining and in resources for exploration. But from the 1970s to the early 1990s, mercury mining in Mexico was only considered a secondary activity, dependent on high international market prices to make the activity profitable (see production data for this period in **Table 2-4**).

From the mid-1990s to the present, it has been possible to produce mercury at relatively lower costs than in the past through informal (not officially reported) mercury mining, because of the following factors:

- The abandonment of mines by their operators allows other individuals (informal miners) to remove sacks of ore to be processed (by grinding and distilling) at off-site locations, such as their backyards. A family or an individual can produce around 3 to 10 kilograms of mercury per week.
- Ore extraction from mines has generally been done manually, and the ovens or retorts and the cooling systems for mercury distillation are usually economically viable installations capable of processing several tons of ore per week, depending on their size (CFM 1968).
- Costs for transporting the ore from the mine to the milling and distillation area include the fuel and vehicle depreciation; however, these costs can be reduced by using mules or horses.
- Miners can generally visually assess the mercury content in mineral veins. For instance, mercury miners at Huancavelica (Peru) were able to determine the grade of the ore from the color intensity of the cinnabar: "…*sangre seca, ley más alta* [if ore is the color of dried blood, the grade is higher]" (as quoted in Brooks et al. 2006).
- In the case of open-pit mines, production costs may be lower than those of underground mining as it is not necessary to invest in tunnel (re)construction or in machinery for excavating.

For the precise costs of informal mercury mining and the associated production processes, it is difficult to determine a consistent rate per kilogram.[17] However, other important elements to consider are as follows:

- Due to dangerous mining conditions in some abandoned or closed underground mines, reconstruction activities demanding larger economic resources may be needed, which will probably have repercussions on mining costs, or else the informal miners would face riskier labor conditions.
- Dynamite is a key element for extracting mercury ore on a medium or large scale. It is extremely difficult to obtain a supply of dynamite due to federal restrictions, as explosives are strictly controlled by the Mexican Army. For this reason, ore extraction from mines is performed by traditional methods.
- Manpower costs (miners' salaries) for mining and handling the ores.
- The electric energy needed to operate the mill that grinds the ores.

[17] In order to estimate approximate mercury production costs, other minerals whose mining processes are similar can be used as a benchmark.

- The gas to operate the oven or retort (in some cases other types of fuels are used, such wastes containing energy value, e.g., used tires).
- When the mercury producer is the legal holder of the concession, some fees and taxes must be added to production costs (this element has to be assessed as it is not known for sure if there are miners formally producing mercury).

No information is available on the volume of informal production in Mexico after 1994. However, a discussion of the production during the years 2007–2009 is presented in **Chapter 5**.

A picture of mercury production in Mexico would not be possible without understanding how the price of mercury fluctuates, depending on supply and demand. According to information compiled on a field trip to San Joaquín, Querétaro, in May 2010, the local mercury retailer was selling a kilogram at 250 Mexican pesos (US$20). In Zacatecas, one kilogram of mercury in August 2010 was at 260 Mexican pesos (US$20.80).[18] In both cases the mercury produced was mined (primary) mercury. By February 2011, prices of mercury had risen to 650 Mexican pesos (US$52) for one kilo mined in Zacatecas or Querétaro, according to information available on the Internet.[19]

As well, the future of formal mining (performed by miners who have the legal right to work a mine) will depend on the international context and future restrictions on mercury trade.

2.4 Estimation of the Volume of Primary Mine Reserves in Mexico

An inventory of approximate mercury reserves throughout Mexico does not exist. The poor record-keeping may be explained in part by the lack of importance credited to mercury mining because of the greater interest in other metals, such as gold, silver and copper, and because the demand for mercury has fluctuated a great deal (especially over the last 30 years), often resulting in prices too low to warrant expensive exploration investments that could be more profitably applied to producing those other metals.

While known mercury reserves have not been quantified to date, studies performed by the CRM and the SGM give some information on mercury quantification from some mines (see **Table 2-6**). These sources show that the richest mercury deposits in Mexico are in locations in central states, like Nuevo Mercurio in Zacatecas, Sierra Gorda in Querétaro, and the High Plateau in San Luis Potosí (Rodríguez-Galeotti 2006).

According to an estimate by Rodríguez-Galeotti, potential reserves of primary mercury exceed 500,000 metric tons and are located mainly in the aforementioned states. He uses information

[18] Field visit findings by author.

[19] This information, in the form of commercial advertising on the Internet, was accessed at: <http://queretarocity.olx.com.mx/venta-de-mercurio-iid-164477046> on 27 February 2011.

generated by the Mexican Geological Service (SGM) to conclude that out of a total of 4,705 registered mineral-producing mines, 83 former mercury producing mines have favorable geological conditions for the resumption of productive and economically advantageous exploitation. These mines are located in six states. Of these 83, 66 produced only mercury and 17 produced mercury and other minerals (Rodríguez-Galeotti 2006). Most of these mines are located in the following areas (see map, **Figure 2-2**):

- Sierra Gorda Region (San Joaquín, Peñamiller, Pinal de Amoles and Palo Verde zones), in Querétaro;
- Northern High Plateau (Real de Catorce and Guadalcazar zones), in San Luis Potosí; and
- San Felipe Nuevo Mercurio (and other zones), in Zacatecas.

Rodríguez-Galeotti believes that the State of Querétaro best meets the social, political, and basic infrastructure conditions for the investment of economic and material resources in developing mining of mercury and of other minerals, such as gold, silver, lead, antimony and zinc, especially at a small or medium scale (Rodríguez-Galeotti 2006).

According to official information, there is a potential reserve of 42,000 metric tons of mercury in the states of Zacatecas, Querétaro, and México (as shown in **Table 2-6**). However, in judging the reliability of this amount, the following factors should be taken into consideration:

- Insufficient records for mercury mining in Mexico have been kept;
- It is not known if the full amount is extractable or economically feasible to extract; and
- There is a significant number of mines noted that have unknown potential to produce mercury (in a formal or an informal manner) (*Secretaría de Economía* 2010).

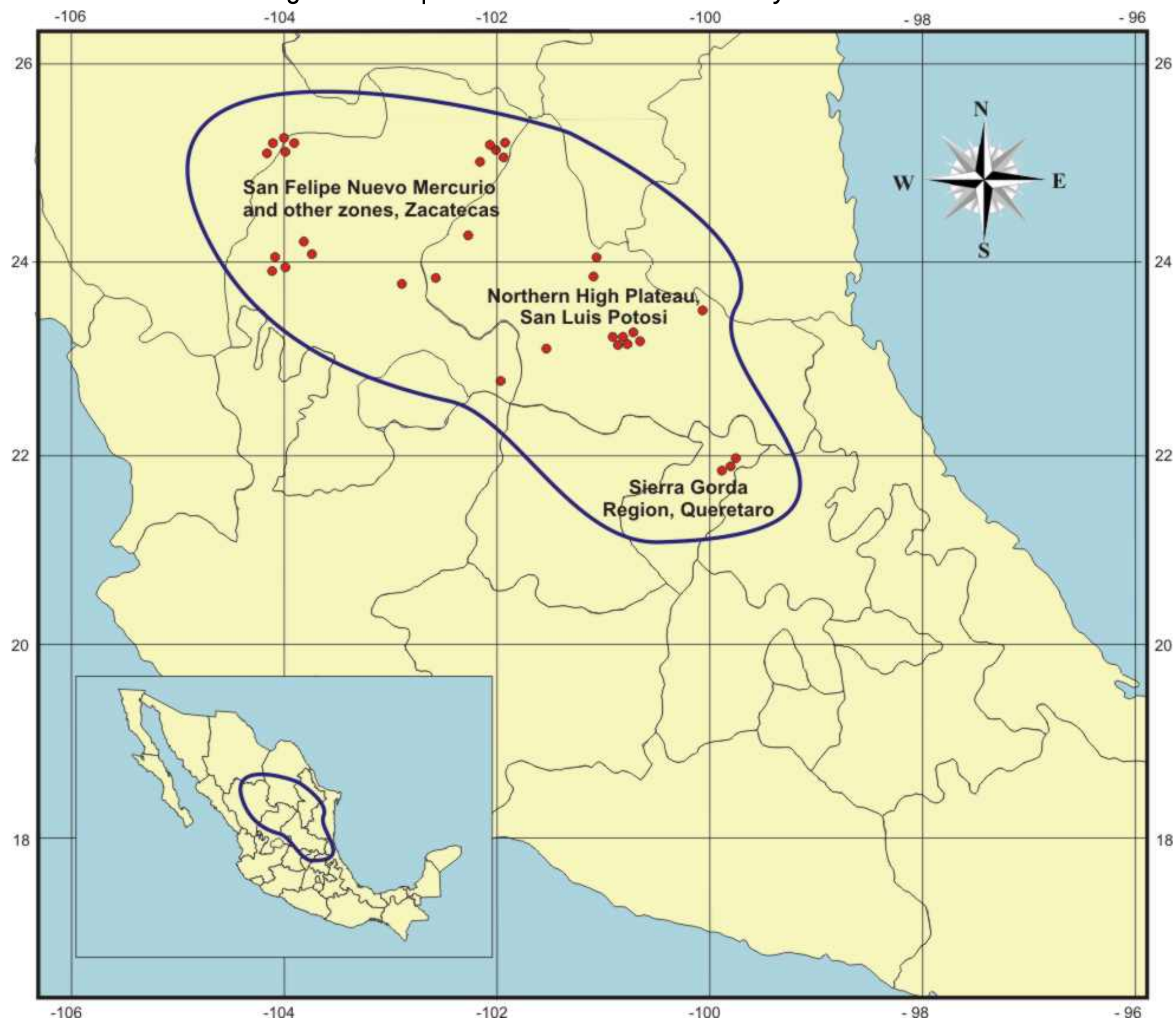
For the above reasons and because the data that gave rise to the reserve figure of 42,000 tons are not current, this report can give it a confidence rating of only “Medium.” A more accurate assessment for the prospective mercury reserve can only be based on a physical inventory of Mexican mines.

Table 2-6: Probable Reserves of Primary Mercury in the States of México, Querétaro and Zacatecas (Data confidence rating level: Medium)		
Information source	Mine's name/location	Potential reserves (tons)
SGM 2006b	Panicuda (Estado de México)	13,050
SGM 2007b	La Guadalupana (Querétaro)	2,250
	La Soledad (Querétaro)	9,500
CRM 1991	Nuevo Mercurio (Zacatecas)	*17,200
Total probable mercury reserves		42,000

Note: The official literature reports four potentially productive mines, although only one, the Nuevo Mecurio mine, has been explored in CRM 1991. *Monografía geológico-minera del Estado de Zacatecas*. Serie Monografías Geológico Mineras. *Secretaría de Energía, Minas e Industria Paraestatal*. México.

* The *Comisión de Fomento Minero* estimated the possible reserves of mercury ores as 860,000 metric tons in 1980 (see CRM 1991, p. 70). The estimated amount of mercury is calculated using a mercury content value of 2 percent in these ores.

Figure 2-2: Map of Potential Productive Mercury Mines in Mexico



Source: Derived from the Geological-Mining Monographs of the states of Zacatecas, San Luis Potosí and Querétaro. The collection of these monographs is available online in English and Spanish at: <http://portal.sgm.gob.mx/publicaciones_sgm/Municipio_b.jsp?wparam=7#>.

2.5 Domestic Regulations and Multilateral Environmental Agreements pertaining to Primary Mine Production

Domestic regulations governing primary mine production

Although no primary production of mercury has been officially reported since 1994, the mining of this metal is not banned in Mexico. According to the Mexican Mining Law, mining concessions confer rights with respect to all mineral substances covered and provided by Article 4 of the Law. Pursuant to Article 4, the following are considered minerals or substances that constitute deposits different from those composing the ground when found in veins, mantles, masses or deposits:

> Minerals or substances from which the following are extracted: antimony, arsenic, barium, beryl, bismuth, boron, bromine, cadmium, cesium, cobalt, copper, chrome, scandium, tin, strontium, fluorine, phosphorus, gallium, germanium, hafnium, iron, indium, iridium, yttrium, lanthanum, lithium, magnesium, manganese, *mercury*, molybdenum, niobium, nickel, gold, osmium, palladium, silver, platinum, lead, potassium, rhenium, rhodium, rubidium, ruthenium, selenium, sodium, thallium, tantalum, tellurium, titanium, tungsten, vanadium, zinc, zirconium and iodine (*Ley Minera* 2006).

Furthermore:

> The Mexican Mining Law, which rules mining activities, is set forth in Article 27 of the Mexican Constitution, which grants the possession of almost all minerals to the Mexican Nation. The right to exploit those minerals is given to private parties through concessions issued by the Federal Executive Branch, as may be established by law. Such concessions may be issued to Mexican individuals, to companies incorporated under the Mexican law, and to foreign individuals.
>
> Article 27…holds that the lands and waters within the national territory originally belong to the Mexican United States, which has the right to transfer title to private persons in order to constitute private property. Article 27 also provides that the Nation has direct ownership of mineral deposits within the national territory, which cannot be transferred. The use and exploitation of such national resources by private parties is only permitted by means of concessions granted by the Federal Executive Branch, through its corresponding government agencies, pursuant to applicable laws and regulations. Such laws and regulations must be complied with in the exploitation of mineral deposits, as of their effective dates, even with respect to previous mining concessions. The corresponding government agencies may cancel concessions in the case of failure to comply with applicable laws and regulations as well as of creating national mining reserves. The creation of national mining reserves will be over the ore deposits required to satisfy the nation's future needs. Once incorporated into national mining reserves, the ore deposits shall not be subject to mining concessions or allotments, unless such zones are cancelled from the mining reserves through a decree issued by the Federal Executive to enable the Ministry of Economy to declare the zone as free land and subject to be granted under a mining concession, or call for a bid to grant one or more mining concessions over such ore deposits.
>
> Article 73, Section X of the Constitution gives the federal Congress the right to enact laws on mining, confirming the federal nature of this activity.
>
> (Mining Law, Article 17, see Sánchez-Mejorada 2000).

Mining concessions include the rights to exploration and exploitation and can be in force for a 50-year renewable term.[20] As previously stated, mining of mercury is allowed under Mexican law;

[20] Mining concessions must be kept current or risk cancellation. This involves the performance of assessment work, payment of mining taxes, and the compliance with environmental laws. A report must be filed in May of each year stating the work performed during the previous year, taxes must be paid in January and July of each year, and

there are no legal impediments to the production of mercury. However, due to the reduced demand for mercury, some mines have been abandoned or their operators have lost their concessions, and formal mercury mining has ceased.

Other general regulatory instruments on environmental issues related to mercury production are included in **Section 3.7**.

Multilateral environmental agreements pertaining to primary mine production

The Governing Council of the United Nations Environment Programme (UNEP) made a commitment to curb the primary mining of mercury through its decision 24/3 of 9 February 2007, which concludes that further long-term international action is required to address the challenges of the adverse effects of mercury, and in consequence:

- 19. "Commits to increased efforts to address the global challenges to reduce risks from releases of mercury, taking into account the following priorities: [...] d) To reduce the global mercury supply, including considering curbing primary mining and taking into account a hierarchy of sources..." [and]
- 20. "Urges Governments to gather information on means to reduce risk that may be caused by the supply of mercury, considering: a) Reduced reliance on primary mercury mining in favor of environmentally preferable sources of mercury such as recycled mercury..." (UNEP 2007). For further information, see <http://www.chem.unep.ch/mercury/Decision%2024-3.pdf>.

Officially, the last remaining primary mercury mine known to export mercury globally is a mine in Kyrgyzstan operated by the Kyrgystan government. The mine is located in Khaidarkan in the Ferghana Valley and is estimated to produce 300–350 tons of mercury per annum. An action plan to help Kyrgyzstan move away from primary mercury mining has been recognized as a priority by the international community. The National Action Plan on Production of Primary Mercury and Its Impact on the Environment in the Kyrgyz Republic was initiated with the help of funds from the governments of Switzerland and the United States of America in late 2007 and implemented jointly by UNEP and the United National Institute for Training and Research. For further information, see:
<http://www.chem.unep.ch/mercury/Sector-Specific-Information/supply_and_storage.htm>.

Finally, UNEP has proposed and is holding discussions on a Global Legally Binding Instrument on Mercury (LBI), which would prohibit new operations or expansion of mercury mining and would phase out existing mining operations (UNEP 2010). It will be important to consider the

environmental laws require the filing and approval of an environmental impact statement for all exploitation work. See: (Sánchez-Mejorada, Velasco and Ribé 2001) at <http://www.smvr.com.mx/art3e.htm>.

national impact of the LBI on the sectors and stakeholders involved, considering that Mexico is both a member state of UNEP and also a potential mercury producer, exporter, and importer.

2.6 Conditions for Resumption of Primary Production

The conditions that could influence the resumption of primary mercury production exist at the local, national and international levels.

Among the local conditions are:

- The existence of mercury mines meeting the physical conditions for them to be reopened with a safe working environment (such as having nonhazardous accessibility to the mine) without financial investment;
- The value of the mercury content present in the mine;
- The type of mine (open-pit or underground)—open-pit mining facilitates ore extraction and lowers operating costs;
- The legal status of the mine—operators of mines with legal concessions may allow others to produce the mercury instead of exploiting the mines themselves;
- The local conditions of poverty or unemployment, which force individuals to enter into mercury-mining activities;
- The existence of an efficient distribution chain (purchase-sales of mercury) at both local and national levels; and, crucially,
- The price of mercury on the national and international markets—high prices are an incentive to mercury mining.

Factors at the national level include the following:

- Informal mercury production will occur and incrementally increase, due to the absence of an adequate legal framework that focuses on regulating and banning mercury mining. The legal framework needed should also take into consideration that in the long run the final confinement of mercury surpluses and residues will be costly.
- Formal primary mercury production and export can occur until Mexico can evaluate the sectors involved (formal and informal producers, national consumers, international consumers, retailers, exporters, etc.), using the framework of the future UNEP Global Legally Binding Instrument on Mercury.

The international conditions leading to the potential reopening of mercury mines in Mexico will depend on the demand and the price of mercury in relation to the costs of extraction. These factors are affected by:

- Mercury demand from gold-producing countries with artisanal gold mines, since increases in demand for mercury parallel increases in gold prices and demand;

- Laws of the United States and Europe that establish mercury export bans, which could motivate a growing, informal market demand from the few mercury-producing countries such as Mexico;
- Anticipation of implementation of the UNEP Global Legally Binding Instrument on Mercury; and
- Poverty and unemployment in developing countries, which could encourage the resumption of mercury production.

CHAPTER 3 SECONDARY MERCURY SUPPLY IN MEXICO

This chapter is dedicated to estimating the reserves of mercury that can be reprocessed from existing tailings from the Colonial and Postcolonial Periods (secondary mercury) through lixiviation, whereby silver or gold are also obtained. In fact, the main objective of lixiviation has been to recover these precious metals; mercury is a by-product of this process and has represented an extra income for lixiviation facilities. This activity has been conducted since the early 1890s.

A parallel study to that of this report was conducted in order to quantify secondary mercury reserves, based on sampling and analytical methods, in the area surrounding Zacatecas City. The objective was to assess potential reserves in this district (Gómez-Santos and Juárez-Damián, 2010.)

From historical information, an initial inventory of sites where mercury-silver amounts can be found was compiled.[21] An estimate was made of potential mercury quantities in the soil of the areas surrounding where amalgamation processes were used in Mexico during the Colonial and Postcolonial Periods (see **Table 3-7**). The Mexican states with districts where significant silver-mining activities took place are Zacatecas, San Luis Potosí, Guanajuato, and Hidalgo. A brief description of the districts is given in order to position possible mercury reserves.

3.1 Characteristics and Locations of Secondary Mercury Sources from Historic Silver-mining Wastes

Nowadays, secondary mercury-silver sources are generally located near the mines where the silver ores were historically extracted. In older times, these ores were transported to certain farms (*haciendas de patio*) whose yards were used to perform mercury-silver/gold amalgamation activities; and subsequently the recovered amalgam underwent separation out of the silver or gold by a distillation procedure during which the mercury content was evaporated. These *haciendas de patio*, also called *haciendas de beneficio*, gave rise to settlements called *reales de minas* (mining districts), where several of these production units were to be found.

Since Colonial times, the mining districts also had prosperous agriculture and commercial activities, supplying rice to populated areas that later became important cities such as Zacatecas, Guanajuato, San Luis Potosí and Pachuca. Mining activities also propelled mechanisms of progress and political-economical control.

[21] This list can be found in **Appendix 2: Initial List and Description of Mercury/Silver Secondary Reservoirs**.

The amalgamation method employed at the *haciendas de patio* to separate silver and gold from base metals through the use of mercury was discovered by Bartolomé de Medina and became known as “the patio process.” It was initially used at the Hacienda la Purísima in Pachuca, in 1555 (Lang 1977) or in 1556 (according to Humboldt 1822, as quoted in Ramos et al. 2004). The process was soon adopted in Zacatecas and in San Luis Potosí, in 1572 (Hausberger 2009). Mercury, an integral part of the amalgamation process, was left behind in the tailings, along with particles of the silver or gold. The use of mercury in silver production started to decrease when the cyanide method began to supplant it, from the 1920s to the 1950s.

Because the patio process was such an inefficient method of extraction, large quantities of mercury were released to the atmosphere and, consequently, settled into the sediments of aquatic systems at distances far from the sites where the mercury was refined. As well, great amounts of wastes containing silver and mercury were released to local soils, resulting in many contaminated sites that still remain today in the areas surrounding the old *haciendas de patio*. Some of these waste sites contain sufficient quantities of silver and mercury to be of significant value today.

The silver production process during the Colonial and Postcolonial Periods consisted of three phases:

1. *Ore extraction* from mines (mining)—Ores with high silver content were separated from low-content ores. The low-content ores were considered wastes (*terreros*) and were disposed of around the *haciendas de patio* or near the mines without being treated with mercury. The high-content ores went through the amalgamation process.
2. *Amalgamation*—In the amalgamation method known as the patio process, silver ore was finely crushed (in order to obtain an adequate amalgamation), and then mixed with copper sulfate (magistral), salt (NaCl) and mercury. The process was continued with tethered mules, made to walk around on the ground on which the powdered ore mixture had been spread. The pressure of their feet crushed the powder into even smaller particles. Eventually, silver-mercury amalgamated particles were obtained and were separated from the remaining ore. The particles were washed to separate out even more solid mineral waste. Most of the rejected matter (the tailings) was disposed of as solid waste on the land near the sites where this process took place; the slurry was often released to the nearest watercourse. This process generally took around five to 10 days, after which the amalgamated particles were sent to refining.
3. *Refining*—The amalgam particles were placed in a cupellation furnace and distilled. The smelting process in the furnace produced pure refined silver and liberated mercury vapor to the air. The smelting also required a number of essential raw materials such as charcoal or wood.

Other methods of silver production besides the patio process were also used (see **Table 3-1**).

Table 3-1: Alternative Methods to the Patio Process	
Method	Description
Smelting	Also known as "silver fire" (*plata de fuego*), smelting coexisted with the amalgamation process, in the early days of silver mining. This method was most appropriate when silver content in natural deposits was high. As this method of smelting did not use mercury, it was the preferred choice when mercury was scarce. Another reason for choosing it was to evade taxes, since the distribution of mercury was controlled by the state mercury monopoly, which thus ensured that the taxes on silver production would be applied to the mines where the mercury was delivered (Lang 1977).
Hot amalgamation	This method, based on the principle of mercury amalgamation, is performed on boards heated by burning wood underneath. This method was used in cold regions (Lang 1977).
Amalgamation in barrels	This process, in which mercury amalgamation is performed inside heated barrels, was introduced by the English companies that settled in the Pachuca–Real del Monte mining district at the end of the nineteenth century (Lang 1977).
Cyanidation	This method was implemented initially in Pachuca by an English company at the beginning of the twentieth century. It differs from amalgamation in that cyanide is used instead of mercury. Nowadays it is the method most used for silver and gold production.

Hot amalgamation and amalgamation in barrels used mercury; these methods also generated tailings. Silver smelting caused vast areas of deforestation due to high consumption of wood. The other methods also consumed wood, but in lesser amounts.

Location of contemporary secondary mercury sources in Mexico can be deduced from historic writings that refer to the places where silver mining and amalgamating activities were carried on. However, at present there is not enough information available about most of these sites to give a full inventory that includes exact locations of the tailings now and whether conditions are right for reprocessing these tailings. It is for this purpose that an initial list of probable mercury reservoirs was compiled in the preparation of this report.[22]

In addition, where contaminated sites are known, it is necessary to derive information on the levels of mercury, silver or gold contained in the tailings. Another reason for difficulty in developing a precise inventory of these silver-mercury-rich tailings is that many were transported to other sites

[22] This list can be found in **Appendix 2: Initial List and Description of Mercury/Silver Secondary Reservoirs**.

during seasonal flash floods over the course of the past 400 years. In some cases the tailings have been moved or spread many kilometers from the patios where they were originally discarded or where the amalgamation process took place. In **Section 3.3**, the areas considered important mercury reservoirs are described.

Location and estimation of secondary mercury sources can be made based on research by Lang, who compiled information on the amounts of mercury used for silver production in the six most important silver production regions. It is possible to rank the places according to these known quantities of mercury used in the amalgamation process. The six regions (see **Table 3-2**) are located in seven states: Zacatecas, Estado de México, San Luis Potosí, Durango, Jalisco, Guanajuato and Hidalgo (Lang 1977).

Table 3-2: Quantities of Mercury Provided by Spain, 1630–1709, to Six Silver-producing Regions of Mexico

(in quintals)

(Data confidence rating level: Medium)

Period	Zacatecas	México	Durango	Guadalajara	Guanajuato	Pachuca	Total
1630–1634	8,000	3,310	4,210	525	725	1,800	18,570
1635–1639	3,725	1,595	1,060	1,170	635	935	9,120
1640–1644	6,300	*2,190	*1,390	*1,385	*1,640	*1,700	14,605
1645–1649	5,100	1,800	1,250	1,600	1,230	1,250	12,230
1650–1654	3,600	*2,190	1,450	*1,385	*1,640	*1,700	11,965
1655–1659	2,800	2,565	*1,390	*1,385	*1,640	*1,700	11,480
1660–1664	1,640	1,390	1,075	1,190	760	1,065	7,120
1665–1669	2,050	1,215	1,340	1,800	1,880	1,325	9,610
1670–1674	2,850	1,220	1,850	2,450	1,835	2,160	12,365
1675–1679	2,690	1,575	700	650	2,070	1,725	9,410
1680–1684	4,910	1,785	1,200	880	2,100	1,255	12,130
1685–1689	5,460	3,245	1,375	2,475	1,970	2,450	16,975
1690–1694	4,685	3,455	470	1,550	1,120	1,800	13,080
1695–1699	2,455	2,185	490	900	1,260	1,540	8,830
1700–1704	5,525	3,250	1,645	1755	2,660	2,795	17,630
1705–1709	4,250	2,035	1,330	1,035	3,100	2,050	13,800
Total quintals**	66,040	35,005	22,225	22,135	26,265	27,250	198,920
Total tons	3,020	1,648	1,006	1,006	1,189	1,281	9,150
Percentage	33	18	11	11	13	14	100

Sources: Derived from Mervyn F. Lang, 1977. *El monopolio estatal del mercurio en el México Colonial (1550–1710). Fondo de Cultura Económica*. Mexico, p. 362. Original data were collected from the *Archivo Historico de Hacienda* (Historic Archive, in the Treasury Ministry); and from the *Archivos de la Tesoreria de Zacatecas* (Archives of the Zacatecas Treasury Office), University of Michigan, Ann Arbor, MI.
Notes: *The author reports no information for these periods; they were calculated based on the average of this 80-year span.
**One quintal equals 46 kilograms.

Although Lang's categorization is based on information covering 80 years of the Colonial Period, it can be taken to represent the trends in silver production for more than the 250 years of that era, and probably the trends observed after the Colonial Period as well. **Table 3-2** reveals that Zacatecas was the most important mercury consumer, mining district, and silver producer. From this we can conclude that it is also the location of the principal secondary mercury reserves.

3.2 Estimation of Potential Volume of Mercury Reserves from Tailings in Mexico

An approximate quantification of mercury (and silver) remaining in tailing deposits generated during precious metals production over a 350-year period (1545 to 1900) in Mexico can be derived in two possible ways:

1) Using information on the silver produced with the amalgamation method and
2) Using data on mercury production in Mexico and imports from Spain (mainly) and other countries.

Estimation of mercury reserves based on silver production data

The first method for estimating the mercury reserves in Mexico is based on the amount of mercury needed using the amalgamation process to produce silver. **Table 3-3** presents historical statistics on silver production from 1521 to 1954, by the various processes used.

From the amounts of silver produced in various regions compared to the amounts of mercury consumed in them, in the early seventeenth century when production methods involved mercury, it is possible to derive the proportion of mercury to silver: it took an average of 2.1 kilograms of mercury to produce 1 kilogram of silver (see **Table 3-4**). This proportion can be assumed to have stayed constant through the Colonial and Postcolonial Periods as well because of the continued employment of the amalgamation method.

Table 3-3: Silver Production in the Colonial and Postcolonial Periods
(in metric tons)
(Data confidence rating level: Low for the 1521–1820 period, Medium for the 1821–1954 period)

Period	Silver production by smelting*	Silver production by amalgamation	Silver production by cyanidation	Total silver production
1521–1544	82	Not used	Not used	82
1545–1700	3,067*	9,201	Not used	12,268
1701–1820	6,172*	34,974	Not used	41,146
Total, Colonial Period	9,321	44,175		53,496
1821–1900	Not used	49,124**	Not used	49,124
1901–1954	Not used	Not used	166,982	166,982
Total, Colonial and Postcolonial Periods	9,321	93,299	166,982	269,602

Source: Data for silver production are from G. González-Reyna, 1956. *Riqueza minera y yacimientos minerales de México*. Third edition. *Congreso Geologico Internacional, XX Sesion, México*, 1956, pp. 96–97.
Notes: *According to Sánchez-Santiró (2002), the smelting method represented around 15 percent of silver production in districts such as Guanajuato, Guadalajara, Bolaños, México and Zacatecas; whereas in Durango, Pachuca, Sombrerete and Zimapán, it represented around 40 percent. However, Pérez Herrero, (as quoted in Sánchez-Santiró 2002, p. 128) estimates that it could be higher than 40 percent, at least in districts where mines had rich veins.
To determine how much silver was produced by the smelting method during the last two time spans in the Colonial Period, considering that rich-vein mines (where the smelting method was implemented on a large scale) were exhausted earlier than mines with lesser silver content, where the amalgamation method was more appropriate, an estimation should be made by assuming modest percentages, as follows: 25 percent of 12,268 = 3,067 tons of silver produced by smelting during the period of 1545–1700; and 15 percent of 41,146 = 6,172 tons of silver produced by the same method from 1701 to 1820.
**The use of the patio process continued from 1821 to 1890 in Zacatecas (González-Reyna 1947). The new cyanidation method was implemented by the end of the nineteenth century in Pachuca, initially in big mines. However, other amalgamation methods, such as amalgamation in barrels, coexisted with cyanidation until 1900–1920. Therefore, it is reasonable to believe that silver production using mercury still continued from 1821 to 1900; the quantity of silver produced during this period is estimated to be 49,124 tons.

Table 3-4: Proportion of Mercury Used in Silver Production, in the Early Seventeenth Century
(Data confidence rating level: Low)

Mining district	Marks* of silver produced per quintal** of mercury	Grams* of silver produced per kilogram** of mercury (230 grams x #marks/46 kg)	Kilograms of mercury used per kilogram of silver produced
Chiautla	80	400	2.5
Chichicapa	90	450	2.2
Cerralbo	100	500	2.0
Comancha	100	500	2.0
Durango	125	625	1.6
Guadalajara	125	625	1.6
Guanajuato	125	625	1.6
Pachuca	100	500	2.0
Sichu	100	500	2.0
Sultepec	80	400	2.5
Taxco	90	450	2.2
Temascaltepec	85	425	2.4
Tetela	90	450	2.2
Tlapujahua	80	400	2.5
Tonalá	100	500	2.0
Zacatecas	100	500	2.0
Zacualpan	80	400	2.5
Average			2.1

Source: Derived from Mervyn F. Lang, 1977. *El monopolio estatal del mercurio en el México Colonial (1550–1710). Fondo de Cultura Económica*. Mexico. p. 214. Original data were collected from the *Archivo General de Indias* (General Archive of the Indies), Seville, Spain.
Notes: *Mark = 8 ounces = 230 grams. **Quintal = 100 pounds (Castellan) = 46 kg.

A somewhat different estimate was derived by another researcher: 1.2–2.2 kilograms of mercury to produce one kilogram of silver (Eissler 1891, as quoted in Ogura et al. 2003).

According to the figures in **Table 3-3**, it is estimated that the silver produced by using the amalgamation method from 1555 to1820 was 44,175 metric tons. Multiplying that by 2.1 kg of mercury gives an estimate of 92,768 metric tons of mercury used during the Colonial Period.

This amount is comparable to other authors' estimates of the amount of mercury utilized in silver production in Spanish America from 1570 to 1820, which range from:

- 100,000 tons (Johnson & Whittle 1999, quoted in Ramos et al. 2004, p. 279); to
- 104,000 tons (González 1944, p. 22); to
- 117,000 tons (Camargo 2002, p. 53); to
- 126,000 tons (Niriagu 1994, quoted in Ramos et al. 2004, p. 279).

It is important to note that these amounts include the consumption in all Spanish colonies in Latin and South America, among which New Spain (Mexico) was the main mercury consumer. They also take into account Peru which, with its large Huancavelica mercury mine, was self-sufficient and also provided mercury to Bolivia (Camargo 2002).

From these 92,768 tons of mercury used in Mexico, it is necessary to determine the proportion released to the atmosphere and the proportion that might remain in tailings.

Camargo (2002) estimates that as much as 75 percent of this mercury was released to the atmosphere during the production process. Thus, we might conclude that perhaps 25 percent remains in tailings.

Another study, on silver and gold production using the amalgamation method in mines in the state of Montana, during 1850–1900, reports that 60 percent of the mercury used was released to the atmosphere, while 40 percent was lost to soil and water through mine tailings and surface runoff (Ganesan 2000).

A third study calculates that the quantities of silver produced in Guanajuato liberated approximately 47.5 percent in used mercury to soils and river sediments; the remaining percentage was released to the atmosphere (Ramos-Arroyo et al. 2004).

From the values quoted above, the authors' approximate percentages and an overall average percentage of mercury released in tailings to soil and/or in sediments in water bodies would be as follows:

- Camargo: ~25%
- Ganesan: ~40%
- Ramos: ~47.5%

Average: 37.5%

This average (37.5 percent) can be considered a rough estimate of the mercury discarded in tailings, soils, and the sediments of water bodies, and about 62.5 percent lost as releases to air.

Therefore, for the Colonial Period (1556–1820), during which approximately 92,768 metric tons of mercury were consumed, 37.5 percent of this can be assumed to have been released to tailings, etc., equaling some 34,788 metric tons of mercury.

Applying the same estimate for the Postcolonial Period (1821–1900), it can be calculated that approximately 38,685 tons of mercury were dispersed in tailings in the territory of Mexico where the patio amalgamation process was used (see **Table 3-5**).

Table 3-5: Summary of Silver Production and Mercury Consumption/Releases, 1556–1900 (in metric tons)

(Data confidence rating level: Low for the 1521–1820 period, Medium for the 1821–1900 period)

Period	Silver production	Mercury consumption (2.1 kg per 1 kg silver)	Mercury releases to atmosphere (62.5%)	Mercury releases to soil (tailings) (37.5%)
Colonial (1556–1820)	44,175	92,768	57,980	34,788
Postcolonial (1821–1900)	49,124	103,160	64,475	38,685
Total	93,299	195,928	122,455	73,473

Source: Derived from **Tables 3-3** and **3-4**.

Summary

Based on historical information, it is estimated that around 73,473 tons of mercury were released to soils and water body sediments from 1556 to 1900 as a consequence of using the amalgamation method to produce silver. However, this quantity does not necessarily correspond to the potential volume of secondary mercury reserves, considering that:

- In an undetermined number of cases, tailings are covered by urban areas; and
- Due to the geographical and physical location of some tailings, it is not possible to carry out the recycling process.
- Part of the total amount released to soils could instead have been emitted to air or leached into water and transported outside the region.

Estimation of mercury reserves based on statistics of mercury imports and production

The other way to calculate the probable reserves of secondary mercury in Colonial and Postcolonial era tailings (method 2) is to use the amounts of imported mercury during the Colonial Period (1556–1820) and imported or produced mercury in Mexico during the Postcolonial Period (1821–1900).

In a review of studies of the historical literature, many of the authors were found to have based their estimates on Lang, Chaunu, Bakewell and Garner, who in turn based their estimates on findings from original documents in collections such as the *Archivo General de Indias* (General Archive of the Indies), in Seville, Spain, and the Colonial records compiled in Latin American countries.

Most of the articles and books consulted generally present information on Spanish exports of mercury to New Spain (Mexico) for only some spans of time during the period from 1556 to 1805 (see **Table 3-6**).

Table 3-6: Available Data on Mercury Imports to New Spain, 1556–1805
(Data confidence rating level: Low)

Information source	Mercury origin	Period	Imported quantity	
			Quintals*	Metric tons
Full period				
Garner (1997)	Spain	1559–1805	1,700,000	78,200
Other partially compiled information				
Lang (1977), based on:				
Chaunu and Mantilla	Spain	1556–1645	241,712	11,119
Archivo General de Indias	Spain	1646–1650	11,258	518
Chaunu and Mantilla	Spain	1651–1700	97,805	4,499
Archivo General de Indias	Spain	1701–1710	29,154	1,341
Archivo General de Indias	Peru	1572–1700	44,000	2,024
Total of the partially compiled information			423,929	19,501

Source: Mervyn F. Lang, 1977. *El monopolio estatal del mercurio en el México Colonial (1550–1710). Fondo de Cultura Económica*. Mexico; and R. L.Garner, 1997. Long-term silver mining trends in Spanish America: A Comparative analysis of Peru and Mexico. *American Historical Review* 93:4, 889–914.
Note: *One quintal = 46 kilograms.

As seen in **Table 3-6**, the most comprehensive and reliable information is compiled by Garner, who reports 78,200 metric tons of mercury exported from Spain to New Spain (Garner 1997). The other isolated data from 1556 to 1700 do not appear to be useful for the purpose of estimating the potential volume of mercury reserves from tailings.

Mercury consumption during the Postcolonial Period (1802–1920) is summarized as follows:

Mercury production, 1840–1921:	9,285 metric tons (see **Table 2-2**)
Mercury imports, 1802–1828:	6,710 metric tons (Herrera 1990)[23]
Total:	**15,995 metric tons**

Comparing the two methods utilized to determine mercury quantities released to tailings scattered in the Mexican mining territory, method 1 (based on silver production statistics) is judged to be more reliable than method 2 (based on mercury imports and production statistics):

- In method 2, the amount reported by Garner—**78,200** tons of mercury imported during the Colonial Period—plus the estimate of **15,995** tons in imports and production during the Postcolonial Period, results in **94,195** tons of mercury, which represents only about half the amount found using method 1.

- The total reached by using method 1—**195,928** tons of mercury consumed from 1556 to 1900—is based on statistical and historical information on silver production, from which the proportion of 2.1 kilograms of mercury used in the production of one kilogram of silver is derived (see **Table 3-5**).

Summary

Due to gaps in the information on silver imports and in the production statistics (used for method 2), the more reliable method to estimate the potential volume of mercury reserves in tailings is to calculate the amount of mercury from the known quantities of silver production, using the average of 2.1 kilograms of mercury consumed per 1 kilogram of silver produced (method 1). However, method 2 could be improved by more research—for example, on mercury imports from the US (California) and Europe during 1810–1840.

[23] Herrera's information does not cover the whole Postcolonial Period; for instance, information from 1802 to 1818 was not available.

3.3 Areas Considered Important Secondary Mercury/Silver Reservoirs

The objective of this section is to indicate where possible mercury secondary reserves are located, and to determine if it is possible for this mercury to be reprocessed.

To locate and assess the sites where mercury might be available and recoverable, it is necessary to consider the following factors:

- Historic information related to the places where mercury consumption took place;
- Quantifying mercury and silver contained in tailings through chemical analysis to determine technical and economical feasibility to recover these metals, taking into account that the gold, silver and mercury content vary depending on the location of the tailings (see **Section 3.3.1**);
- Meteorological factors which would lead to wide dispersal of the tailings, resulting in small proportions of the metals which would not be economically feasible to recover;
- Surrounding areas where tailings are located—urban, rural, wet lands;
- Legal status and type of property (private, public, agricultural, urban) where tailings are located;
- Determining if secondary production would be possible on the type of property involved;
- Transportation costs of tailings to the site where they will be treated; and
- Legal-environmental requirements.

Although in an unknown number of cases tailings probably were dispersed in different ways over a broad area, in many places dispersal created reservoirs in lower lands, such as in the case of El Pedernalillo Dam, near Zacatecas City, where around 2,350 tons of mercury were deposited (Ward 2005).

In some states, such as Zacatecas and San Luis Potosí, the trends in silver production and thus in uses of mercury in the Postcolonial Period were similar to those in the Colonial Period; whereas in other states, such as México and Jalisco, silver production declined. Still others, such as Chihuahua, emerged as important producers in the Postcolonial Period.

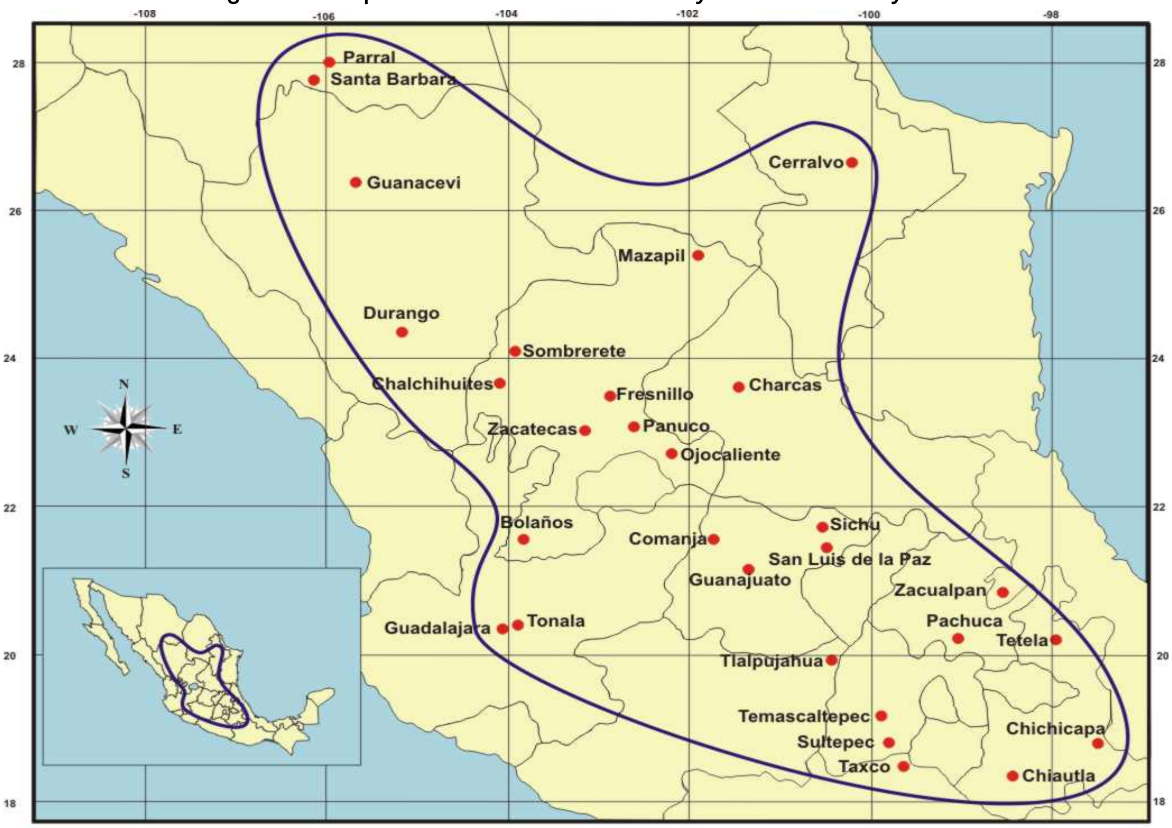
Table 3-7 shows the states where colonial silver production resulted in the dispersal of significant quantities of mercury. Tailings areas where the *haciendas de beneficio* were located and other areas considered polluted with mercury are listed (and briefly described) in **Table 3-**7[24] and are also noted on the map in **Figure 3-1**, which shows probable mercury reservoirs in Mexico.

[24] A more detailed list is included in **Appendix 2: Initial List and Description of Mercury/Silver Secondary Reservoirs**.

Table 3-7: Areas Considered to be Secondary Reservoirs of Mercury/Silver (Data confidence rating level: Medium for Zacatecas; Low for the other States)		
State	General description and sites	Estimated probable Hg reserves (in tons)
Zacatecas	According to historic and official information, it is estimated that one-third of the silver production in the Colonial and Postcolonial Periods was carried out in Zacatecas (Ogura et al. 2003). Therefore, if the amount of mercury released to tailings in Mexico is equal to 73,473 tons, it is likely that as much as 24,500 tons (one-third) may be available in Zacatecas. This quantity includes the estimated 1,974 tons of secondary mercury actually produced in Zacatecas during 1900–2009 (see **Table 3-9**) and the estimated 2,350 tons located in El Pedernalillo Dam (listed below). That would mean that there are probably still around 20,176 tons remaining in Zacatecas. However, this amount of mercury will not be entirely accessible for recovery because some of it is now covered by urban areas, or because landowners will not permit recyclers to access the tailings for processing. Therefore, calculation of the reserves has to be based on making low- and high-end estimates: 1) 35 percent of these tailings can be recovered, or 2) 70 percent of these tailings can be recovered. This results in an estimated range of 7,000 to14,000 tons. El Pedernalillo Dam (amount of mercury estimated by Ward, 2005)………………………………………………………………. ***Sites:*** Zacatecas, Pánuco, Fresnillo, Sombrerete, San Martín, San Andrés, Avino, Nieves , Chalchihuites, Ranchos, Santiago, Cuencamé, Cedros, Mazapil, Charcas, Sierra de Pinos, Tacoaleche	7,000 to 14,000 2,350
Hidalgo	The information from CRM about the sites noted below shows the existence of 107,659,225 tons of tailings, with content values of 0.18 g/ton in gold and 46.93 g/ton in silver (CRM 1992d). If the proportion of mercury is conservatively estimated to be 60 g/ton, then there are probably around 6,500 tons of mercury in the tailings… ***Sites:*** San Juan, Regla, San Antonio, San Miguel, Sánchez, La Nueva, Velasco, Loreto, Guadalupe.	6,500

Guanajuato	Based on the CRM mining monograph for Guanajuato State, Rámos-Arroyo et al. (2004) report that around 20 million metric tons of tailings remain in Santa Teresa Valley, where sediments that may be a potential source of secondary gold production have an approximate content value of 0.3 grams gold per metric ton (CRM 1992a). Assuming 60 grams of mercury per ton means that perhaps 1,200 tons of mercury may be present in Santa Teresa……………. ***Sites:*** Around 45 haciendas were involved, most of them located on the shore of Guanajuato River, including Santa Teresa.	1,200
Jalisco	In El Barqueño District, two sites are reported: La Pilarca and Peña de Oro, where an area with 1,000,000 tons of tailings having 1.5 to 2 grams of gold per ton is reported (CRM 1992b, p. 61). If the proportion of mercury is considered to be 60 g/ton, then around 6 tons may remain in these tailings……………………………….. ***Sites:*** La Pilarca and Peña de Oro	6
San Luis Potosí	***Sites:*** Cerro de San Pedro, Charcas, Mazapil and Real de Catorce	No data
Durango	***Sites:*** Birimoa, Guanacevi, Guarisamey and Sianory	No data
Chihuahua	***Sites:*** Uruachi District, Cusihuiriachi, Pilar-Moris, Maguarichi, Temoris, Guazapares and Morelos	No data
Nayarit	***Sites:*** Cucharas District, Aguila de Oro and Cebadillas	No data
Estada de México	***Sites:*** Sultepec, Temascaltepec, Tetela, Chiautla, Chichcapa and El Oro	No data
Michoacán	***Sites:*** Tlalpujahua	No data
Guerrero	***Sites:*** Taxco District	No data
Total estimated secondary mercury reserves (range)		17,056 to 24,056
Total estimated secondary mercury reserves (average of range)		20,556

Figure 3-1: Map of Areas Considered Mercury/Silver Secondary Reservoirs



Source: Derived from the Geological-mining Monograph of the states of Chihuahua, Durango, Zacatecas, San Luis Potosí, Querétaro, Hidalgo and Guerrero. The collection of these monographs is available online in English and Spanish at: <http://portal.sgm.gob.mx/publicaciones_sgm/Municipio_b.jsp?wparam=7#>.

Quantification of secondary mercury reserves, based on sampling and analytical methods, in Zacatecas

This section presents a summary and the results of a parallel field study undertaken to quantify (through soil samples and chemical analysis) secondary mercury reserves in Zacatecas (Gómez-Santos and Juárez-Damián 2010).

Objectives of the study

- Determine mercury assay values in different sites, for the purpose of estimating potential reserves of mercury in larger areas;
- Provide elements that allow assessing possible environmental and health risks resulting from recycling activities; and
- Understand the state and movement of tailings during the last five hundred years.

Selected areas where mercury quantification was performed

The criteria used to determine which sites should be sampled were:

- Areas where amalgamation processes previously took place;
- Areas where it is supposed tailings were displaced by seasonal flash flood events over the course of the past years;
- Sites where tailings have not been removed; and
- Sites where tailings have previously been processed.

Ninety-four soil samples (sampling depth, one meter) were collected during the first week of August 2010 from four sites in the area surrounding Zacatecas City and from one site in Sombrerete. Additionally, seven representative samples were collected to be analyzed for arsenic, lead, and cadmium, since these elements are of environmental concern and little is known about what happens to them when tailings are removed and processed.

Although the sample size was low, the results will be useful for providing criteria for the future selection of other sites, in order to obtain a better estimate of potential mercury and silver reserves in Zacatecas and other silver-producing states.

The study includes background information on the selected sites and describes the sampling, analytical and quantification methods used to determine the mercury amounts. Results of this study are presented in **Table 3-8**.

Description of sampled sites

Lampotal

This area is located northeast of Zacatecas City. Tailings in the Lampotal area were deposited in natural floodlands in the valley of Zacatecas, where they are found in significant quantities and have supplied two local recycling plants over the last 15 years. Lampotal covers an area of 6,033,044 square meters in Guadalupe County.

The area was selected for sampling in order to estimate the amount of mercury that remains after tailings in some sectors were removed for recovery of metals. Where tailings are still present in the soil, the criterion that governed selection for sampling was the willingness of the farmer to allow the soil to be treated by the recyclers.

The sampling exercise in Lampotal involved 32 simple samples. The results of the analysis showed that the lowest mercury content found was <0.1 milligrams (mg)/kg (or parts per million), while the highest value was 250.2 mg/kg. The average for these 32 sites was 35.8 mg/kg.

The volume of tailings remaining is approximately 8,212,855 cubic meters (m^3), yielding an estimate of the quantity of mercury present of 887 metric tons (see **Table 3-8**).

Panuco

According to Bakewell (1977), the region in which the Hacienda de Panuco was situated was one of the richest mining districts in Zacatecas. This area is located north of the city of Zacatecas and has not been explored before. The zone in Panuco selected for sampling covers 24,300 square meters.

The sampling exercise in Panuco involved 20 samples in the area of the Hacienda: five simple samples and five three-site composite samples were taken. Analysis of the results revealed that the lowest mercury content found was <0.09 mg/kg (or parts per million), while the highest value was 263.6 mg/kg. The average for these 20 samples was 182.0 mg/kg.

The estimated volume of tailings in Panuco was approximately 72,900 m^3, yielding an estimate of the quantity of mercury present of more than 35 metric tons (see **Table 3-8**).

Francisco I Madero

This area is located east of Zacatecas City. Tailings in the Francisco I Madero area were deposited in the natural floodplain of the valley of Zacatecas. The site covers an area of 1,450,000 square meters.

The sampling exercise in Francisco I Madero involved taking 39 samples: 9 simple samples and 10 three-site composite samples. Analysis of the results showed a very wide range, with the lowest mercury content of 1.2 mg/kg (or parts per million) and the highest of 72.6 mg/kg. The average for these 39 samples was 37.0 mg/kg.

The estimated volume of tailings in Francisco I Madero was approximately 1,450,000 m^3, yielding an estimate of the quantity of mercury present of 48 metric tons (see **Table 3-8**).

Vetagrande

This area, situated to the north of Zacatecas City, is the location of one of the most important Zacatecan open-pit silver mines of the seventeenth and eighteenth centuries. One of its veins is still producing silver today. The sampling exercise involved 20 sites in the area, immediately surrounding the old mine: five simple samples, and five three-site composite samples were taken. Analysis of the results showed the lowest mercury content found was <0.08 mg/kg (or parts per million), while the highest value was 3.0 mg/kg. The average for these 20 sites was 1.4 mg/kg. Values in this range are usually consistent with background (natural) levels, and not with mercury content in tailings resulting from the amalgamation process.

The results in Vetagrande would indicate that the areas holding tailings rich in mercury are located 10 to 20 kilometers away from the old mine, where the ore was transported to the local *haciendas* to undergo the silver production process. It was decided that the level of mercury (and silver) within the perimeter immediately surrounding the mine was too low for recuperation to be economically feasible.[25]

Sombrerete

This town is located about 66 kilometers northeast of Zacatecas City. According to Bakewell (1976), this mining district was an important silver producer.

The sampling exercise involved 13 sites in the selected area, from which 13 single samples were taken. Analysis of the results revealed that the lowest mercury content found was 0.3 mg/kg (or parts per million), while the highest value was 2.1 mg/kg. The average for these 13 sites was 0.796 mg/kg.

This range in values is usually consistent with background (natural) levels, and not with of mercury content in tailings resulting from the amalgamation process. However, chemical analysis led to the conclusion that it was in fact not the amalgamation method that was used to produce the silver in this area in the town of Somberete, but the smelting method (see **Table 3-1**, where a brief description of this method is given).

Summary

Only one of the five sites selected for soil sampling (see **Figure 3-2**) had been previously examined. Results were in line with previous estimates; in fact, this location (Lampotal) has provided tailings to the two active plants located in this area for the last 25 years. Sampling results obtained show that around 900 tons of mercury could be available.

With regard to the other four sites (not examined previously), results show that the amalgamation process was likely not conducted in Vetagrande and Sombrerete, as mercury and silver are only minimally present in the tailings.

The results from the Panuco zone, with an average mercury concentration of 182 mg/kg, show that significant amounts of amalgamation processing took place in earlier times and the resulting mercury content present in the tailings is significant. Considering that this area was the smallest of the five studied, it is recommended that another study be performed in a wider area.

Concerning to the Francisco I Madero area, results indicate that tailings had probably been transported or dispersed over the years, considering that the tailings were deposited in a floodplain

[25] Usually, the amount of silver or gold is in very small proportion to the amount of mercury, depending on the type of mineral deposit.

and the wide range of the values sampled: the lowest mercury content found was 1.2 mg/kg, while the highest value was 72.6 mg/kg. It is also recommended that a further study be performed in a wider area that considers dispersal of tailings to other areas.

Figure 3-2: Selected Sampling Sites for the Zacatecas Mercury Quantification Study

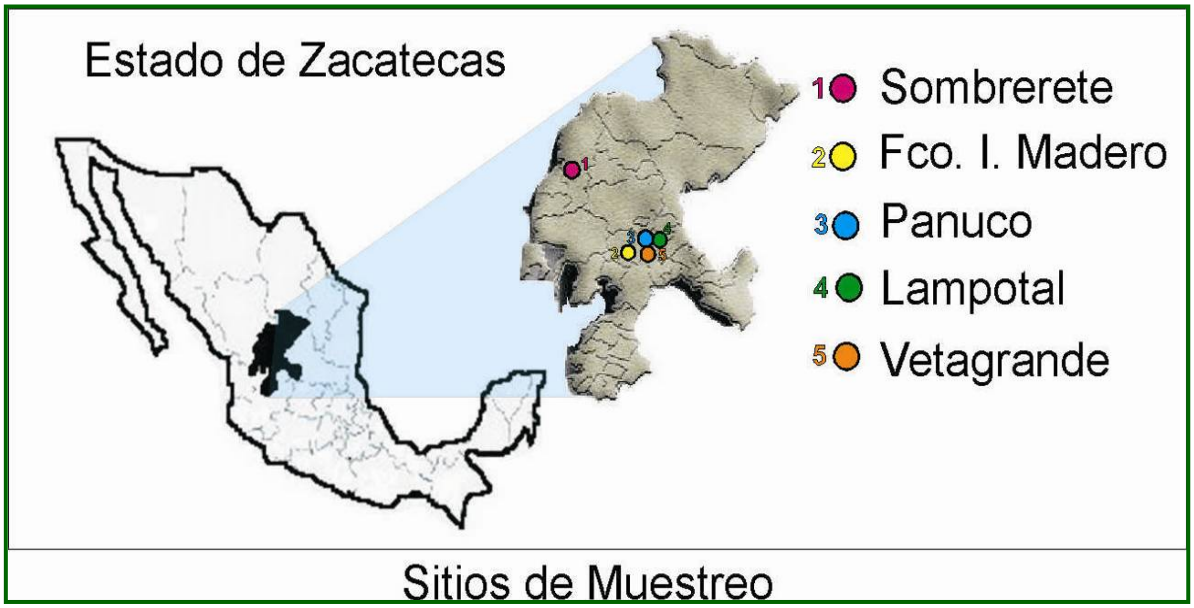


Table 3-8: Quantification of Secondary Mercury Reserves in Sites in Zacatecas August 2010 (Data confidence rating level: Medium)					
Site	**Total area (m^2)**	**Estimated volume of tailings (m^3)**	**Collected samples**	**Average Hg concentration per site (mg/kg)**	**Estimated quantity of mercury (in tons)**
Lampotal	6,033,044	8,212,855	32	35.8	887
Panuco	24,300	72,900	20	182.0	>35
Francisco I Madero	1,450,000	1,450,000	19	37.0	48
Total	**7,507,124**	**9,735,755**	**71**		**970**

Source: Field study by author, Zacatecas, August 2010.

3.4 Historic Levels of Secondary Mercury Production in Mexico

The production of recycled mercury from tailings started in 1890, in Zacatecas City, with the installation of the first lixiviation plant. By 1900, in Fresnillo, Zacatecas, 2,000,000 tons of tailings had been recycled by the lixiviation and the cyanidation methods (CRM 1991). Since mercury content in these tailings was around 110 grams per ton, approximately 220 tons of mercury were probably produced.

In Hidalgo state, silver-recycling activities were reported but not described. Information on Chihuahua and Guanajuato generated by Semarnat (2010) indicates the existence of abandoned sites where tailing recycling activities occurred. In 1956, in San Luis Potosí, a recycling plant was installed in El Cedral, Matehuala, and closed in the 1960s.

The most important documented cases are in the area surrounding Zacatecas City, where two plants were installed in 1890 and 1929: La Pimienta Plant, with a small capacity, and Santa Teresa, located near the shore of El Pedernalillo Dam. In the areas surrounding these plants, significant quantities of tailings rich in mercury have been located (González-Reyna 1947). Both plants used the lixiviation process (see description in **Section 3.5**).

During the 18-year-period 1929 to 1946, the Santa Teresa plant processed 700,000 tons of tailings, and produced around 188 tons of mercury, giving an annual average of 10.4 tons of mercury. The silver and gold production during the same period was approximately 100 tons of silver and 131 kilograms of gold (González-Reyna 1947).

In view of the absence of reliable records on the volume of secondary mercury produced since 1900, an estimate must be calculated from available information (see **Table 3-9**).

Currently, two of the plants listed in **Table 3-9** are producing around 24 tons of mercury a year, operating at only 50 percent capacity. Increasing their production will depend on the future demand for and prices of silver, gold and mercury.

The information given in **Table 3-7** suggests that there are at least 20,556 metric tons of mercury in tailings distributed in the Mexican silver-producing states that could be processed in the future; however, the table does not provide information for all the silver-mining states, due to the difficulty of obtaining such data. A discussion on future trends in the demand for and secondary production of mercury is presented in **Chapter 5**.

Table 3-9: Historic Production of Secondary Mercury in Zacatecas and San Luis Potosí (1900–2009)
(Data confidence rating level: Low)

Facility	Installed capacity (tons of tailings/day)*	Period of operation	Estimated yearly Hg production (in tons)	Total Hg produced (in tons)
Fresnillo Company of New York [1]	No data	1900–1912	No data	220
Santa Teresa [2] Pedernalillo, Guadalupe, Zacatecas	250	1929–1946	10.4	188
La Pimienta Guadalupe, Zacatecas	100	1890–1940	4.1	209
Beneficiadora de Jales formerly **La Pimienta** Guadalupe, Zacatecas	200	1941–1990 1992–2009	8.2	410 148
Jales de Zacatecas formerly **Compañía Minera** La Piñuelita Osiris, Guadalupe	400	1984–1985 1986–1990 1993–2001	16.4	33 82 148
San Luis Potosí plant	100	1951–1965	4.2	63
Active plants				
Mercurio del Bordo Lampotal, Vetagrande	800 Has operated at: 37.5% capacity 300	1986–2000 2010–2010	16.4 8	246 8
Jales del Centro La Era, Vetagrande	Has operated at: 25% capacity 275 for 2 years 100% capacity 1,100 *60% capacity for 13 years * 660	1995–1996 1997–2010	7.8 15.6*	16 203
Total			**23.6****	**1,974**

Sources: [1]CRM 1991. *Monografía geológico-minera del Estado de Zacatecas. Serie Monografías Geológico Mineras. Secretaría de Energía, Minas e Industria Paraestatal*. Mexico. [2]Information derived from G. González-Reyna, 1947. *Riqueza minería y yacimientos minerales de México*. *Monografias Industriales del Banco de México,* S.A. **Note**: *660 tons of tailings/day containing 65 g/ton/Hg = 42.9 kg/hg x 7 days = 300.3 kg/hg/ x 52 weeks = 15.6 tons. **For the two Vetagrande plants at 2010 operating levels (37.5 % and 60%, respectively).

Summary and Explanation of Table 3-9

The key elements for optimum mercury production depend on:

- The mercury (and silver) content per ton of tailings, and
- The technological performance of each plant (the older plants treated tailings with higher mercury content, around 100–120 grams per ton, but with poor technology).

It is important to remember that the main objective of these plants is to produce silver, not mercury; the latter simply represents additional income.

Also, it is should be noted that all the plants reported in **Table 3-9** had nonproductive periods due to:

- Low prices for silver, which halted production altogether in most of the plants, sometimes for years;
- Low availability of tailings; and
- Rainy seasons, which reduce the efficiency of the lixiviation process.

The estimate of current production of secondary mercury, based on the installed capacity of the two plants still operating (*Mercurio del Bordo* and *Jales del Centro*) and calculating that each ton of tailings contains 65 grams of mercury, is approximately 23.6 tons/year.

3.5 Secondary Production from Tailings: Methods and Costs

Using available data sources and field research, this section describes the lixiviation process used to extract precious metals and mercury from tailings. Also, the various conditions that affect secondary production, such as production costs, value and volume of recovered products, recycling facilities capacity, availability of tailings, reprocessed tailings disposal restrictions, and availability of extraction chemicals, are presented.

The lixiviation process recovers approximately 50 to 80 percent of the metal that was left there in tailings because of the inefficiency of the amalgamation process. The lixiviation process is also known as the Zacatecan method. It consists of the following procedures:

1) The contaminated tailing soil is placed in an artificial pond (see **Figure 3-3**),[26] where it is treated with an aqueous solution of calcium thiosulfate (CaS_2O_3), formed by passing sulfur

[26] There are typically four to six ponds at each plant. The size of each pond is about 25 m (meters) wide x 50 m long x 1 to 1.5 m deep, with a sloping bottom.

dioxide through an aqueous suspension of lime and elemental sulfur. The mercury in the tailing soil solubilizes after about two weeks, usually oxidizing as thiosulfate complexes, e.g., $Hg(S_2O_3)_2^{2-}$.

2) The resulting solution is pumped into square vats or tanks (see **Figure 3-4**) made of concrete (2 x 2 x 1.5 m deep) for precipitation using a copper wire to aid in the breakdown of the thiosulfate complexes into an insoluble sludge of metal sulfides of mercury, silver, and gold, and soluble sulfate ions. The sludge is retorted in a furnace to drive off the sulfur, and the silver and gold are collected. The mercury vapor and water vapor are directed to a cooling chamber where both are condensed and the subsequent flow directed to a separation well (Ogura et al. 2003). The mercury metal is poured into 76-pound (35-kg) mercury flasks.

3) A large post-processing tailings heap near the facilities rises to an elevation of about 10 to 15 meters above the surrounding land (see **Figure 3-5**). As the lixiviation process does not free all the mercury and silver, these processed tailings still contain a certain amount of bound silver and mercury (around 46 grams per metric ton [27]). The feasibility of subjecting these tailings to a second recycling process will depend on the demand for and price of silver, gold and mercury.

Figure 3-3: Lixiviation Ponds

Photo: José Castro Díaz.

[27] According to the study of Ogura et al. (2003), only 121 ppm of Hg was freed from 168 ppm of extractable Hg.

Figure 3-4: Cement Precipitation Tanks for Metals

Photo: José Castro Díaz.

Figure 3-5: Mountain of Recycled Tailings at One of the Recycling Plants

Photo: José Castro Díaz.

The following are important aspects to consider in relation to the cost of secondary production of mercury:

- Abundant rain generally affects the lixiviation process, and metals are recovered in a smaller proportion. In some years, plant operation has been closed during the rainy season.
- In order to determine which sites have tailings rich enough to make processing profitable, a sampling and chemical analysis of the contents of precious metal must be performed.
- As several hundred years may have passed since the original mining operations, tailings may have been deposited near or far from where they were generated; therefore, transport costs will vary depending on the distance of the tailings to the plant.
- When tailings are located on farmlands, recyclers usually have to pay farmers for their permission to remove the tailings.
- The metal contents in tailings determine the recycling activity. For instance, in Zacatecas, according to González, the amounts of precious metals were determined to be 70 g of silver per ton of tailings, 0.25–1.0 g of gold/ton and 125 g of mercury/ton. He also reported that the lixiviation method in the first installed plant recovered approximately 50 percent of the metal content, as follows: 35 g silver/ton, 0.12 g gold /ton and 75 g mercury /ton (González-Reyna 1947). However, since the time when this first plant began operating, the lixiviation method has been upgraded and the recovery rate has been improved.
- The concentration of metals is of course not the same in all tailing reserves and various mercury levels have been found in soil samples in the area around Zacatecas City, such as 168 g/ton reported by Ogura et al. (2003); 198 g/ton and 90 g/ton (Santos 2004); 88 g/ton and 123 g/ton (Nuñez-Monreal 2002).
- The price of the metals helps determine profitability. For instance, tailings with values over 50 g/t of silver are profitable. On the other hand, if silver values in tailings are below 50 g/t, but the price of silver is higher than US$20.00 an ounce, the recycling process is also cost-effective.

Since 2010, the economic situation has been favorable for recyclers, as the demand for gold and mercury and their prices have gone up. The economics of recovery should be analyzed in order to anticipate possible future scenarios with respect to production of mercury. As an example of the relation between international prices and secondary production, information on cost and prices in current recycling activities in Zacatecas is presented in **Tables 3-10** to **3-12**. In **Table 3-10**, the current international prices are given. **Table 3-11** shows the breakdown of values of these metals in a recycling plant per week. **Table 3-12** presents an analysis of the costs and profits of the processes involved.

Table 3-10: International Prices of Gold, Silver and Mercury

Metal	Unit	Price (US$)
Gold	Troy ounce 31.103 grams	1,355.00/ounce[1] 43.564/gram
Silver	Troy ounce 31.103 grams	29.140/ounce[2] 0.936/gram
Mercury	Flask 34.47 kilograms	1,450.00/flask[3] 42.065/kilogram

Sources:
[1] 4 February 2010. World Gold Council, at: <http://www.gold.org/investment/statistics/prices/>.
[2] 4 February 2011, Monthly average. Kitco, at: <http://www.kitco.com/charts/livesilver.html>.
[3] January 2011. USGS, at: <http://minerals.usgs.gov/minerals/pubs/commodity/mercury/mcs-2011-mercu.pdf>.

Table 3-11: Economic Value of Recovered Metals in a Recycling Plant in Zacatecas (over a production cycle of one week)
(Data confidence rating level: Low)

Metal	Tailings processed (tons/week)	Processed yield in metal (g/ton)	Quantity of metal obtained (g)	Unit price (US$/g)	Total income in one week¹ (US$, P$)	Contribution of each metal in relation to total generated values (%)
Gold	3,150	0.04	126	43.564	US$5,489	2.82
Silver	3,150	60	189,000	0.936	US$176,904	90.74
Mercury	3,150	95	299,250	0.0420	US$12,568	6.44
Value of recovered products					US$194,961	100.00
Value of recovered products in Mexican pesos (at P$12/US$)					**P$2,339,532**	

Source: Derived from field visit interview with plant owner, and from Ogura et al. 2003. Zacatecas (Mexico) companies extract Hg from surface soil contaminated by ancient mining industries. *Water, Air, and Soil Pollution.* Vol. 148, pp 167–177. Silver prices from the Silver Institute, at: <http://www.silverinstitute.org/site/silver-price/silver-price-history/>.
Note: ¹The weekly income is estimated based on a facility's having the capacity to process 450 tons of tailings daily per lixiviation pond, using seven ponds per day by week.

The total value of metals recovered in this recycling plant in one week amounts to approximately US$194,961, or US$61.89 per ton. Silver represents 90.74 percent of the total income; gold and mercury represent 2.82 and 6.44 percent, respectively. These results reflect the fact that the production of silver is the main objective of these plants, while mercury and gold are by-products. But as the latter two metals contribute to the earnings, it is reasonable to regard their production costs as being zero. On the other hand, if it is theoretically supposed that the plant's production processes were dedicated only to producing mercury, recovery processing would not be economically worthwhile unless the mercury content in the tailings were twice its actual amount (95 x 2 = 190 g/ton) and the price for mercury were approximately eight times higher than at present (US$0.042 x 8 = US$0.336/g), in order to achieve an income equivalent to that given by the present combination of metals (US$61.89/ton): US$0.336 x 190 = US$63.84/ton.

Table 3-12 shows that production costs per ton of tailings are estimated to be equal to 50–55 percent of the generated product value, or approximately US$30.94/ton. The profit is estimated to be 20–25 percent. At the lower profit margin, revenues would equal about US$38,992 per week (or US$12.38 per ton). It should be remembered that factors affecting this amount include the fluctuation in mercury, silver and gold prices and the extent to which the rainy season interrupts recycling activities.

Table 3-12: Costs and Profits of Secondary Production in a Plant in Zacatecas

Description	% of product value
Tailings transport: 3,150 tons in trucks of 16-ton capacity = 197 round trips x 25 km (or more, depending on the distance from the deposits of tailings) Machinery and vehicles maintenance and depreciation Fuel: diesel for transport and machinery; gas for preparation of the calcium thiosulfate solution Substances needed: sulfur, lime, water, copper Electricity for retorting (furnace) and for pumping solutions Permission fees paid to landowners where tailings are located, to allow recyclers to take their tailings to recycling. Generally, recyclers pay this cost by using the value of one year's harvest as a reference. Sampling and analysis in sites considered potential reserves of metals	50–55
Silver-refining process costs Insurance, administrative costs, salaries and taxes	30
Profit	20–25*

Source: Proprietary information based on a site visit and interview. Also from Ogura et al. 2003, as they describe the process. For silver prices, see <http://www.silverinstitute.org/site/silver-price/silver-price-history/>.
Note: *An increase in profit is related to the increase in metal prices.

3.6 Conditions that Would Cause an Increase or Decrease in Secondary Mercury Production

An increase in demand from the artisanal gold-mining sector could stimulate the demand for mercury but might not be linked directly to an increase in secondary mercury production, since that production occurs in plants whose main objective is secondary silver production. However, it is important to note that gold prices have indirectly motivated secondary mercury production in the following ways:

- The possible decreased supply of mercury worldwide, due to the export bans in place and the anticipation of the future international restrictions on mercury commerce, has resulted in incremental increases in the price of the metal, which in turn may have motivated countries where secondary mercury is produced to supply countries where artisanal and small-scale gold mining is taking place.
- Secondary silver production, which is the principal objective of the recycling process, depends for its profitability on a price for silver of at least US$20 per ounce. In fact, in the past, plants have closed when silver prices dropped below that price. Note that silver prices in 2011 were above US$29 per ounce. In addition, as increasing demand raises the price of gold, secondary recyclers may depend on secondary gold production to boost their profits.

National and local factors that might make secondary mercury production infeasible or even impossible are:

- The unavailability of tailings, considering that urban areas now cover large amounts of former tailing reserves and that facilities might not be located near enough tailings;
- Permission withheld by landowners for access to remove tailings for processing, or permission granted but at too high a price; and
- Public health and environmental concerns, which should be addressed through an appropriate risk assessment study on the species of mercury, lead, cadmium, and other metals involved in the silver recycling process.

Finally, the factors that might facilitate secondary mercury production are:

- New and more efficient technology for recycling tailings, which would also improve environmental impacts; and
- More efficient methods for the detection of precious metals and mercury and for the quantification of tailings.

3.7 Domestic Regulations and Multilateral Environmental Agreements pertaining to Secondary Mercury Production

Domestic aspects

- In response to increased pressure at the international level, raising public awareness of the need to reduce exposure to mercury, avoid or reduce its use, and reduce anthropogenic emissions, Mexico is undergoing the initial process of internal reflection among all the sectors and stakeholders involved in order to plan the environmentally sound management of mercury.

- Although Mexican environmental regulations have limited the emissions of mercury to air and water and controlled its disposal in wastes, this chemical element has not been regulated as a product and it is commercially available without restriction.

- On the legal front, mercury mining is allowed and there is no impediment to the production and sale of mercury. The situation is the same with regard to secondary production of mercury, as there is no restriction on its sale.

- On the environmental front, Article 30 of the General Act for the Prevention and Comprehensive Management of Wastes (LGPGIR—*Ley General para la Prevención y Gestión Integral de Residuos*) determines and lists the wastes that are subject to a management plan, which includes recycling activities (LGPGIR 2003). Part III of Article 30 deals with wastes containing persistent, bioacumulative and toxic substances (PBTs) such as mercury, a criterion that is used to enable and facilitate the control of toxic wastes through specific management plans that are compulsory for all involved actors. Although to date there is no mercury recycling program in Mexico, this Article provides legal support for the organization of mercury recovery programs for end-of-life mercury-containing products and even for mercury recovered from tailings.

- Final confinement of mercury is covered under Article 67, Part II, of the LGPGIR, which prohibits the final confinement of liquid or semi-solid hazardous waste without previous treatment or stabilization to transform it into a solid state (LGPGIR 2003). The difficulty involved in application of this regulation to mercury shows the need for the development of a specific standard, or for modification of the LGPGIR, to define the technical-economic issues related to the final storage of mercury and mercury-containing waste, and appropriate stabilization methods.

Application of current Mexican environmental law to mercury is problematic, because mercury's properties are unique. They require the development of specific regulatory measures to completely cover all stages of mercury's interaction with the environment.

For instance, mercury-containing tailings generated by silver production and dispersed over Mexican territory are considered to have all been released before any environmental regulation had been issued. However, from an environmental perspective, tailings are considered hazardous waste under the LGPGIR due to their mercury content.

The recycling plants currently in operation that are dedicated to recycling mercury from tailings fulfill all the environmental requirements and have a permit to operate. Mercury, silver and gold recovery also must meet the requirements stated in the Official Mexican Standard NOM-147-SEMARNAT/SSA1-2004, which sets the criteria for determining the concentrations for remediation of soil contaminated by arsenic, barium, beryllium, cadmium, hexavalent chromium, mercury, nickel, silver, lead, selenium, thallium, and/or vanadium (Semarnat 2004b). This standard establishes a total reference concentration (CRT) for mercury according to the type of soil used, as follows: agricultural, residential, commercial soil: 23 mg/kg; industrial soil: 310 mg/kg. The average concentration found remaining in the tailings after they have undergone the lixiviation process in these plants is around 5–10 mg/kg.

What the recycling companies in Zacatecas have been doing during the last 100 years is to remove the soils (approximately one-meter deep) where the elevated concentrations of mercury are found and transport them to the plants for treatment. In respect to the above Standard, this action represents a kind of remediation, since the treated soils have had their mercury contents reduced and have been finally transferred to a post-processing tailings dump, where they are kept within the facility in a stabilized form (see **Figure 3-5**). However, from a toxicological perspective, a detailed environmental-health risk assessment should be performed on these post-processed tailings to confirm that no other toxic metals besides mercury are bioavailable—such as lead, arsenic and cadmium, which can also occur naturally in the ores and still be present after the lixiviation process. An initial study on this issue is recommended.

An important regulatory tool recently introduced for industry is the Annual Certificate of Operation (*Cédula de Operación Anual*—COA), which was implemented in 2004. Holders of a COA must report mandatory waste-generation and management records to the pollutant release and transfer register (*Registro de Emisiones y Transferencia de Contaminantes*—RETC) and these are publicly accessible. Information on mercury consumption, releases and imports by the industrial sector can be obtained through the retrieval tools of this registry (Semarnat 2011).

The COA system is an important instrument that provides a means of determining how facilities are operating and, if necessary, require upgrades in technology or improved conditions for reprocessing the tailings.

The multilateral aspect

Because of the potential of its secondary mercury reserves, quantified to be at least 20,556 tons (see **Section 3-3** and **Table 3-7**) that can be recuperated from mining wastes generated in the past, Mexico has a unique position on the international stage that has yet to be specifically considered in the multilateral agreement process. Since secondary mercury production derives from the silver/gold recuperation activity, it will have to be decided if this mercury should be confined or be reincorporated into the international market. Therefore, it is important to initiate a dialogue right away among importer and exporter countries (such as Mexico), with the objective of rationalizing the future market between mercury-demanding countries and mercury-supplying countries, in order to assure the best strategy, economically and environmentally.

Such a dialogue should also cover the potential Mexican reserves of primary mercury, estimated to be at least 42,000 tons.

CHAPTER 4 OTHER MERCURY SUPPLY SOURCES IN MEXICO

This chapter evaluates other potential sources for supplies of mercury in Mexico that could be drawn upon if the mercury contained therein could be recovered through collection-recycling programs. The sources covered are: mercury in chlor-alkali plants converted to non-mercury-cell technology; by-product mercury resulting from mining and metal-processing operations; and mercury generated from future collection programs of mercury-containing instruments and devices.

4.1 Conversion of Mercury-cell Chlor-akali Plants

At a mercury-cell chlor-alkali facility, elemental mercury is used as a fluid electrode in electrolytic production of chlorine and sodium hydroxide (NaOH) or potassium hydroxide (KOH) from salt brine (the electrolysis splits the salt, NaCl). Hydrogen is also liberated as a by-product. The process is sometimes referred to as the “mercury cell” process. Note that two other (non-mercury) methods are also used widely: the membrane process and the diaphragm process (UNEP 2005). In Mexico, this sector is the most important mercury consumer: it was estimated to have a yearly consumption of between 5.66 and 13.7 tons (CEC 2001 and INE 2008), when all three plants in Mexico were in operation. This quantity of mercury is usually released to the environment in emissions to air, releases to water, and as solid wastes, and to a minor degree in products.

Until 2006, the total mercury content of these three chlor-alkali plants was distributed in 120 cells (titanium anode type). Each cell contained on average 2,287 kg of mercury, resulting in an inventory of functioning mercury of about 274.44 metric tons (CEC 2001). Unfortunately, the information presented by CEC (2001) is aggregated and does not give details about how many mercury cells were in each plant.

In 2007, one of the three mercury technology plants (the Mexichem facility in Santa Clara, Estado de México) began being converted from mercury-cell to membrane technology.

In order to compile information for developing the *Mexican Mercury Market Report* (CEC 2008), Semarnat sent an official letter to Mexichem on 7 July 2008, requesting information about the date when this plant started using mercury-free technology and about the management of the mercury available due to this change in technology. The requested information had not arrived by the time the preparation of the above report was completed.

To gauge mercury volumes in the absence of updated official information from the two remaining plants which will be undergoing technological change, a rough estimate can be made based on the CEC (2001) report, by extrapolating the chlorine production–capacity data of each plant with the total mercury stock in the three plants (274 metric tons). Thus, as presented in **Table 4-1**, since the converted Mexichem plant contributed 12.25 percent of the total chlorine production, and the total mercury stock in the three plants is 274 tons, the corresponding amount of retired mercury can be estimated at 34 tons, plus perhaps as much as 3 tons formerly held in reserve for process losses.[28]

With regard to the other two remaining plants, the plant in Monterrey contributes 19.75 percent of the total chlorine production; thus 19.75 percent of 274 tons equals slightly more than 54 tons of mercury (plus reserve). At the plant in Coatzacoalcos, the estimate of mercury in its cells is 68 percent of 274 tons, which equals 187 tons of mercury (plus reserve).

[28] The same calculation and rationale is advanced in the 2008 *Mexican Mercury Market Report*, section 3.2.

Table 4-1: Amount of Mercury in Chlor-alkali Plants Using Mercury Technology (in metric tons) **(Data confidence rating level: Medium)**					
Company and location	Year*	Type of technology	Contribution of each plant to the total chlorine production using Hg technology (%)	Retired mercury***	Estimated mercury in cells
Mexichem, Santa Clara, Estado de México	1958	De Nora 14TGL, 14x3F Mathiesen E11.'66	12.25	34	
Industria Química del Itsmo, Nuevo León, Monterrey	1958	Mathiesen E8	19.75		54
Industria Química del Itsmo, Veracruz, Coatzacoalcos	1967	De Nora 18x4, 18H4'72	68.00		187
Total			100% (274 tons)	**34 plus reserve	241
10% Hg reserves in plant				3	24
Total potential supply when chlor-alkali plants change to mercury-free technology				~34–37	~265

Notes: *When each plant initiated operations.
**Derived from CEC 2001, p. 27
***Reported in CEC 2008, p. 30.

Summary
The quantity of mercury in the cells in the two remaining chlor-alkali plants is approximately 241 metric tons. At least 10% (24 tons), corresponding to the reserves to cover mercury losses during the production process, should be added to this amount. Thus, approximately 265 tons will be available when these two plants change to non-mercury-cell technology.

The retired mercury resulting from the conversion of the Mexichem plant, amounting to between 34 and 37 tons, was probably sold on the national market, or exported in 2008.

4.2 Possible By-product Generation from Other Metal Processes

It is important to mention that trade in by-product mercury is not occurring in Mexico, as there is apparently sufficient recycled mercury from tailings or imported mercury to satisfy the local and export markets. Nevertheless, and although by-product mercury can be considered an unlikely supply source due to its high recovery costs, an estimate of the possible amount available is presented in this section, however with a "Low" confidence rating.

Because mercury is often associated in deposits with copper, lead, zinc, silver, gold, and with some ferrous metals in different concentrations, it can be produced as a by-product from the mining and processing of these metals. Mercury is particularly associated with gold; in fact, in the gold-prospecting industry, mercury is considered an indicator metal for the presence of gold. Mexico is an important producer of these metals.

The concentrations of mercury in natural deposits of these metals can range from 0 ppm (parts per million) to 10 ppm or more, depending on different geological conditions. In some cases its concentrations are high enough to make its recovery commercially viable during the production process of these other metals. Recovery of mercury may also be motivated partly by the desire to reduce mercury releases to the environment.

In order to find out if by-product mercury is being produced in Mexico, a letter from Semarnat was submitted on 16 November 2007, to the Mexican Mining Association (Camimex), requesting information related to the production of virgin mercury and the production of mercury as a by-product of the mining of other minerals (primarily gold, silver, lead, zinc and copper). On 21 January 2008, Camimex sent a letter of response to Semarnat stating that none of its members produces mercury as by-product or uses the amalgamation technique for the recovery of precious metals. Information about mercury-containing waste provided by Camimex, which represents the most important companies, claimed that in most of the recovery processes of precious metals, mercury is not generated as a waste. With respect to other processes (initial refining or smelting of these metals), according to Camimex, some mercury-containing waste is generated (sludge) due to the gas wash in the condensers, but that waste is sent to controlled confinement as confined sludge (CEC 2008).

Small, gold- and silver-mining companies comprise another sector to be considered. For them, the destiny of the mercury generated by their activities has not been characterized; this mercury could be being released to the atmosphere or being recovered.

Mexico is therefore not officially producing by-product mercury. However, if any such mercury were to be recovered (for environmental reasons as is the case in some instances)[29] and reintroduced to the market, its production might have stemmed from the following sources:

[29] It should be emphasized that in this sector the intention to recover mercury is usually not for economic reasons but

- Mining ores that contain only a few milligrams of mercury per ton. This waste is generated during the initial mining when high-grade ores are separated from low-grade ores. These low-grade ores may contain traces or even small amounts of mercury in proportions, which may in some cases be elevated compared to other raw components. For instance, the mercury content in gold ore is sometimes high enough to motivate its recovery from residual ores. However, usually low-grade residual ores that are not processed are abandoned over wide areas surrounding the mines; this is especially true of past mining activities or of informal mining. Recovering mercury from these ore wastes is not economically feasible due to the small quantity of mercury present per ton, but the wastes may nonetheless release mercury to the atmosphere or to water bodies.
- Recovering mercury from vapors. As mercury has a low boiling point relative to other metals contained in ores, it typically evaporates during the initial thermal refining stage. In some cases where the mercury concentration in the ore is high enough to make the recovery economically attractive; mercury retort furnaces and condensers are used to evaporate and recover it from the ore.
- Processes conducted after the mining and initial refining phases, namely:
    - During the steps following the metal extraction processes; these are a combination of physiochemical operations that normally involve concentration by gravity and/or flotation; and
    - Specific chemical processes designed to separate metals (e.g., gold from other constituents of ore, by using cyanide, which dissolves the gold out of the rock material); the resulting concentrates containing these metals usually go through supplementary extraction procedures involving several steps at temperatures high enough to thermally release mercury, which in most cases is captured in filters or condensers.

A theoretical estimate of mercury generated as by-product can be derived from the information produced in the National Inventory of Mercury Releases (*Inventario Nacional de Liberaciones de Mercurio*) (INE 2008), which was built using the UNEP Toolkit methodology (UNEP 2005) and compiles data on companies and national emissions in 2004.

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related more to environmental concerns and to control the quality of the other metals being produced. The production cost of this mercury is definitely higher than for mercury recycled from tailings or obtained from mines.

The National Inventory is based on the following information sources (among others):

- Hazardous Pollutants National Emissions and Transfers Report (Semarnat 2004a)
- Previous Mexican mercury releases and emissions inventories and partial reports
- Semarnat—2004 industrial annual certificate of operations (COA) database
- Inegi—2000 and 2004 population censuses; 2004 manufacturing industry census; and economic-information database
- Secretariat of Economy (SE)—the Mexican Business Information System (SIEM) and the Tariff Information System via the Internet (SIAVI)
- Annual reports and other documents from commercial and/or industrial chambers, associations and institutes (e.g., Canacero, Camimex, among others)

To develop the National Inventory, mercury releases were estimated using source-specific input obtained from the information sources mentioned above, and taking into account the distribution factors and/or emission factors, as suggested by the UNEP Mercury Inventory Toolkit (UNEP 2005).

The amount of mercury that can be recovered from releases from production processes for other metals was estimated for four different vectors (air, water, land, and waste products) in the National Inventory[30] (INE 2008). However, for the purposes of this chapter, only air and waste vectors are considered. Emissions to water are not considered, as these were not reported in the inventory (INE 2008). Mercury releases to land are not considered either because the cost of recycling mercury from residual ores is not economically feasible, due to the amounts of energy needed (and yet, according to the Mexican standard NOM-141-Semarnat-2003, tailings and ores containing mercury, or other toxics, must be deposited in safe confinements).[31]

The likely generation of by-product mercury resulting from the processes used in the different metal production sectors can be estimated, assuming that the reported emissions of mercury to air (4.44 tons) were captured in the condensers or filters and recycled. The mercury by-product that can be recycled from the waste generated by these sectors, such as spent concentrates, sludge, and other solid waste, equals 3.83 tons, as reported in the INE inventory (see **Table 4-2**).

[30] This inventory is undergoing a revision process by the National Institute of Ecology (INE) and the Mining Association of Mexico (Camimex).

[31] See text at <http://dof.gob.mx/nota_detalle.php?codigo=661988&fecha=13/09/2004>.

Table 4-2: Possible By-product Mercury from the Metal Production Sector (in metric tons) **(Data confidence rating level: Medium)**		
Source of recovered mercury	Air (sludge from condensers)	Waste (sludge from the process)
Gold extraction and initial processing (non–mercury amalgamation processes)	0.45	0
Zinc extraction and initial processing	2.52	7.57
Copper extraction and initial processing	0.73	2.19
Lead extraction and initial processing	0.54	1.63
Primary ferrous metal production	0.203	0.011
Totals	4.443	3.831
Combined total possible by-product mercury	8.274	

Source: Derived from INE. 2008. *Inventario Nacional de Liberaciones de Mercurio, 2004*. Semarnat.

According to information provided by Camimex, the resulting mercury from the different production processes is sent to controlled confinement instead of to the recycling process. However, even though this mercury is not currently being recovered by Mexico, for the purposes of this report it is considered as by-product that could theoretically be entering the market.

4.3 Prospective on Secondary Mercury Production from Product Recycling

This section presents a preliminary estimate of secondary mercury generation based on the hypothesis that programs for the collection and recycling of discarded mercury-containing products have already been established and are working adequately and that the proportion of end-of-life mercury-containing products being collected by 2012 will be 50 percent. The confidence rating given the information generated in this section is "Low."

In order to estimate the possible secondary mercury generation in Mexico, it must be assumed that the mercury in question can be recycled. Although secondary mercury production from discarded mercury-containing products is not formally occurring in Mexico, in 2010 some mercury-containing wastes and products began to be collected in Mexican hospitals through a pilot program for thermometer and sphygmomanometer replacement initiated under the Management Program for Mercury-containing Products and Mercury-containing Waste in Mexican Hospitals, Phase 1.[32]

[32] *Programa de manejo de productos, instrumentos y residuos que contienen mercurio en hospitales de México, organizado por el Sector Salud, Fase 1*. Prepared by José Castro for the Commission for Environmental Cooperation's

Also taken into consideration in this estimate are the end-of-life products in the electricity sector, such as relays, switches and other electrical devices.

Accepting the supposition that 50 percent of the mercury generated from end of life products in the health and the electric sectors will be recycled in 2012 and that the remainder will be recycled in 2013, the possible quantity of mercury that may be available in these sectors can be estimated from the information given on this subject in the *Mexican Mercury Market Report* (CEC 2008).[33]

According to that report, it is estimated that the mercury available in discarded thermometers, sphygmomanometers, relays, switches and other electrical devices amounted to approximately 14.3 tons in 2012 and a similar quantity in 2013. If half of this amount were to be recycled, then the hypothetical quantity of mercury recovered would be around 7.15 metric tons per year (see **Table 4-3**).

North American Regional Action Plan (NARAP) on Mercury, in 2009.

[33] The objective of the CEC *Mexican Mercury Market Report* (CEC 2008) was to collect and analyze available information from Mexico in order to describe supply, demand, trade, market characteristics, and trends of elemental mercury and mercury-containing products in commerce.

Table 4-3: Estimated Mercury that Can Be Recovered from Potential Collection Programs in 2012–2013*
(in metric tons)
(Data confidence rating level: Low)

Type of product	Estimated mercury in discarded products per year **	Estimated mercury, calculating 50% recovery rate, 2012	Estimated mercury, calculating 50% recovery rate, 2013
Mercury thermometers	2.4	1.2	1.2
Mercury sphygmomanometers	1.3	0.65	0.65
Mercury relays and other electrical devices	10.6	5.3	5.3
Total	14.3	7.15	7.15

Notes: * In early 2012, Mexico is to begin initiating collection and recovery programs in the health and electric sectors.
**These quantities of mercury are based on estimates of production, import and consumption data presented in the *Mexican Mercury Market Report* (CEC 2008).

In order to have a good perspective on the status of secondary mercury production from discarded mercury-containing products, it is important to remember that this activity is not officially occurring in Mexico at present, due to a lack of companies interested in recycling. However, the possible factors that may motivate the recycling of this mercury are:

- The future mercury export ban in developing countries;
- The demand in the artisanal gold–mining countries;
- The environmental need to discourage primary (formal and informal) mercury mining;
- Mercury recycling or recovery costs; and
- Legal and mandatory collection-recycling programs.

Other important issues that emerge are:

- What to do with the resulting recovered mercury—should it be resold in the international market in order to make the collection-recycling programs self-sufficient?—and
- How to confine the recovered mercury temporarily or permanently, which requires the allocation of adequate technical and economic resources.

Summary

Assuming that a collection and recycling/recovery program at a 100 percent collection rate over two years were successful, an estimate of the potential quantity of recovered mercury during 2012–2013 gives 14.3 tons (see **Table 4-3**). This could be considered as reserves for a future national and international mercury market, or as an amount requiring final confinement or stabilization. A factor will be Mexico’s ability to develop an adequate infrastructure for mercury retirement.

This estimate assumes that it will take two years to collect and recover (or confine) the amount of mercury in these instruments or devices. However, additional amounts of this mercury should be expected to appear over time, as hoarded objects reach the end of their lifespans.

CHAPTER 5 TRENDS IN MERCURY SUPPLY AND DEMAND IN MEXICO

This chapter aims to provide some elements for assessing future trends in mercury supply and demand in Mexico, based on historical and other official information collected and presented in the previous chapters of this report.

5.1 Current Demand for Mercury in Mexico

The Mexican mercury market has been self-sufficient since the 1920s, in that its production (primary and secondary) has satisfied its national consumption. According to the *Mexican Mercury Market Report* (CEC 2008), which is based on official information, the national consumption of mercury is around 24.5 tons per year, distributed as shown in **Table 5-1**.

Table 5-1: National Annual Demand for Mercury in Mexico for 2007
(metric tons)
(Data confidence rating level: Low)

Products or processes	Estimated mercury demand
Amalgam sphygmomanometers and their maintenance	5.4
Lighting and neon signs	1.0
Chlor-alkali process	5.0
Basic inorganic chemical production and other industrial uses	9.1
Biopharmaceutical laboratory uses and other products and uses	4.0
Total	24.5

Source: CEC 2008. *Mexican Mercury Market Report.*

The annual total of 24.5 tons could be considered to apply to the last ten years. It does not include mercury contained in imported products such as thermometers or electrical parts, as they are not produced in Mexico. Nor does the information in **Table 5-1** cover informal uses of mercury in areas not included in the list, such as in jewelry, fireworks, or cultural applications.

It is estimated that these 24.5 tons annually consumed will decrease in the medium term, thanks to future reduction programs aimed at eliminating the use of mercury. The annual total is nearly equal to the average from secondary production from tailings during the last eight years, which is about 23.4 tons.

5.2 Supply of Mercury and Informal Mining

An important international condition that may drive an increase in the Mexican supply of mercury is the average price for a flask of this metal, which went up by approximately 50 percent between 2009 and 2010, from US$600 to approximately US$900. Moreover, as of July 2011 (the source of the most recent data), the price per flask had risen to US$1,950 but prices were also reported in the $2,400 to $2,600 range (based on figures reported by the USGS[34]).
Mercury price increases have been driven by the following factors: 1) the mercury export ban in the European Union (in 2011) and anticipation of the United States ban (in 2013); 2) the rising price of gold, as mercury is used in the amalgamation process for gold production; 3) the diminishing supplies of reclaimed mercury from end-of-use mercury-containing products in developed countries; and 4) the future reduced availability of mercury from China and Kyrgyzstan (USGS 2011).

As discussed in **Chapter 2**, no official primary mining of mercury has been reported in Mexico since 1994, due to the significant reduction in demand on the global market. However, it is important to note that mines and productive infrastructure still remain, that it is possible for informal mining on a small scale to be carried on in most of the closed mines, and that, by doing some restoration work, which in fact is probably already occurring, formal primary mining can be reinitiated.

After primary production ceased in 1994, Mexico became an importer-exporter country. Its imports have mainly come from developed countries, while its exports have mainly been to developing countries. Over 21 years (1985–2006), Mexico was a net importer—of an average seven tons annually. However, since 2007, Mexico has been a net exporter (see **Table 5-2**). It is important to remember that, once the EU and US export bans have taken effect, Mexican imports from these countries will be reduced to zero.

The current estimate for secondary-mercury production from tailings is approximately 24 tons per year (see **Table 3-9**). However, the installed capacity in these two plants is estimated to be around 45 tons.[35] The level of production and any future increase in it depends on the availability of tailings containing mercury, the silver and gold content in these tailings, the prices of silver (which must meet a level adequate to make production profitable), and the effects of the rainy seasons.

The international market for mercury is framed, on the one hand, by the reduced supply caused by the export bans on mercury imposed by Europe and the United States and, on the other, by the increased demand for it because of increased artisanal gold production noted since 2009. At the national level, these bans are probably the reason why, during the last three years, informal

[34] See USGS 2011 online at: <http://minerals.usgs.gov/minerals/pubs/commodity/mercury/mcs-2011-mercu.pdf>.

[35] See Note ** to **Table 3-9**, presuming operation at full installed capacity.

primary mercury mining has been detected in Mexico. This has posed a significant challenge to the goal of this study to quantify and characterize informal production of mercury. Perhaps unreported production should be considered part of the supply of surplus mercury; the problem is how to differentiate informal production of mercury from surpluses. A rough estimate can be derived by applying the following formula:

Surplus mercury = *apparent supply* - *exports* - *estimated domestic consumption*, where:

- ***apparent supply*** = primary production (officially reported) + secondary production (from tailings) + imports,
- ***exports*** = mercury sold to other countries that is officially registered (produced formally or informally, or imported from other countries and then re-exported), and
- ***estimated consumption*** = domestic consumption for industrial and institutional uses.

Using this formula and the information presented in **Table 5-2**, the estimate of surplus mercury for year 2006 would be as follows (all amounts in tons):

Surplus mercury = 44.86 *apparent supply* - 8.14 *exports* - 24.5 *domestic consumption* = 12.22 tons.

The quantity 12.22 tons is a positive number which represents the amount of surplus mercury (mercury which may be available, or some proportion of it, for future export), but could also correspond to mercury not reported as estimated domestic consumption and probably dedicated to other, non-registered informal uses, such as in fireworks or cultural applications.

On the other hand, if the formula is applied to the year 2007, the result for surplus mercury is negative, as follows:

Surplus mercury = 27.43 tons *apparent supply* - 21.36 *exports* - 24.5 *domestic consumption* = -18.43 tons.

The figure "-18.43" represents the first time in all recorded years that surplus mercury has been a negative number. A negative surplus means that not only was the surplus exported but also that an extra exported amount was not reported as produced or imported during 2007. The explanation for this difference must lie with informal production (or with unregistered imports, a matter not considered here).

In other words, Mexico could not export more mercury than the total amount officially produced and imported and still satisfy its national consumption, unless the negative amounts actually correspond to informal production, or to other unreported reserves. The latter, for instance, might have come from the quantities of mercury "retired" from the Mexichem chlor-alkali plant that switched to mercury-free technology in 2007. After the conversion, the fate of the mercury from the mercury-chlor cells, which is estimated at around 36 tons (see **Section 4.1**, **Table 4-1**), was not documented, but it was possibly sold on the national market and then exported. This quantity must be considered part of the accumulated 74.37 tons of mercury not officially reported, or part of the "negative surplus" amounts generated during 2007–2009, as calculated below (see also **Table 5-2**).

“Negative surplus” of exported mercury
2007: -18.43 tons
2008: -44.24 tons
2009: -11.7 tons
Total: -74.37 tons

During this period, the retired amount from the closed chlor-alkali plant equals approximately 36 tons, and since approximately 74 tons of “negative surplus” mercury was calculated, informally produced mercury must have equaled about 38 tons.

Another argument that supports the idea that informal mercury production activities are occurring is the publicly available information on the Web and in newspapers which indicates that in Querétaro and Zacatecas mercury is being produced but not reported officially. For instance, the *Rotativo* newspaper, on 8 January 2007,[36] reported that at least six families have been mining and producing mercury in an artisanal manner, and that it is expected that some mines in Sierra Gorda, Querétaro, will be reopening and operating informally. Another newspaper in Zacatecas (*Imagen*, 28 June 2011) also reports informal mercury production in the Nuevo Mercurio mine; the notice indicates that five men have been extracting mercury for a company located in Monterrey during the last six months. Substantiating information is found in commercial messages on the Web offering mercury.[37] As there is evidence of the existence of informal mercury production, field research and a social-economic study are recommended.

[36] See <http://rotativo.com.mx/queretaro/detectan-contaminacion-de-mercurio-en-sierra-gorda-queretaro/698/html/>.
[37] See <http://www.imagenzac.com.mx/#>.

Table 5-2: Probable Informal Production of Mercury in Mexico, 1985–2009

(in metric tons)

(Data confidence rating level: High for Primary Production, Imports and Medium for Secondary Production and Domestic Consumption)

Year	Apparent supply			Exports	Estimated domestic consumption[4]	Positive surpluses of mercury	Negative surpluses (informal production and chlor-alkali conversion)
	Primary production[1]	Secondary production[3]	Imports				
1985	394	24.9	0.70[1]	92.00[1]	24.5	303.1	
1986	185	24.9	0[1]	154.00[1]	24.5	32.4	
1987	124	24.9	0[1]	121.00[1]	24.5	3.4	
1988	345	24.9	0.40[1]	142.00[1]	24.5	203.8	
1989	651	24.9	276.10[1]	91.00[1]	24.5	836.5	
1990	735	24.9	0.40[1]	23.20[1]	24.5	712.6	
1991	340	16.4	2.15[1]	0.30[1]	24.5	333.75	
1992	21	16.4	101.90[1]	1.90[1]	24.5	112.9	
1993	12	24.9	40.50[1]	0.30[1]	24.5	52.6	
1994	11	24.9	27.80[1]	0.30[1]	24.5	38.9	
1995	0	33.3	9.87[2]	0.31[2]	24.5	18.36	
1996	0	33.3	7.74[2]	4.00[2]	24.5	12.54	
1997	0	33.3	8.21[2]	7.01[2]	24.5	10	
1998	0	33.3	19.80[2]	0.24[2]	24.5	28.36	
1999	0	33.3	26.38[2]	54.02[2]	24.5	5.66	
2000	0	33.3	9.60[2]	6.22[2]	24.5	12.48	
2001	0	30.85	52.06[2]	15.41[2]	24.5	43	
2002	0	23.4	43.84[2]	4.39[2]	24.5	38.35	
2003	0	23.4	21.09[2]	2.38[2]	24.5	17.61	
2004	0	23.4	24.77[2]	0.66[2]	24.5	23.01	
2005	0	23.4	26.21[2]	5.92[2]	24.5	19.19	
2006	0	23.4	21.46[2]	8.14[2]	24.5	12.22	
2007	0	23.4	4.03[2]	21.36[2]	24.5		-18.43
2008	0	23.4	15.34[2]	58.48[2]	24.5		-44.24
2009	0	23.4	26.09	36.69	24.5		-11.7
Total	2,818.00	649.85	766.44	759.23	612.5	2,862.56	-74.37

Sources: [1]*Consejo de Recursos Minerales*. *Anuarios Estadísticos de la Minería Mexicana*: 1983-1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994 and 1995. Collection available at: <http://www.sgm.gob.mx/index.php?option=com_content&task=view&id=157&Itemid=44&seccion=Productos>.
[2]*Secretaría de Economía* (Secretariat of Economy) 2008. SIAVI < http://www.economia-snci.gob.mx/siavi4/fraccion.php>, consulted 28 November 2007 and 6 June 2008.

[3]Figures were estimated based on historical information from: *Gobierno del Estado de Zacatecas* (Government of the State of Zacatecas) 2002; CEC 1998; Profepa, official communication 1996; and Ogura et al. 2003. Amounts are also estimated based on Table 2-4.
[4] The estimate of 24.5 tons corresponding to yearly domestic consumption is based on data from 2008; it is probably an underestimate for the years 1985–1994 when mercury primary production was high; however, no official information is available.

Summary

Total informal production of mercury during 2007–2009 is estimated to be approximately 38 tons, which gives an annual average of a little less than 13 tons.

5.3 Potential Supply of Secondary Mercury from End-of-life Products

Along with the possible increase in informal primary mining as a factor in the future supply of mercury in Mexico, there is a quantity of secondary mercury that could become available as recycling programs become instituted; however, the incipient recycling market faces serious challenges.

In developed countries (for example, the United States), mercury recycling became established at a time, over the last decade, when the price of mercury and the quantity available made recycling economically viable, because:

- The generators (or manufacturers) of the waste mercury-containing products could afford to pay the cost of recycling; and
- Possibilities of selling recovered mercury on the international market were good.

In Mexico today, however, mercury recycling programs must be established under different conditions. The viability of a recycling business or program will be affected by:

- An absence of investors interested in the mercury-recycling business because the cost of recycling is high, in part due to Mexican regulations (and high cost will affect demand, lowering business); and
- The future disappearance of legal markets for recovered mercury, which will force recyclers (or customers) to pay the cost of the final confinement or stabilization.

These economic conditions mean that the success of an effective national mercury collection and retirement program will depend heavily on strong government support.

If such a program were initiated right away and supported to the extent that sale of this secondary mercury to the international market could occur within the next two years, before the international ban policy comes into effect, this could contribute to discouraging informal primary mercury mining.

CHAPTER 6 FINDINGS AND RECOMMENDATIONS

This chapter describes the main findings of this report and develops a recommended path forward for the best management of any excess mercury supply in Mexico.

6.1 Findings

The current situation of the national and global mercury market is characterized by:

- An increase in international demand for mercury (reflected in Mexican exports), especially from artisanal gold–producer countries;
- A significant increase in mercury prices on the international market; and
- Informal mercury mining taking place in Mexico, attested to by at least three sources of information:
  - Import-export statistics, indicating more exports than recorded by official sources for total amounts of mercury produced and imported;
  - Reports by journalists, referring to informal artisanal production in Querétaro and Zacatecas; and
  - Commercial advertising on the Web, offering literally tons of mercury for sale.

Primary formal and informal production

- Although mercury mining officially ceased in 1994, due to a significant reduction in the global demand for mercury, the physical infrastructure of the mines that were productive at the time still exists and the mines can be reactivated, for either formal or informal mining. There are indications that some of these mines are in fact in "informal" operation at present. A preliminary estimate of the potential national reserves yields approximately 42,000 tons.
- The estimate of informal mercury production during 2007–2009 (**Section 5.2**) yields an annual average of a little less than 13 tons.[38]
- Commercial advertising on the Internet by companies and individuals wishing to retail mercury indicates an active Mexican mercury market.

Because of its historic role as a primary mercury producer, Mexico possesses latent conditions to produce at least 40–50 tons/year of primary mercury now (by formal or informal methods), with even more potential for the years ahead. In fact, as this report was being brought to conclusion, the Mexican Tariff Information System via the Internet (SIAVI) reports mercury exports from January to September 2011 in the amount of 82.88 tons. For imports, this system also reports 13.86 tons (10.35 tons brought from Kyrgyzstan and 3.45 from Spain). If we assume that

[38] The confidence rating for the 42,000-ton estimate of potential reserves is considered to be "Medium," since this number is based on unverified data. The estimate of 13 tons for annual informal production should be considered as "Medium" as well, since the data for this conclusion are limited.

secondary production of mercury from Colonial tailings amounts to approximately 20 tons, the primary mercury produced informally for this period might be around 49 tons.[39]

- The export bans now in effect in the EU and due in the US in 2013 may trigger further increases in the price of mercury, likely motivating more Mexican production, either formal or informal or both, especially since the costs of informal mercury production in Mexico are relatively low.

Sources of secondary production

Tailings

- It is estimated that Zacatecas state has about 7,000 to 14,000 tons in potential secondary mercury reserves from tailings generated by previous silver-mining activities. Potential reserves that could possibly be recycled but have not yet been quantified are found in Hidalgo, San Luis Potosí, Guanajuato, Durango and Chihuahua.
- There is currently secondary production of mercury happening in two existing reprocessing plants in Zacatecas, amounting to around 23 tons per year. An increase in this level of production in these plants depends on: the availability of tailings containing silver and mercury; mercury content in these tailings; and silver and mercury prices and demand. The potential installed capacity to produce mercury in these two plants is approximately 45 tons per year.

The chlor-alkali sector

- The available mercury in the two remaining chlor-alkali plants that use mercury technology is estimated to be approximately 265 tons, which will become available once these plants change to mercury-free technology.

Recovery from end-of-life products

- The incipient secondary production of mercury recovered from end-of-life mercury-containing products is influenced by two factors:
    - The uncertain outlook on the mercury market in the not-too-distant future, when the international bans on commerce in mercury take effect, after which recyclers (or customers) will likely have to pay the costs of final confinement or stabilization of recovered mercury; and
    - The absence of investors for the national recycling mercury business, due to the uncertainties identified above and to high recycling costs.
- Considering the above-mentioned issues, Mexico faces a challenge to develop as soon as possible a strategy for implementing recycling programs and safe storage for the recovered

[39] See *Sistema de Información Arancelaria Vía Internet* <http://www.economia-snci.gob.mx/siavi4/fraccion.php>. Consult fracción arancelaria No. 28 05 40 01.

mercury and, in the meantime, to sell the mercury recovered from products, at least during the next four or five years, as an alternative means of reducing future surpluses of mercury in the country, and responding to demand from countries where mercury is still needed.

By-product mercury

- Investigations for this report found that recovery of by-product mercury is not taking place at present. Instead, waste generated containing mercury is disposed in environmentally sound conditions or is released to different environmental media. This is an issue that should be well studied.

6.2 Recommendations

Through a joint effort by the Secretariat of Economy and Semarnat, Mexico should develop a strategy for the management of mercury that encompasses the following recommendations.

1) Develop a regulatory framework for mercury, derived from current environmental, health and economic regulations and taking into account the following issues:
   - A ban on primary mercury production in Mexico;
   - Promotion of initiatives for the recycling of mercury; and
   - Long-term storage for elemental mercury and mercury-containing wastes.

2) Carry out an assessment of current informal production of mercury in Mexico and of future prospects for formal and informal production. This assessment should incorporate and be based on the results of the following measures:
   - Develop and undertake a socio-economic study on the informal-mining communities in Querétaro and Zacatecas, which would assess the current situation in these states, taking into account the number of people who are making a living from mercury production and supply.
   - Create an inventory of mines in Mexico that would include:
     - The type of mine (underground or open pit);
     - Its legal status (granted to a party or abandoned);
     - A determination of whether it is currently being explored formally or informally and how it has been explored in the past; and
     - An estimate of the possible reserves of mercury.
   - Develop and undertake a study to assess how and to what extent artisanal gold mining using mercury amalgamation is occurring in Mexico (an issue that has not been covered in this report).
3) Develop and implement a national mercury collection and retirement program that would include the following components:
   - Temporary storage of waste/recycled mercury;

- Mercury stabilization technologies;
- Final disposal of mercury; and
- Regional infrastructure.

4) Develop and implement as soon as possible a strategy for temporary storage of mercury-containing wastes in Mexico, pending recycling.
5) Develop and implement as soon as possible a plan for the temporary storage of mercury recovered from collection and recycling, until programs come into effect and an official location for temporary storage is selected.
6) Develop and conduct a technical feasibility study on the final disposal of mercury.
7) Develop a strategy, through a joint effort with Cydsa, the UN Environment Program, and the appropriate Mexican authorities, to formulate a strategy for managing approximately 265 tons of mercury that will be available from the two functioning chlor-alkali facilities when these plants change to mercury-free technology.
8) Develop and implement a strategy for the continuing elimination of mercury in products and processes.
9) Implement, through a joint effort with national customs authorities of Mexico and other countries, a mechanism to monitor the actual imports and exports of mercury and mercury-containing products, including mercury compounds.
10) Assess and work toward enacting in the near future a ban on exports of mercury from Mexico, as well as on imports of mercury to Mexico from other countries; and, if such a ban is pursued, develop a working group with the CEC (and, if necessary, representatives of the EU countries) to study the impact of the global mercury market.

In order to support and advance the implementation of the proposals above, the following mechanisms are suggested.

1) Convene a national meeting(s) of all key and interested sectors and stakeholders, with the initial objectives:
    - To disseminate information on mercury-related issues ;
    - to facilitate communication;
    - to initiate joint efforts and recourses dedicated to avoiding mercury uses and releases; and
    - to elaborate and submit a draft for a National Mercury Action Plan.
2) Hold a multinational workshop, with the support of the CEC and UNEP, on moving forward with Mexican commitments to international initiatives, such as the UNEP mercury program and the CEC's North American Sound Management of Chemicals (SMOC) Initiative. The workshop should pursue the following objectives:
    - Prepare and submit a proposal for a multilateral plan (involving the mercury-consumer countries) for an environmentally sound transition period toward the anticipated international cessation of almost all mercury uses, that ensures movement of mercury between countries would be prevented, taking into account:

  - the unique situation of Mexico, in relation to its potential primary and secondary reserves of mercury;
  - the fact that Mexico has the latent conditions to allow it to compensate gradually (starting in two to three years) for the supply gap that will result from the international ban policies adopted by the EU and the US; and
  - the possible growth in mercury demand from some countries which have artisanal, small-scale gold-mining operations.
- Bring together representatives from the following sectors, among others:
  - the artisanal gold producers industry;
  - staff of the government authorities for environment and for mineral resources, from the mercury-consumer countries where artisanal gold mining is taking place;
  - representatives of the United Nations Industrial Development Organization (UNIDO), UNEP, The World Health Organization (WHO), and the United Nations Development Programme (UNDP); and
  - customs authorities at the national and international levels.
- Assess the regional factors involving the supply, demand and production of mercury in the immediate and more distant future in order develop the best plan to accomplish the objective of eliminating anthropogenic emissions of mercury.

Finally, it is important to note that some of these recommendations coincide with elements of the UNEP International Legally Binding Instrument on Mercury (LBI) currently being discussed by many countries. As a result, the timescale for some of the recommendations included here might depend on the schedule set in the LBI for the Parties signing and ratifying that instrument.

APPENDIX 1: LISTS OF MERCURY AND MERCURY-ASSOCIATED METALS MINES

No.	Mine Name	Mineral Contents	Physical Status	Latitude/ Longitude	Municipality
1	La Cantera	Hg	Abandoned		Ojinaga
1	**Total Chihuahua**				
1	La Colorada	Au, Ag, Hg	Abandoned		Parras
1	**Total Coahuila**				
1	Cerro Blanco Norte	Hg, Sb	Abandoned		Cuencamé
2	Cerro Blanco Sur	Hg, Sb	Abandoned		Cuencamé
3	La Escondida	Hg, Sb	Abandoned		Cuencamé
4	La Envidia	Hg, Sb	Abandoned		Cuencamé
5	La Blanca	Hg, Sb	Abandoned		Cuencamé
6	Fabalena	Hg, Sb	Abandoned		Cuencamé
7	Chapala	Hg, Sb	Abandoned		Cuencamé
8	Tentaciones	Hg, Sb	Abandoned		Cuencamé
9	El Ranchito	Hg, Sb	Abandoned		Cuencamé
10	Cerro Prieto	Hg, Sb	Abandoned		Cuencamé
11	Palomas	Hg, Sb	Abandoned		Cuencamé
12	El Perro	Hg, Sb	Abandoned		Cuencamé
13	El Caballo	Hg, Sb	Abandoned		Cuencamé
14	El Gallo	Hg, Sb	Abandoned		Cuencamé
15	El Arbolito	Sb, Hg	Abandoned		Cuencamé
16	Pedernalillo	Sb, Hg	Abandoned	24°32’/ 103°35’	Cuencamé
17	La Roca	Sb, Hg	Prospect	24°47’/ 103°29’	Cuencamé
18	Mina De Palomas	Hg	Abandoned		Durango
19	La Fe	Hg, Mn.	Abandoned		El Oro
20	La Esperanza	Hg	Prospect		Peñón Blanco
21	La Alemania	F,Hg,Au	Abandoned		San Bernardo
22	Soledad	Au,Ag,Hg	Abandoned		San Bernardo
23	Agua Colorada	Au,Ag,Hg	Prospect		San Bernardo
24	Agua Colorada 2	Au,Ag,Hg	Prospect		San Bernardo
25	Agua Colorada 3	Au,Ag,Hg	Manifestación Pequeña De Mineral En Situ		San Bernardo
26	Bonanza	Au, Ag, Hg	Abandoned		San Bernardo

27	El Puerto	Au, Ag, Hg	Abandoned		San Bernardo
28	Pájaro Prieto 2	Au, Ag, Hg	Prospect		San Bernardo
29	El Cuarenta	Au, Ag, Hg	Abandoned	26°11'/ 105°30'	San Bernardo
30	Pájaro Prieto	Au, Ag, Hg	Prospect		San Bernardo
31	El Cuarenta Sur	Au, Ag, Hg	Abandoned		San Bernardo
32	Paralinse	Au, Ag, Hg	Abandoned		San Bernardo
33	Los Tiros	Au, Ag, Hg	Abandoned		San Bernardo
34	La Joya	Au, Ag, Hg	Abandoned		San Bernardo
35	El Cuarenta Oeste	Au, Ag, Hg	Low values		San Bernardo
36	La Paloma	Au, Ag, Hg	Abandoned		San Bernardo
37	Tulices 1	Au, Ag, Hg	Abandoned		San Bernardo
38	El Ojito	Au, Ag, Hg	Abandoned		San Bernardo
39	Tulices 2	Au, Ag, Hg	Abandoned		San Bernardo
40	Mina Alta	Hg, Au, Ag	Abandoned		San Bernardo
41	Las Auras	Hg, Au, Ag	Abandoned		San Bernardo
42	Las Vacas	Hg, Au, Ag	Abandoned		San Bernardo
43	La Paz	Hg, Au, Ag	Abandoned		San Bernardo
44	Mala Noche	Pb, Zn, Hg	Abandoned		San Juan De Guadalupe
45	Guadalupe	Hg	Abandoned	25°09'/ 104°32'	San Juan Del Rio
46	Mariana	Hg	Abandoned		San Juan Del Rio
46	**Total Durango**				
1	Santa Rita	Mn, Hg	Low values		Allende
2	La Lobera	Mn, Hg	Low values		Allende
3	La Magueyada	Hg	Abandoned		Atarjea
4	Fides	Hg	Abandoned		Atarjea
5	San Gerardo	Hg	Prospecto		Atarjea
6	El Terrero	Hg	Abandoned		Atarjea
7	La Blanca	Hg	Abandoned		Atarjea
8	El Salitrillo	Hg	Prospecto		Atarjea
9	Dos Amigos	Hg	Abandoned		Atarjea
10	La Centella	Hg	Abandoned		Atarjea
11	El Mago	Hg	Abandoned		Atarjea
12	El Águila	Hg	Abandoned		Atarjea
13	El Huerto	Hg	Abandoned		Atarjea
14	Enrique	Hg	Abandoned		Atarjea
15	La Centella	Hg	Abandoned		Atarjea

16	Estancia III	Hg	Abandoned		Dolores Hidalgo
17	Copal	Mn, Hg	Low values		Irapuato
18	Picachito	Mn, Hg	Low values		Irapuato
19	Picachito 2	Mn, Hg	Low values		Irapuato
20	Picachito 3	Mn, Hg	Low values		Irapuato
21	El Mercurio	Hg	Abandoned		Jerecuaro
22	La Víbora	Hg, Au, Ag	Low values		San Felipe
23	Las Tapias	Hg	Abandoned		San Felipe
24	Los Indios	Hg	Abandoned		San Felipe
25	El Carrizo	Mn, Hg	Low values		Santa Cruz De Juventino Rosas
26	El Amole	Mn, Hg	Low values		Santa Cruz De Juventino Rosas
27	Zarca	Mn, Hg	Low values		Santa Cruz De Juventino Rosas
28	Los Cuartos	Hg	Abandoned		Santa Cruz De Juventino Rosas
28	**Total Guanajuato**				
1	La Esperanza	Ag, Hg	Prospect		Ahuacuotzingo
2	La Esperanza	Hg, Cu	Abandoned		Ajuchitlan Del Progreso
3	San Gabriel	Cu, Hg	Prospect		Ajuchitlan Del Progreso
4	La Concepción	Hg	Abandoned		General Canuto A. Neri
5	Alicia	Hg	Prospect		General Canuto A. Neri
6	Coahuilote	Hg	Abandoned		Huitzuco De Los Figueroa
7	La Rosita	Hg, Au, Ag	Abandoned		Huitzuco De Los Figueroa
8	La Guillermina	Hg, Sb	Abandoned		Taxco
9	Huahuaxtla	Hg, Sb	Low values		Taxco
10	La Aurora	Hg, Sb	Abandoned		Taxco
11	Irsa	Cu, Hg	Abandoned		Tlapehuala
12	México 70	Cu, Hg	Abandoned		Tlapehuala
13	María Félix	Cu, Hg	Abandoned		Tlapehuala
14	La Esperanza	Cu, Hg	Abandoned		Tlapehuala
15	Las Lajitas	Cu, Hg	Abandoned		Tlapehuala

16	El Coacoyul	Cu, Hg	Abandoned		Tlapehuala
17	Andrómeda	Cu, Hg	Abandoned		Tlapehuala
18	Guerrero	Cu, Hg	Abandoned		Tlapehuala
19	México 70	Hg, Cu	Abandoned		Tlapehuala
20	María Félix	Hg, Cu	Abandoned		Tlapehuala
21	María Isabel	Hg, Cu	Abandoned		Tlapehuala
22	Las Fraguas	Hg, Cu	Abandoned		Tlapehuala
23	Las Veronas	Hg, Cu	Abandoned		Tlapehuala
23	**Total Guerrero**				
1	Noxtey 1	Sb, Hg	Low values		Tasquillo
2	Pontiu	Fluorite, Sn, Hg, Sb	Low values		Zimapan
2	**Total Hidalgo**				
1	Las Parotas	Hg, Ag	Abandoned		Tlatlaya
2	El Limón	Hg, Ag	Abandoned		Tlatlaya
3	Zicatecoyan	Hg, Ag	Abandoned		Tlatlaya
4	Cruz Del Sur	Hg, Ag	Abandoned		Tlatlaya
5	Gavilán	Hg, Ag	Abandoned		Tlatlaya
5	**Total México**				
1	San Antonio	Hg	Abandoned		Epitacio Huerta
1	**Total Michoacán**				
1	El Capomo	Ag, Au, Zn, Hg	Prospect		La Yesca
2	San Rafael	Au, Ag, Zn, Hg	Prospect		La Yesca
2	**Total Nayarit**				
1	Capricornio	Au, Ag, Hg	Prospect		San Juan Del Estado
2	Los Tejocotes	Sb, Hg.	Abandoned		San Juan Mixtepec
3	La Guajolota	Sb, Hg	Abandoned		Santiago Juxtlahuaca
3	**Total Oaxaca**				
1	Camino Al Cielo	Hg	Abandoned		Pinal De Amoles
2	La Rosita	Hg	Abandoned		Pinal De Amoles
3	El Rodadero	Hg	Abandoned		Pinal De Amoles
4	Todos Los Santos	Hg	Abandoned		Pinal De Amoles
5	Otates	Hg	Abandoned		Pinal De Amoles
6	Encinos	Hg	Abandoned		Pinal De Amoles
7	La Soledad	Hg	Abandoned		Pinal De Amoles
8	El Ratón	Hg	Abandoned		Pinal De Amoles
9	La Cruz	Hg	Abandoned		Pinal De Amoles

10	Guadalupe	Hg	Abandoned		Pinal De Amoles
11	Maravillas	Hg	Abandoned		Cadereyta De Montes
12	Palo Santo	Hg	Abandoned		Cadereyta De Montes
13	La Fe	Hg	Abandoned		Cadereyta De Montes
14	La Barranca	Hg	Abandoned		Cadereyta De Montes
15	La Negrita	Hg	Abandoned		Cadereyta De Montes
16	San Carlos	Hg	Abandoned		Cadereyta De Montes
17	El Niño	Hg	Abandoned		Cadereyta De Montes
18	El Cascaral	Hg, Ag, Zn	Abandoned		Cadereyta De Montes
19	Lorena	Hg	Abandoned		Cadereyta De Montes
20	La Pastilla	Au, Hg	Abandoned		Cadereyta De Montes
21	Calabacillas	Hg	Abandoned		Cadereyta De Montes
22	Cedro	Hg	Abandoned		Peñamiller
23	Balcones	Hg	Abandoned		Peñamiller
24	Los Gallos	Hg	Abandoned		Peñamiller
25	Las Flores	Hg	Abandoned		Peñamiller
26	Sonia	Hg	Abandoned		Peñamiller
27	La Liga	Hg	Abandoned		Peñamiller
28	El Bordo	Hg	Abandoned		Peñamiller
29	La Esperanza	Hg	Abandoned		Peñamiller
30	Camargo	Hg	Abandoned		Peñamiller
31	La Tranca	Hg	Abandoned		Peñamiller
32	La Estrella	Hg	Abandoned		Peñamiller
33	J. Bernardo	Hg	Abandoned		Peñamiller
34	El Rosario	Hg	Abandoned		Peñamiller
35	El Carnicero	Hg	Abandoned		Peñamiller
36	La Sorpresa	Hg	Abandoned		Peñamiller
37	El Muerto	Hg	Abandoned		Peñamiller
38	Morelos	Hg	Abandoned		Peñamiller
39	Providencia	Hg	Abandoned		Peñamiller
40	El Sótano	Hg	Abandoned		Peñamiller
41	Santo Niño	Hg	Abandoned		Peñamiller
42	Tres Marias	Hg	Abandoned		Peñamiller
43	El Mono	Hg	Abandoned		Peñamiller
44	La Colmena	Hg	Abandoned		Peñamiller
45	Los Pájaros	Hg	Abandoned		Peñamiller
46	Ma. De La Paz	Hg	Abandoned		Peñamiller
47	Cristo Rey	Hg	Abandoned		Peñamiller
48	Sótano	Hg	Abandoned		Peñamiller

49	La Colonia	Hg	Abandoned		Peñamiller
50	La Campaña	Hg	Abandoned		Peñamiller
51	Esperanza	Hg	Abandoned		Peñamiller
52	Palmas	Hg	Abandoned		Peñamiller
53	La Fe	Hg	Abandoned		Peñamiller
54	Mezquite	Hg	Abandoned		Peñamiller
55	Peña Blanca	Hg	Abandoned		Peñamiller
56	Rosita	Hg	Abandoned		Peñamiller
57	Las Minitas	Hg	Abandoned		Peñamiller
58	La Zorra	Hg	Abandoned		Peñamiller
59	La Negra	Hg	Abandoned		Peñamiller
60	San Antonio	Hg	Abandoned		Peñamiller
61	La Flor	Hg	Abandoned		Peñamiller
62	La Caro	Hg	Abandoned		Peñamiller
63	Guadalupe	Hg	Abandoned		Peñamiller
64	San Javier	Hg	Abandoned		Peñamiller
65	El Carmen	Hg	Abandoned		San Joaquín
66	El Caporal	Hg, Pb, Zn	Prospect		San Joaquín
67	Las Calabacillas	Hg	Prospect		San Joaquín
68	El Otatal	Hg	Abandoned		San Joaquín
69	Santa Rita	Hg	Abandoned		San Joaquín
70	El Coyote	Hg, Zn	Prospect		San Joaquín
71	Los Puerquitos	Hg	Abandoned		San Joaquín
72	Esperanza	Hg	Abandoned		San Joaquín
73	Tres Estrellas	Hg	Abandoned		San Joaquín
74	Niños Héroes	Hg	Abandoned		Toliman
75	La Morada	Hg	Abandoned		Toliman
75	**Total Querétaro**				
1	La Manga	Sn, Hg, Sb	Producing		Ahualulco
2	Los Cerritos	Au, Ag, Hg	Low values		Armadillo De Los Infante
3	El Polvo	Au, Ag, Hg	Low values		Armadillo De Los Infante
4	La Fortuna	Hg	Low values		Catorce
5	El Astillero	Hg	Abandoned		Charcas
6	Mefistófeles	Hg	Abandoned		Charcas
7	Picachos (N)	Hg, Sb	Abandoned		Charcas
8	Las Magdalenas	Au, Ag, Hg	Abandoned		Charcas
9	Las Lajas	Hg	Abandoned		Charcas

10	Las Lajas - Junchape	Hg	Low values		Charcas
11	Mesa Los Caballos	Hg	Abandoned		Charcas
12	Caballos (W)	Hg	Abandoned		Charcas
13	Las Presitas	Au, Ag, Hg	Prospecto		Charcas
14	El Tecolote I	Hg	Abandoned		Charcas
15	El Tecolote II	Hg	Abandoned		Charcas
16	El Cobre Chiquito	Hg	Abandoned		Charcas
17	Guadalupe	Hg, Sb	Abandoned		Charcas
18	El Pájaro	Zn, Pb, Ag, Hg	Prospect		Charcas
19	San Basilio	Hg	Prospect		Charcas
20	La Tinaja	Hg	Abandoned		Charcas
21	Eloriza	Hg	Abandoned		Charcas
22	El Socavón	Hg	Abandoned		Guadalcazar
23	La Constancia	Hg	Abandoned		Guadalcazar
24	El Quijote	Hg	Abandoned		Guadalcazar
25	El Lorito	Zn, Pb, Hg, Ag	Low values		Guadalcazar
26	Los Yugos	Hg	Abandoned		Guadalcazar
27	La Trinidad	Hg	Abandoned		Guadalcazar
28	Tatanaya	Hg	Abandoned		Guadalcazar
29	San Martin	Hg	Abandoned		Guadalcazar
30	Los Timones	Hg	Abandoned		Guadalcazar
31	Corinto	Hg	Abandoned		Guadalcazar
32	Guadalupe	Hg	Abandoned		Guadalcazar
33	San Antonio	Hg	Abandoned		Guadalcazar
34	Los Patos	Hg	Low values		Guadalcazar
35	Peña Colorada	Hg	Abandoned		Guadalcazar
36	Las Candelas	Hg	Abandoned		Guadalcazar
37	Las Chagoyas	Hg	Abandoned		Guadalcazar
38	La Constancia	Hg	Producing		Guadalcazar
39	El Socavón	Hg	Producing		Guadalcazar
40	Quijote II	Hg	Producing		Guadalcazar
41	El Corto	Hg, Sb, Sn	Producing		Mexquitic De Carmona
42	Picacho De Santa Genoveva	Hg, Sb, Sn	Producing		Mexquitic De Carmona

43	Morados	Hg, Ag	Low values		Moctezuma
44	San José Del Grito	Hg	Low values		Moctezuma
45	Mojoneras Antiguas	Au, Hg	Producing		Moctezuma
46	Estanco I	Sn, Ar, Hg	Producing		Moctezuma
47	La Paisana	Hg	Low values		San Luis Potosí
48	San Sebastián	Hg	Abandoned		San Luis Potosí
49	Las Coloradas	Hg	Low values		San Luis Potosí
50	Santa Cruz	Hg	Abandoned		Santa María Del Rio
51	La Capilla	Au, Ag, Hg	Abandoned		Soledad De Graciano Sánchez
52	El Horno	Au, Ag, Hg	Abandoned		Soledad De Graciano Sánchez
53	Cinco De Febrero	Au, Ag, Zn, Hg, Pb, Cu	Abandoned		Venado
54	Coronado	Hg	Abandoned		Villa De Guadalupe
55	La Presa	Au, Ag, Hg	Manifestación Pequeña De Mineral En Situ		Villa Hidalgo
56	Las Palmas	Sb, Hg	Producing		Villa Hidalgo
56	**Total San Luis Potosí**				
1	La Minita	Hg	Abandoned		Fresnillo
2	La Loma Blanca1	Hg	Abandoned		General Francisco R. Murguía
3	El Patrocinio	Hg	Abandoned		General Francisco R. Murguía
4	San Juan	Hg	Abandoned		General Francisco R. Murguía
5	Carolina	Hg	Abandoned		General Francisco R. Murguía
6	Progreso	Hg	Abandoned		General Francisco R. Murguía
7	La Pringa	Hg	Abandoned		General Francisco R. Murguía
8	Loma Alta	Hg	Abandoned		General Francisco R. Murguía
9	El Afinador	Hg	Abandoned		General Francisco R. Murguía
10	Seis De Enero	Hg	Abandoned		General Francisco R.

					Murguía
11	El Rey Baltasar	Hg	Abandoned		General Francisco R. Murguía
12	El Buby	Hg	Low values		General Francisco R. Murguía
13	Mérida	Hg	Abandoned		General Francisco R. Murguía
14	Las Minas	Hg	Abandoned		General Francisco R. Murguía
15	Falcón	Hg	Abandoned		General Francisco R. Murguía
16	Santa Rosa	Hg, Sb, Au	Abandoned		General Francisco R. Murguía
17	Santa Rita	Hg, Sb, Au	Low values		General Francisco R. Murguía
18	El Cristo 3	Hg, Sb, Au	Abandoned		General Francisco R. Murguía
19	El Cristo 2	Hg, Sb, Au	Abandoned		General Francisco R. Murguía
20	El Cristo 1	Hg, Sb, Au	Abandoned		General Francisco R. Murguía
21	El Gringo 1	Sn, Hg, Au	Abandoned		General Francisco R. Murguía
22	El Gringo	Sn, Hg, Au	Abandoned		General Francisco R. Murguía
23	Las Estrellas	Sn, Hg, Au	Abandoned		General Francisco R. Murguía
24	El Gringo 2	Sb, Hg, Au	Abandoned		General Francisco R. Murguía
25	Los Llanitos	Sn, Hg, Au	Abandoned		General Francisco R. Murguía
26	La Pelona	Sn, Hg, Au	Abandoned		General Francisco R. Murguía
27	Irma	Sb, Hg, Au	Abandoned		General Francisco R. Murguía
28	La Fortuna 1	Sn, Hg, Au	Abandoned		General Francisco R. Murguía
29	La Fortuna	Sn, Hg, Au	Abandoned		General Francisco R. Murguía
30	El Volcán 2	Sn, Hg, Au	Abandoned		General Francisco R.

					Murguía
31	Los Berrendos	Sb, Hg, Au	Abandoned		General Francisco R. Murguía
32	La Pinta	Hg, Au	Abandoned		Mazapil
33	La Roja	Hg, Au	Abandoned		Mazapil
34	La Mora	Hg	Abandoned		Mazapil
35	Santa Cristina I	Hg	Abandoned		Mazapil
36	Nuevo Mercurio	Hg	Abandoned		Mazapil
37	San Martin	Hg	En Producción		Mazapil
38	La Tinaja	Hg	Abandoned		Mazapil
39	El Cinabrio	Hg, Au	Abandoned		Melchor Ocampo
40	La Pinta	Hg, Ag, Au	Abandoned		Melchor Ocampo
41	El Tequesquite	Hg, Au	Abandoned		Rio Grande
42	San Martin	Au, Ag, Hg	Abandoned		Rio Grande
43	Santa Rosa	Hg	Abandoned		Sain Alto
44	Arroyo Hondo	Hg, Au	Low values		Sain Alto
45	El Sauz	Hg, Au	Abandoned		Sain Alto
46	El Tasajo III	Hg, Au	Abandoned		Sain Alto
47	El Tasajo II	Hg, Au	Abandoned		Sain Alto
48	El Tasajo	Hg, Au	Abandoned		Sain Alto
49	Mineral De Mercurio	Hg	Abandoned		Sain Alto
50	El Rosario	Au, Ag, Hg	Abandoned		Sain Alto
51	Mineral Mercurio	Hg	Abandoned		Sain Alto
52	El Triunfo II	Hg, Ag	Reactivated		Sombrerete
53	El Triunfo IV	Hg, Ag	Reactivated		Sombrerete
54	El Granel	Hg	Low values		Sombrerete
55	El Huracán	Hg	Low values		Sombrerete
56	Buenos Aires	Hg	Abandoned		Sombrerete
57	Buenos Aires	Hg	Abandoned		Sombrerete
58	Los Cuatillos	Hg	Prospect		Sombrerete
59	Pérez	Hg	Prospect		Sombrerete
60	El Encino	Hg	Prospect		Sombrerete
61	El Indio	Hg	Abandoned		Valparaíso
62	La Guadalupana	Hg	Prospecto		Valparaíso
63	San Antonio	Sb, Hg, Au	Abandoned		Villa De Cos
64	El Cochinillo	Hg, Mn	Abandoned		Villa De Cos
65	Minas Las Papas	Hg	Abandoned		Villa De Cos
66	La Sierpe	Hg	Abandoned		Villa De Cos

67	Canoas	Hg	Abandoned		Villa García
68	El Picacho	Hg	Abandoned		Villa García
69	La Esperanza	Hg	Abandoned		Villa García
70	Juan Álvarez	Hg	Abandoned		Villa García
71	El Paxtle	Hg	Low values		Villa García
71	**Total Zacatecas**				
314	**Total Mines**				

Mercury Mines in Mexico, Quoted in Maps

Name	Latitude	Longitude	Name	Latitude	Longitude
Chihuahua			Querétaro (cont)		
Luz Julieta	28°26’	107°05’	La Maravilla	20°55’	99°36’
Cerros Prietos	28°01’	105°21’	La Pequeña	20°54’	99°53’
Maijoma	28°56’	104°24’	La Barranca	20°53’	99°37’
San Miguel	28°18’	104°13’	La Lana	20°54’	99°37’
Nuevo Almadén	27°52’	108°30’	San Juan	20°50’	99°35’
Batopilillas	27°53’	108°27’	San Luís Potosí		
Piloncillos	26°51’	104°09’	C. Tecolote	23°11’	100°56’
Durango			El Socorro	23°03’	100°54’
Angelita	24°42’	103°32’	Huancavélica	23°00’	100°57’
Berrendo	24°46’	103°22’	Los Morados	22°50’	100°40’
El Colorado	26°04’	105°42’	San Juan	22°47’	100°40’
El Cuarenta	26°11’	105°30’	El 18	22°46’	100°40’
Guadalupe	25°09’	104°32’	Soc. el Refugio	22°45’	100°36’
La Gaviota	24°42’	103°26’	M. La Trinidad	22°39’	100°29’
La Perla	24°47’	103°29’	El Picachito	22°38’	101°10’
La Roca	24°27’	103°43’	Arroyo El Barro	22°37’	100°44’
La Sirena	24°42’	103°27’	Santa Julia	22°50’	100°39’
Otinada	24°03’	105°01’	El Socorro	22°50’	100°39’
Pedernalillo	24°32’	103°35’	Los Caliches	22°52’	100°35’
Rodeo	25°11’	104°31’	La Vocadora	22°48’	100°33’
San Pedro	24°38’	103°58’	Lupe 1 y 2	22°47’	100°33’
Sonrisa	24°40’	103°41’	Las Narices	22°46’	100°35’
Tebicos	23°58’	105°27’	El Padre	22°36’	100°44’
Estado de México			Agua Nueva	22°36’	99°51’
Sn. José de Solís	nd	nd	Zacatecas		
Cruz del Sur	nd	nd	Carbonerillas	24°29’	101°24’
Guanajuato			El Duraznillo	24°25’	101°25’
Atarjea	21°16’	99°41’	Tanquecito	24°22’	101°39’

Guerrero			San Benito	24°18’	101°34’
La Hedionda	18°15’	100°30’	El Orégano	24°18’	101°32’
Las 3 Marías	18°39’	99°44’	Cortes	24°16’	101°32’
Vicente Guerrero	18°25’	99°38’	La Arracada	24°15’	101°27’
La Cruz o Marina	18°17’	99°20’	C. El Muerto	24°14’	101°28’
Querétaro			Buena Suerte	24°08’	101°55’
La Sonia	21°14’	99°44’	El Triunfo	23°51’	103°24’
La Liga	21°14’	99°44’	El Castro	23°36’	103°13’
Los Banquitos	21°10’	99°40’	El Cuervo	23°25’	103°39’
La Mora	21°08’	99°36’	Los Hornillos	23°31’	103°52’
La Tranca	21°06’	99°43’	Los Cuates	23°12’	102°44’
Morelos	21°05’	99°41’	Mezquitillos	23°10’	102°47’
Soyatal	21°05’	99°41’	Lucia	23°06’	102°20’
El Mono	21°04’	99°42’	Canoas	22°10’	101°52’
Cristo Rey	21°03’	99°42’	Majona	23°50’	101°40’
Todos Santos	21°02’	99°36’	Maravillas	23°21’	103°51’
San Cristóbal	20°57’	99°39’	Total: 83 mercury mines		
Las Calabacillas	20°57’	99°38’			

Source*:* Compiled from Consejo de Recursos Minerales, *Monografía Geológico Minera de los Estados de*: Chihuahua, 1994; Durango, 1993; Estado de México, 1996; Guanajuato, 1992, Guerrero, 1999; Querétaro, 1992; San Luis Potosí, 1992; 1994; Zacatecas, 1991. As quoted in CEC 2000b.

APPENDIX 2: INITIAL LIST AND DESCRIPTION OF MERCURY/SILVER SECONDARY RESERVOIRS

Tailing areas where *haciendas de beneficio* were located and other areas likely polluted with mercury are listed and briefly described below. Also, **Figure 3-1** in the main report shows probable mercury reservoirs that are related to silver mining. Specifically silver-producing sites are listed below in the sections under the respective silver-producing State; however, they are not necessarily shown on the Map, as the intention there is to show the possible mercury-contaminated areas by amalgamation method. See also **Table 3-7** for a summary of sites considered mercury-containing tailings deposits.

Zacatecas State

According to historic and official information, it is estimated that one-third of all Mexican silver production in the Colonial and Postcolonial Periods was situated in Zacatecas. In consequence, if the amount of mercury released to tailings is equal to 73,473 tons, one-third of this, around 24,500 tons of mercury, probably still remains in Zacatecas State. If we deduct the mercury recycled there during the last one hundred years (around 2,000 tons, see **Table 3-7**) and the already estimated reserves in El Pedernalillo Reservoir (around 2,350 tons, see **Section 3.3**), and suppose that perhaps one-half of the historical tailings areas are perhaps now covered by urban development, it may be realistic to estimate the probable remaining, accessible reserves at between 7,000 and 14,000 tons.

Principal Silver Producing Sites in Zacatecas

Exploited during 16th and 17th centuries: San Bernabé (1548), La Albarrada (1548), Veta Grande (1548 to-date), Chalchihuites (1556), Saín Alto (1558), Ramos (1608), Ojocalinete (1608), Tepezala (1574), Sierra de los Pinos (1593), Ramos (1608), Sombrerete (1558) (Bakewell 1976, p. 354 (map)) and La Quebradilla (no date provided) (Sánchez-Santiró 2002)

Tailing Areas Where Haciendas de Beneficio Were Located and the Year of Their Foundation

Zacatecas (1548), Pánuco (1548); Fresnillo (1566), Sombrerete (1558), San Martín (1556), San Andrés (1556), Avino (1558), Nieves (1574), Chalchihuites (1556), Ranchos (1574), Santiago (1574), Cuencamé (n.d.), Cedros and Mazapil (1578), Charcas (1574), Sierra de Pinos (1603), Tacoaleche (n.d.) (Bakewell 1976, 354)

Zacatecas City Area

Mining operations started around 1547, when Zacatecas City was founded; by 1550, there were fifty mines in operation and thirteen amalgamation Patios dedicated to processing silver in a 4 km^2

area in and around the city (Bakewell 1976, pp. 23, 32); by the end of the 1550s, road infrastructure allowed mercury transportation to Zacatecas (Bakewell 1976, pp. 47, 354). In addition to these mines in Zacatecas, smaller mines were found in the neighboring towns of Fresnillo, Sierra de los Pinos, Chalchihuites, Mazapil, Nieves, Rio Grande, Charcas and Ramos (Bakewell 1976, p. 161).

Secondary Mercury Reserves

El Pedernalillo Reservoir

Situated in the area known as La Zacatecana, near Zacatecas City, there is a tailings deposit that lies within and around a depression, presently filled with water as a man-made reservoir, and surrounded by agricultural land. Several previous studies estimated the resource to contain 6 to 9 million tons of solids with around 50–60 grams of silver per ton, plus gold and mercury. The reservoir covers 120 hectares (ha) and has a surface area of 12 km by 2 km. The depth of water in the reservoir varies according to the amount of rain and can range from essentially dry to over three meters high. Wastewater is now diverted from the lagoon through several channels, but the water is still used for irrigating crops along a sloping upstream surface (Pan American Silver Corp. 1995).

Tailings in El Pedernalillo were deposited through stream action and flood events in a large area to the east of Zacatecas.

Reserves in El Pedernalillo Reservoir are estimated to be:

Tailings containing Ag, Au and Hg: 8,624,837 metric tons

Silver: 389.7 metric tons

Gold: 1.08 metric tons

Mercury: 2,349 metric tons (Ward 2005)

Fresnillo

Discovered in 1554, from 1717 to 1751 mining in this area was initially performed by small groups of miners. The main amalgamation activities were in Cerro Proaño; the main hacienda de patio was Hacienda Proaño, built in 1842, with a capacity of 140 tons/day ore processing.

According to information consulted, it is probable that Fresnillo lacks significant quantities of tailings because the lixiviation method was implemented in 1900 and around 2,000,000 tons of tailings were treated (CRM 1991).

Sombrerete

As quoted in Bakewell, important silver production occurred during the XVII century; however, the proportion of silver produced by the smelting process is not known. A more detailed study is recommended (see **Appendix 1**, where results of chemical analysis are presented).

Other Important Sites in Zacatecas State

After the foundation of Zacatecas City, conquistadores organized expeditions to find other silver seams. During succeeding centuries, other small mining districts were founded.

Hidalgo

Pachuca-Real del Monte area

Pachuca, the present capital city of Hidalgo State, and Real del Monte are some of the most important mining districts (together with Zacatecas and Guanajuato). The mines in Pachuca were discovered in 1552. Silver has been continually produced from that time up to the present.

The Patio Method, discovered by Bartolomé de Medina, was implemented for first the time in the Hacienda la Purísima in Pachuca in 1555 (Lang 1977).

Mining Districts

The four main Reales de Minas (royal mines) founded in the middle of XVI century in the region are: Real de Tlahuililpan or Tlaulilpa (Pachuca), town council, where the main economic and political activities took place; Real del Monte; Real de Arriba (San Miguel del Cerezo); and Real de Atotonilco (Atotonilco el Chico, and present-day Mineral del Chico) (Cubillo 1991, p. 34, as quoted in Saavedra and Sánchez 2008).

Mines

The Compañía Minera Real del Monte controlled the production of more than one hundred mines located around the Real del Monte and Pachuca (Saavedra and Sánchez 2008, p. 97), among them an important one: La Vizcaína in Real del Monte (Sánchez-Santiró 2002, p. 127).

Tailing areas where Haciendas de Beneficio were located

San Juan, Regla, San Antonio, San Miguel, Sánchez, La Nueva, Velasco, Loreto, Guadalupe

Secondary Mercury Reserves

Hidalgo State contributed with around 16% of Mexican silver production until 1950 (CRM 1992d). Considering that the national silver production from the amalgamation method was 93,299 tons, as much as 14,928 tons of silver were produced here, and mercury released to soil in this region probably was around 11,756 tons.

The CRM information, from the cited District, reports the existence of 107,659,225 tons of tailings with values of 0.18 g/ton of gold and 46.93 g/ton of silver (CRM 1992d); if the mercury proportion is considered in 60 g/ton, then around 6,500 tons may probably remain in tailings (this quantity represents less than one-half the amount mentioned in the previous paragraph).

It is important to consider that the metropolitan area of Pachuca grew on sites where haciendas de patio and mines were located, (Saavedra and Sánchez 2008, p. 97); important volume of tailings containing mercury and silver are covered. However, a local and more specific study is recommended

Guanajuato

The area around Guanajuato City is considered one of the major silver producing regions in the world: it is estimated that around 95 million tons of ore were processed using the smelting and Patio methods (CRM 1992a). The Patio method was used in Guanajuato from 1648 to 1905; from 1905 to the present, silver has been produced by the cyanidation method; and from 1946 to the present, the flotation method has been implemented (Ramos-Arroyo et al. 2004, p. 268)

Main Silver Mines

La Luz, Bolañitos, Sirio, Golondrinos, San José, San Pedro Xilmonene, Asunción, Monte de San Nicolás, Pasadena, Albertina, El Cubo, Copenhagen, Cebada; San Elías, Guanajuatito, La Valenciana, Tepeyac, Cata, Rayas, Mellado, Garrapata, Aparecida, La Sirena, Las Torres Cedro, Purísima, Santo Niño and El Nayal (Ramos-Arroyo et al. 2004, pp. 272 and 275)

Haciendas de Patio

In the area surrounding Guanajuato city approximately 45 haciendas were in operation, most of them located along the banks of the Guanajuato River (Jáuregui de Cervantes 1996, as quoted in Ramos-Arroyo et al. 2004, p. 275)

Estimated mercury-containing tailings area

Ramos-Arroyo et al. estimate that approximately 95 million metric tons of tailings and waste were dispersed at forty different points in an area of 100 square kilometers, and that 20 million metric tons made their way into the sediments of the Guanajuato River (Ramos-Arroyo et al. 2004, p. 278). Local and more specific study is recommended to ascertain if valuable metal ores remain in the river sediments.

Reported tailings reprocessing activities and secondary mercury production in Guanajuato

Ramos-Arroyo et al. also reported that probably from 1905 to 1930 silver-mercury recovery operations took place utilizing tailings and low grade ores using the cyanidation method (Ramos-Arroyo et al., 2004, p. 279). No information related to volumes of precious metal and mercury recovered is reported.

Based on the CRM mining monograph for Guanajuato State, Ramos-Arroyo et al. also reported that around 20 million metric tons of tailings were deposited in the Santa Teresa Valley—sediments that may be a potential source for secondary gold production yielding approximately 0.3 grams per metric ton of tailings (CRM 1992a). Assuming a yield of 60 grams of mercury per ton, probably 1,200 tons of mercury may be present and recoverable in Santa Teresa.

Jalisco

Colonial silver mining started in 1548 when the Bolaños deposit was discovered, other important mines are Espíritu Santo, Xaltepec, Xonotlán, Etzatlán, Guachinango and Purificación. In 1552–1556, Mololoa, Villa de San Sebastián, and los Reyes Oxtotipac were important mining districts.

In the XVII century, the main mining districts were Chimaltitlaá, Xora, Ocotitlán, La Resurección and the mines of Maloya and San Marcial. In the XVIIIth century, Santa María de las Flores was an important district. In the XIXth century, the vein of Cuale and El Bramador produced important quantities of silver. In the XXth century, mining activity decreased.

Zones of Tailings

In El Barqueño district, two sites are reported: La Pilarca and Peña de Oro, where an area with 1,000,000 tons of tailings with 1.5 to 2 g gold/ton is reported (CRM 1992b, p. 61). If the mercury proportion is considered as 60 g/ton, then around 6 tons may perhaps remain in these tailings.

San Luis Potosí

In some periods this state has been the third- or fourth-largest silver producer. The city of San Luis was founded in 1592; near the city, the first silver strike was Cerro de San Pedro, which initiated operations in1583 (Bakewell 1976, p. 52). Other important districts were Charcas and Mazapil discovered at the end of the sixteenth Century. Real de Catorce, another important district, with important silver production between 1610 and 1620.

A local and more specific study is recommended.

Durango

Durango was discovered in 1563; an important district is the Santa Barbara mines, discovered at the end of the XVIIth century. By 1897, there were 709 silver mines and 69 Haciendas de Patio; of which the most important were: Birimoa, Guanacevi, Guarisamey and Sianory.

Also gold amalgamation activities were reported in San Miguel del Cantil, Pueblo Nuevo and Magistral del Oro (Secofi 1996).

Chihuahua

In Chihuahua the most important district is Parral, which was discovered in 1547 and had an important productive period from 1630 to 1650 (Lang 1977; Bakewell 1976, p. 51).

In 1778 amalgamation activities were reported in the Uruachi District; in 1861, amalgamation activities were also reported in Cusihuiriachi and Pilar-Moris, Maguarichi, Temoris, Guazapares and Morelos (Secofi 1996).

Nayarit

In the Cucharas mining district eight haciendas de patio are reported, and in Águila de Oro and The Cebadillas mining districts where also silver and gold amalgamation took place (Secofi 1996).

State of Mexico

Silver-Gold recovering activities were important during the early Colonial times in Sultepec, Temascaltepec, Tetela, Chiautla, Chichicapa and El Oro (Lang 1977).

Michoacán

Tlalpujahua has been an important district since Colonial times, where six Haciendas de Patio are reported by the end of the XIX century (Secofi 1996).

In San Diego de Chupaceo district, and in another mineralized zone called El Ahijadero, silver and gold recovering activities using amalgamation are reported (Secofi 1996).

Guerrero

The most important silver mining district since 1534 is Taxco; little is known in regard to mercury consumption, as fire reduction was the main method used here to obtain silver mined from native rich veins (Talavera-Mendoza et al. 2005). Considering the importance of this region, a more detailed study related to mercury in tailings is recommended.

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