Preliminary Atmospheric Emissions Inventory of Mercury in Mexico

-Final Report-

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List of Symbols, Units and Acronyms

AHMSA	Altos Hornos de Mexico S.A. de C.V.
ANIQ	Asociación Nacional de la Industria Química, *(National Chemical Industry Association)*
CANAME	Camara Nacional de Manufacturas Electricas *(National Chamber of Electric Manufacture)*
CEC	Commission for Environmental Cooperation
CFE	Comision Federal de Electricidad *(Federal Electricity Commission)*
CNICP	Camara Nacional de las Industrias de la Celulosa y el Papel *(National Chamber of Pulp and Paper industries)*
DGGIA	Direccion General de Gestion e Informacion Ambiental *(General Directorate of Management and Environmental Information)*
DGMRAR	Direccion General de Materiales, Residuos y Actividades Riesgosas *(General Directorate of Materials, Waste and Risk Activities)*
DICTUS	Departamento de Investigaciones Científicas y Tecnológicas de la Universidad de Sonora *(University of Sonora Department of Scientific and Technological Research)*
DMT	Direccion de Materiales Toxicos *(Directorate of Toxic Materials)*
EPA	Environmental Protection Agency
GIS	Geographic Information System
Hg	Mercury
IMADES	Instituto del Medio Ambiente y del Desarrollo Sustantable del Estado de Sonora *(Sonora State Institute of Environment and Sustainable Development)*
IMMSA	Industrial Minera Mexico S.A. de C.V.
INE	Instituto Nacional de Ecología, *(National Institute of Ecology)*
INEGI	Instituto Nacional de Estadística Geografía e Informática, *(National Institute of Statistics, Geography and Information)*
kg	Kilogram
L	Liters
lb	Pounds
m	Meters
M	Thousand
m^3	Cubic meters
MACT	Maximum Achievable Control Technology
Maquiladora	In-bond manufacturing plant in Mexico
mg	Milligrams
MM	Millions
ng	Nanograms
PEMEX	Petroleos Mexicanos (The Federal State-owned oil company)
ppm	Parts per million
ppb	Parts per billion
ppbwt	Parts per billion in weight

....**List of Symbols, Units and Acronyms**

PROFEPA	Procuraduría Federal de Protección al Ambiente, *(Federal Bureau of Environmental Protection)*
RETC	Registro de Emisiones y Transferencia de Contaminantes *(Pollutant Release and Transfer Register)*
Ton	Metric tons
USGS	United States Geological Survey

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Appendices

1.0 Project Description

Acosta y Asociados (AyA) was contracted by the Commission of Environmental Cooperation to prepare a preliminary inventory of atmospheric emissions of mercury (Hg) from stationary sources in Mexico for the year of 1999. We have attempted to methodically carry out both primary and secondary research to build upon two previous studies of mercury air emissions and mercury-enriched sites in Mexico: the 1997 EPRI study coordinated by Bill Powers of Powers Engineering *(39)* and the May 2000 draft INE study coordinated by Jose Castro from *INE's Dirección de Materiales Tóxicos* (Toxic Materials Directorate) *(21)*. Mr. Powers was a subcontractor on this study and the Principal Investigator Gildardo Acosta worked very closely with Mr. Castro.

Some relevant information such as mercury content of smelters feedstock, heavy fuel oil, diesel fuel and carbon, required to estimate mercury emissions from potentially important sources, such as smelters and utilities, was directly requested by *INE's Dirección de Materiales Tóxicos* through an official letter of request. No information has been received as per the date of closing this report. The project team has to rely then in information directly obtained through interviews or by indirect approaches.

2.0 Project Background

The EPRI-funded study identified the lack of accurate data on Hg concentration in heavy crude oil and refined heavy fuel oil (*combustóleo*) as the major unknown in assessing with some degree of accuracy the Hg emissions associated with oil combustion in Mexico. Lack of information on airborne Hg emissions from the processing of ores at Mexican gold and silver mines was identified as a second major unknown in the inventory. Lack of data on Hg concentration in smelters feedstock was a third major unknown for a more precise estimation of Hg emissions from these sources. Preliminary Hg emission ranges for the first two of these source types were estimated in the EPRI study by: 1) identifying the maximum concentration of Hg in heavy crude oil based on available oil assay laboratory data; 2) evaluating Hg production rates and capture efficiencies of Hg control systems at large U.S. gold and silver mines to develop a range of Hg control efficiencies for Mexican gold and silver mining operations, and 3) by using U.S. EPA's emission factors for primary and secondary smelters.

Samples of carbon, coke, heavy fuel oil and diesel fuel were collected and sent for Hg analysis to U.S. laboratories. Additionally, arrangements were made with a Houston based laboratory to analyze four samples of PEMEX's Maya crude oil from some of its U.S. customers. Results are summarized in Appendix G.

3.0 Availability of Atmospheric Mercury Emissions Data for Anthropogenic Sources in Mexico

There is very limited official information on atmospheric mercury emissions from the source categories of interest in Mexico. Since 1998, mercury emissions have been regulated only for incinerator facilities of hazardous waste and medical waste, and for cement plants burning waste combustibles. No other sources are required to monitor their mercury emissions or to analyze mercury content in feedstock or wastes. Only emissions of Particles and of Combustion Gases are regulated and as such must be measured and reported annually. Project members reviewed files of the "*Registro de Emisiones y Transferencia de Contaminantes* (*RETC*)", Mexico's equivalent to the U.S. Toxic Release Inventory or the Pollutant Release and Transfer Register, submitted by several facilities of the source type of concern in Mexico, and found practically no data on Hg emissions nor Hg concentration in process feedstock or waste streams. This was the case even for gold mine operations that included mercury retorts and condensers in their process schematics or flow diagrams submitted to INE. For these reasons, a fundamental objective of the project has been to identify a comprehensive list of potential stationary sources of atmospheric mercury emissions in Mexico, to provide annual process throughputs for these sources and to the extent possible, to do primary sampling and analysis.

4.0 Anthropogenic Sources of Mercury Emissions in Mexico

Atmospheric emissions of mercury from the sources of interest in Mexico are estimated based on annual process throughputs for these sources, using commonly acceptable emission factors or available data on mercury content in feedstock or product. Unless otherwise specified, Ton units used in this report are metric tons.

4.1 Electric Power Generating Plants

By the end of year 2000 there were 172 electric power generating plants in operation in Mexico with five more scheduled for construction by 2005 *(24)*. 67 % of Mexico's total capacity to generate electricity is based on fossil fuel combustion processes.

TABLE 4.1 ELECTRICITY GENERATION CAPACITY BY TYPE OF TECHNOLOGY

(Megawatts)

TECHNOLOGY	1994	1995	1996	1997	1998	1999
Total	**31 649**	**33 037**	**34 791**	**34 815**	**35 256**	**35 666**
Hydraulic	9 121	9 329	10 034	10 034	9 700	9 618
Nuclear	675	1 309	1 309	1 309	1 309	1 368
Geothermal	753	753	744	750	750	750
Eolic	2	2	2	2	2	2
Fuel Combustion	21098	21644	22702	22720	23495	23928

Source: INEGI: *El Sector Energético en México, 2000*

The principal crude oil used by Mexican refineries as the feedstock to produce heavy oil, known as "*combustóleo,*" and various diesel fuel grades used in thermal power plants and industrial/ commercial boilers, is Maya crude oil. It is a heavy crude high in sulfur and trace metals. PEMEX does not perform Hg analyses on this crude, nor on refined products such as *combustóleo* or diesel. The CFE performs analytical test of PEMEX fuel oil samples used by their power generating facilities. Mercury is not tested for in the fuel and it is not routinely analyzed in the slag or ash from their steam boilers. Ash is tested once for mercury only for the purpose of hazardous waste characterization by the Toxicity Characterization Lecheate Procedure (TCLP). TCLP test results provided indicated no mercury above the levels of detection, 0.01 ppm. *(32).* Mercury did not appeared in ash sampled from the power units Guaymas I and II, located in Guaymas, Sonora *(12)*.

It is quite possible that much of the Hg present in the Maya crude remains in the heavy oil or middle distillates during the refining process used in Mexico. One reason for this is that Mexican refineries are generally very basic facilities. Hg has a boiling point of approximately 670 ^{o}F. The feed temperature of refinery atmospheric fractionation towers is typically 650 to 750 ^{o}F. Crude oil components that do not flash to vapor in the atmospheric fractionation tower become the principal components in the heavy oil (*combustóleo*) produced from the tower bottoms. Another reason is that crude oil contains various chemical forms of mercury that exhibit significantly different chemical and physical behavior and thus partition to fuels, products and effluents in a complex fashion *(50)*.

The mid-range boiling point of diesel fuel is approximately 550 ^{o}F. The Hg vapor pressure at this temperature is relatively high, and it is reasonable to assume that significant condensation of Hg could occur in this portion of the atmospheric fractionation tower if Hg is present in the crude oil.

Maya crude oil is well known in international oil trading markets as a dirty crude oil that is quite high in sulfur and heavy metals. Maya crude oil is essentially the only feedstock used for the production of the heavy oil used in thermal power generating stations in Mexico. *Combustóleo* is used as fuel by older Mexican thermal power plants and constitutes almost 63% the fuel energy consumed to generate electricity *(24)*. For these reasons, electric power generation units may be an important source of mercury emissions in Mexico.

A laboratory that specializes in crude oil assays in the Houston area, ITS Caleb-Brett performed Hg analysis of four Maya crude oil samples supplied by PEMEX customers. Also, ITS Caleb-Brett and AOL, a second laboratory of their choosing, analyzed duplicate samples of each *combustoleo* and diesel fuel from PEMEX. Mercury content in heavy fuel oil and diesel samples analyzed were lower than these laboratories detection limit: 10 ppbwt for ITS Caleb-Brett and 100 ppbwt for AOL These anecdotal samples are encouraging but are not of statistical value.

TABLE 4.2 FUEL CONSUMPTION IN THE ELECTRIC INDUSTRY BY FUEL TYPE

FUEL TYPE	1994	1995	1996	1997	1998	1999 P/
Heavy Fuel Oil a/	19 047	16 750	17 285	19 809	21 681	21 288
Diesel a/	44	269	245	342	495	529
Natural gas *b/*	2 204	2 553	2 626	2 801	3 283	3 826
Coal c/	6 696	7 496	8 984	8 853	9 345	9 468
Uranium Dioxide d/	6 077	11 690	11 189	14 766	13 217	14 184

a/ Thousands of cubic meters
b/ Millions of cubic meters
c/ Thousands of metric tons
d/ Mwd/st (Megawatts-day per short ton)
P/ Preliminary
Source: INEGI: *El Sector Energético en México, 2000* from CFE: *Informe de operación (several years)*

No comprehensive oil characterization studies have been done, but data in the literature report mercury concentrations in crude oil ranging from 0.023 to 30 ppmwt, while the range of concentration in residual oil (*combustoleo*) has ranged from 0.007 to 0.17 ppmwt. *(16).* For diesel, EPA reported only one test with less than 12 ppb of mercury. Mercury emissions from power plants in Mexico will then be calculated based on U.S. EPA's best typical value determined for heavy fuel oil, 0.004 ppmwt of mercury *(17)* and <10ppb for diesel as determined by ITS Caleb-Bret. An emission factor of 5 ug of mercury per cubic meter of Natural Gas will also be used *(17).* Mean specific gravity for Heavy Fuel Oil will be taken as 0.98 kg/lt (8.2 lb/gal) and for Diesel as 0.86 kg/lt (7.16 lb/gal) *(37)*. Taking fuel consumption figures from above, mercury emissions from electric power generating plants in Mexico are estimated to be **0.1263 ton/y**.

The issue of Hg emissions from coal-fired power plants is limited to the Rio Escondido (1,200 Mwatt), also known as Carbon I or Jose Lopez Portillo, and Carbon II (1,400 Mwatt) facilities in Coahuila and perhaps to the Petacalco unit in Guerrero which was scheduled to begin burning coal in 2001 *(9)*. The Carbon I and II plants are located in the U.S.-Mexico border region, and thus, have been a focus of concern regarding SO_2 emissions. For this reason, increasing amount of mined coal are cleaned in Mexican washing plants prior to combustion *(33)* and low sulfur coal is being imported from Colorado *(52)*. Coal that is utilized by the carbon power plants include approximately 1.5 million tons of imported coal from Fideil Creek, Colorado mine. This coal is being utilized because it is much lower in sulfur than Coahuila coal *(26)*. Samples of washed, unwashed coal as well as coke were obtained from the Escondido vein and sent to two U.S. laboratories: Severn-Trent in Austin and Commercial Testing and Engineering in Deerpark, Colorado for analysis of mercury. Two different methods were employed with 6 ppb and 20 ppb detection limits respectively. Results are summarized in Appendix G.

Most coal produced in Mexico is from the Rio Escondido vein (thermal coal) and from the Sabinas region (metallurgical coal). The largest producer of coal in Coahuila is Minera Carbonífera Rio Escondido (Micare), with a production capacity of 6-7 million tons per year *(33)*. Mimosa is the second largest producer of Coal in this region and is part of *Grupo AHMSA*, the major steel maker in Mexico *(1)*. All of the coal mined by Mimosa and some of the coal mined by Micare is washed and converted to coke for AHMSA *(21).* It is unclear how much of the Mexican coal burned by the Carbon power plants is washed. INE requested CFE information regarding quantities of carbon used from Colorado (all washed carbon) and from local miners and what percentage of this is washed. No information has been received by the time of closing this report.

The same considerations made regarding characterization of fuel oil apply to analysis of mercury in coal. Since the results of analysis of coal made by the two laboratories used differ greatly one another, these results are not used for estimating mercury emission from these sources. Instead, best typical value for mercury in bituminous coal is used: 0.105 ppmwt *(50)*.

TABLE 4.3 COAL PRODUCTION BY STATE
(Metric tons)

STATE	1995	1996	1997	1998	1999
Total	**11 800 258.00**	**13 746 817.00**	**12 707 443.30**	**12 378 788.40**	**13 302 345.10**
Coahuila	11 800 258.00	13 745 528.00	12 706 483.30	12 378 728.40	13 300 180.10
Sonora		1 289.00	960.00	60.00	2 165.00

Source: INEGI: *El Sector Energetico en Mexico, 2000; from* SECOFI , *Direccion General de Minas.*

Coal consumption by CFE in 1999 was 9,468,000 tons *(24)*. Since both Carbon plants have only electrostatic precipitators to control particles, no significant reduction in mercury emission is expected in these pollution control devices *(17)*. It will be assumed a reduction of 21% in mercury content by the washing process *(17)*. Then, mercury emissions from Carbon I and II are estimated as **0.7855 ton/yr**.

4.2 Industrial/Commercial Boilers

The EPA's Mercury Study Report to Congress *(17)* identifies mercury emissions from industrial/commercial boilers as a major source of mercury emissions in the U.S. Approximately half of these mercury emissions are associated with coal-fired industrial boilers. No coal use is reported in industrial/commercial boilers in Mexico *(24)*. Heavy oil and diesel fuel appear to be the principal fuel used in industrial/commercial boilers, with natural gas use also common in Mexican cities located on or near the U.S. border.

INEGI has published data on total heavy oil and diesel fuel used by the commercial and industrial sectors nationwide as well as heavy oil and diesel fuel consumed in electric power generating stations, cement plants, petrochemical facilities, mining and other type of industrial activities *(24)*. Diesel used for transportation is not included in these statistics. According to INEGI's statistics, wood is not used as a fuel by industry in Mexico.

TABLE 4.4 INDUSTRIAL/COMMERCIAL ENERGY CONSUMPTION
(Petajoules)

ORIGIN	1994	1995	1996	1997	1998 P/
Industrial[1]	**723.16**	**754.619**	**735.015**	**707.132**	**724.108**
Solid fuel	77.251	89.441	89.193	97.392	100.187
Cane bagasse	72.148	84.032	83.247	91.372	93.617
Coke	5.103	5.409	5.946	6.02	6.57
Petroleum products	210.043	182.666	216.358	223.529	233.038
Liquid gas	18.268	16.688	17.232	17.115	18.01
Kerosene	1.071	1.026	1.218	1.205	0.124
Diesel	62.114	63.381	68.045	74.293	80.912
Heavy fuel oil	128.59	101.571	129.863	130.916	133.992
Natural gas	435.866	482.512	429.467	386.211	390.883
Commercial	**34.188**	**27.972**	**32.416**	**33.741**	**36.544**
Diesel	2.475	1.601	1.7	1.827	3.428
Heavy fuel oil	31.713	26.371	30.716	31.914	33.116

Source: INEGI: *El Sector Energetico en Mexico, 2000* from SE. *Balance Nacional de Energía,* 1998
(1): Figures do not include fuel used by cement/lime plants and iron/steel plants. Calculated from Table 5.4.5, pg 257

Assuming that industrial and commercial boilers have not installed any type of pollution control device, mercury emissions from the combustion of fossil fuels in these type of boilers are estimated as **0.0954 ton/y**.

4.3 Residential Wood Combustion

According to INEGI, in 1998 Mexico consumed a total of 243.913x10^{15} Joules from wood. Assuming an average heating value for wood of 8, 989 Btu/lb *(53)*, Mexico consumed 11, 679,000 tons of wood in residential combustion processes. Using an emission factor of 0.1 grams of mercury per ton of wood burned, which is the average of the range assumed by Parcom-Atmos *(35)*, atmospheric emission of mercury from residential wood combustion in Mexico is estimated as **1.168 ton/yr**.

4.4 Ferrous and Non-Ferrous Smelters and Foundries

4.4.1 Gold/Silver Mining and Refining

Mexico is a major producer of copper, silver, lead, zinc, gold and has important deposits of mercury. These metals are often found together in various concentrations as reduced sulfur compounds, such as CuS, PbS, ZnS and HgS (cinnabar). Mercury is particularly associated with gold, and is apparently found within the crystal structure of gold in many gold deposits *(48)*. Mercury is considered an indicator metal for the presence of gold in the gold prospecting industry. In the U.S., gold mining operations are the major domestic producer of mercury. Mercury readily forms an amalgam with gold, and for this reason mercury was used as a "sponge" in simple gold mining operations to extract gold that is finely dispersed in ore or soil.

Mercury has a low boiling point relative to gold and silver. For this reason, mercury is typically evaporated during the initial refining of these metals. In the U.S., in cases where the mercury concentration in the ore is sufficiently high to make recovery economically attractive, mercury retort furnaces are used to evaporate mercury from the ore. Condensers are used to condense and recover the mercury. Until recently, the condenser was often a simple shell-and-tube heat exchanger using tap water as the cooling medium. As a result, a significant percentage of the mercury bypassed the condenser and was exhausted to atmosphere. Refrigerant condensers are used at larger, more sophisticated gold mines to ensure relatively complete capture of the mercury evaporated in the retort furnace *(31)*. Another factor that encourages gold mine operators to remove the mercury from the gold ore during initial refining is the economic penalty imposed by gold refiners for gold/silver concentrate, known as “dore,” that contains more than 1,000 mg/kg of mercury.

There is no documented Hg recovery from gold mining operations in Mexico. AyA reviewed air emissions inventories and semi-annual report of hazardous waste generated from four major gold producers in a State’s SEMARNAT delegation for 1998 and 1999 years. No Hg emissions and no Hg-containing by-product or waste were reported by any of the mines reviewed. Two of these mines included Hg condensers and Hg “washing towers” in their flow diagram schematics and on their list of equipment. According to the environmental coordinator of another of these gold mines interviewed by AyA, from 1994 to 1998, tailings from old amalgamation *patios* were recovered at this mine, but Hg was neither recovered nor reported. According to SECOFI’s *Dirección General de Minas* (General Directorate on Mines), mercury has not been produced from mining operations in Mexico since 1995 (*64*). The project team concluded that either all mercury in gold/silver ore is evaporated during the roasting and smelting operations to produce dore or mercury recovered and mercury-containing sludge is recycled -to recover precious metals- or disposed on site. Three of the four mines analyzed are in the SECOFI’s top ten list of gold producers in Mexico *(42)*.

There are a large number of *pequeños mineros* (small miners) operating gold/silver mining operations in Mexico states of Sonora, Chihuahua, Durango, Zacatecas, Queretaro and Guerrero. These operations are essentially unregulated by the state or federal government. However, small miners usually do not have thermal processes in their mining operations, but send their concentrates to anyone of the three gold/silver smelters operating in the country *(18, 27)*. As a default, AyA team will assume that roasting/smelting take place in gold mining operations processing more than 500,000 tons of ore per year, or producing more than 400 Kilograms of gold per year. Table 4.5 below lists those gold/silver mines meeting the above criteria, most of which are in the 1999 SECOFI’s top ten gold producers in Mexico.

Nevada is the leading gold producer in the U.S. with two operating gold mines: Jarret Canyon-Anglo Gold and Barrick Gold. Jarret Canyon processes 2,190,000 tons/year of ore that is high in sulfur material and for this reason it must be roasted. Jarret Canyon emits 7,000 lb/yr of mercury at the roaster, although roasters are equipped with spray tower/scrubbers. Barrick Gold processes about 7,500,000 tons/year of ore and emits about 5,000 lb/year of mercury *(38)*. Using these Nevada mines as a surrogate to determine the potential atmospheric mercury emissions from gold/silver mining operations in Mexico based on the total ore processing rate, mercury is being emitted at a rate of 0.965 g/ton of ore. Applying this factor to gold/silver mines in Table 4.5 above, mercury emissions from gold mining operation in Mexico are estimated as **11.270 ton/year**.

TABLE 4.5 GOLD MINES WITH ROASTING/SMELTING OPERATIONS

Mine	Location	Gold Production Rate (Kg/yr)	Source
La Herradura	Caborca, Sonora	4,550 (2,292,000 ore)*	Randolph '98
La Ciénega	Santiago P., Durango	493,723 (ore)	Randolph '98
La Colorada	La Colorada, Sonora	2,532 (1,275,500 ore)*	INE Sonora
San Francisco	Imuris, Sonora	1920 (967,000 ore)*	INE Sonora
El Cubo	Guanajuato, Gaunajuato	3,285,000 (ore)	Randolph '98
San Felipe	San Felipe, B.C.N.	1,000,000 (ore)	COREMI
Las Torres-Cedros	Guanajuato, Guanajuato	962,500 (ore)	D. Fitch
Santa María de la Paz	Villa de la Paz, S.L.P.	730,000 (ore)	D. Fitch
San Antonio	San Dimas, Sinaloa	715 (360,000 ore)*	Randolph '98
San Martín	Colón, Queretaro	624 (314,000 ore)*	Randolph '98

* Ore in tons; obtained by extrapolation from La Colorada figures

4.4.2 Mercury Mining/Refining

Mercury is extracted from silver mine tailings in Zacatecas at the municipalities of Guadalupe and Veta Grande. According to SECOFI these are the only mercury producer operations in Mexico. A total of 60.63 metric tons were reported as recovered during 1998 *(22)*. This is almost twice the secondary production of mercury of 33.2 ton/yr reported by INE and PROFEPA in 1996 *(21)*. In 1999 only 29 tons of mercury were reported as recovered from these tailings *(44)*. Processing of these tailings largely depends on the market price of silver. The process of mercury extraction does not currently require an INE permit.

TABLE 4.6 SECONDARY PRODUCTION OF MERCURY
(from tailings)

Company	Products	By-products
Jales de Zacatecas, S.A. de C.V.	Silver precipitate: 9 ton/yr	Mercury 4.2 ton/yr
Beneficiadora de Jales de Zacatecas, S.A. de C.V.	Gold/Silver precipitate: 8.4 ton/yr	Mercury 10 ton/yr
Jales del Centro, S.A. de C.V.	Gold/Silver/Copper precipitate: 24 ton/yr	Mercury 8.3 ton/yr
Mercurio del Bordo, S.A. de C.V.	Gold/Silver/Mercury precipitate: 6 ton/yr	Mercury 6.5 ton/yr

Source: INE (44)

Mercury retort furnaces are used to evaporate the mercury from the silver/mercury concentrate produced in the initial refining steps. Mercury is recovered in a condenser. Recovered mercury is sold principally to Philips, a fluorescent light bulb manufacturer, and other clients in San Luis Potosí and Nuevo León.

Mercury recovery rate is estimated from average Hg content in tailings and in recovered bottom waste (*54*), tons of tailings processed and tons of mercury recovered (*44*). Using mercury secondary production of 29 tons as reported for 1999 and an estimated averaged condensation efficiency of 75 % in the mercury condenser after the retort/kiln used to separate gold/silver from mercury *(61, 64)* , emissions from these "*Plantas de Beneficio*", are estimated to be **9.666 ton/yr** of mercury.

4.4.3 Primary Copper Smelters

Mexico is a major producer of copper, processing approximately 1,100,000 tons/yr. of copper concentrate at the Mexicana de Cobre copper smelter in Nacozari, Sonora and approximately 22,000 tons of copper in the Industrial Minera Mexico (IMMSA) plant in San Luis Potosi (*60*). The mercury concentration in this concentrate can range from less than 1 ppm to as much as 1,000 ppm, depending on the ore deposit being worked *(13)*. Copper concentrates processed by IMMSA contains 1.4 ppm of mercury as an average *(30)*. The Nacozari smelter is equipped with a state-of-the-art sulfuric acid plant to control and convert SO_2 emissions from the smelter furnaces and converters to sulfuric acid, while the San Luis plant operates with no control in place.

The acid plant at Nacozari is equipped with high efficiency wet electrostatic precipitators to protect the SO_2 catalysts from exhaust gas particulate. Virtually all mercury entrained in these exhaust gases is condensed and captured in this control system. A lead-, arsenic-, and mercury-laden sludge is produced by the acid plant particulate control system and diverted to holding ponds at the smelter. This sludge is eventually sent to the IMMSA copper smelter in San Luis Potosi for reprocessing *(13)*. If this is the case, it is likely that the mercury contained in the sludge would be emitted to atmosphere during the copper smelting process, unless a similar pollution control system is in place. Sludge from the Mexicana de Cobre acid plant is not reported to INE, but it is considered a recyclable waste. Mexicana de Cobre performs routine analysis of mercury to its concentrates and sludge, as well as do test mercury in the exhaust gas from the acid plant, but do not report results to INE. IMMSA historically has not analyzed mercury in its process streams. Very recently they characterize feedstock and air emissions at the San Luis plant.

INE requested Mexicana de Cobre and Grupo Mexico, owner of IMMSA, to provide the project team with an estimate of the mean mercury concentration in the copper concentrate, amount of concentrate processed and amount of sludge produced as well as mercury concentration in the sludge for the last five years. Information did not arrive by the time of writing this report.

Figures of concentrate processed in 1999 *(55,60,62)* and data on mercury concentration obtained from personal communications (*30*) are used to estimate emissions of mercury from these sources to the atmosphere Assuming 98% efficiency in the pollution control system of Mexicana de Cobre smelter and knowing there is no emissions control in IMMSA plant, mercury emissions are estimated as of **1.543 Ton/yr** from these primary copper smelters.

4.4.4 Primary Lead and Zinc Smelters

Mexico has a primary lead smelting capacity of 360,000 tons/yr and a primary zinc smelting capacity of 380,000 tons/yr (*60*). The Mercury Study Report to Congress does not identify any mercury emission factors for the primary lead or zinc smelters in the U.S., and notes only that the mercury concentration in the U.S. lead ores are known to be relatively low. No discussion is provided on the potential mercury emissions from primary zinc smelters. Virtually all mercury present in the lead or zinc ore would be emitted to atmosphere due to the nature of lead and zinc smelting processes. As a result, information on the approximate mercury concentration of the lead and zinc ores being processed in Mexico is necessary to determine if mercury emissions from these smelters are potentially significant.

There is only one primary lead smelter in México, Met-Mex Peñoles in Torreon. This Torreon plant, along with Industrial Minera Mexico (IMMSA) in San Luis Potosi, are the only two primary zinc smelters in the country. Peñoles is in the process of expanding its primary zinc smelting capacity from 260,000 t/yr to 400,000 t/y (*27*). Both plants are equipped with sulfuric acid plant to control and convert SO_2 emissions from the smelter furnaces and converters to sulfuric acid. Figures of concentrate processed in 1999 *(55,60)* and data on mercury concentration (20-25 ppm in Pb concentrates and 5-10 ppm in Zn concentrates) obtained from personal communications (*30, 63*) are used to estimate emissions of mercury from these sources to the atmosphere. Assuming 98% efficiency in the pollution control system of Peñoles and IMMSA smelters, mercury is emitted at a rate of **0.1893 ton/yr** for Peñoles and **0.0183 ton/yr** for IMMSA. These figures do not take into account fugitive emissions which at least in the case of Peñoles caused this plant to exceed ambient SO_2 maximum allowable limits set for by PROFEPA *(28)*.

4.4.5 Secondary Lead and Zinc Smelters

The secondary lead smelting industry in Mexico is relatively large, although some plants have closed for economic reasons due to the low price of secondary lead compare to continued high price of junks *(4)*. The majority of lead processed at these smelters is derived from automotive batteries, though the remaining lead scrap comes from a wide variety of other sources. One of the major manufacturer of automotive batteries in Mexico runs a 75, 000 tpy-secondary lead smelter, recently ISO-14001 certified *(15)*.   This plants recycles approximately 90% of all automotive batteries recycled in Mexico *(19)*. This plant has not detected mercury in its emissions and on its waste streams, at least during the last five years of operation.   Dust and sludge recovered from the plant pollution control system are recycled within the plant. Mercury is not routinely present in the recovered lead *(45)*. Lead is received from Peñoles (80 % of Peñoles production) and from its own secondary smelter. Routine mercury analysis are performed to their feedstock. Maximum mercury content detected so far is 0.002 ppm.   This lead recycling plants is equipped with dust collector and wet scrubber. Collected dust and sludge is recycled. But even if no pollution control equipment is assumed, mercury emission from this plant would be lower than 150 g/yr.

The EPA performed extensive heavy metals testing of a number of U.S. secondary lead smelters during the development phase of the MACT standard for this industry. One plant, East Penn Manufacturing Company, had a measured mercury emission rate of approximately 1.2 lb/hr upstream of the control device (a baghouse). Assuming this plant is in continuous operation, this equates to an uncontrolled mercury emission rate of approximately 5.6 tons/yr. It is not clear why the EPA essentially ignored this source category in the Mercury Study Report to Congress, assigning a mercury emissions estimate of 0.1 ton/yr. to the entire U.S. secondary lead smelting industry.   The raw material for this US smelter consisted of approximately 80 percent automotive batteries, 15 percent industrial batteries and 5 percent plant scrap. No data was provided by EPA in this study on the mercury content of the smelter feedstock. In Mexico, the only batteries recycled are the automotive type, which are assumed to have no significant mercury level.

There is one secondary zinc smelter in Mexico, Zinc Nacional, with a rated production capacity of 240,000 tons per year. Zinc Nacional is the largest and often only importer of hazardous waste containing mercury from the U.S. Retort dust largely form U.S. steel sources is exported for "recycling" and shipments may contain mercury according to EPA's import-export office *(56)*. EPA has not yet accessed figures for 1995, the last year manifests were recorded, nor have they characterized mercury in waste.

4.4.6 Ferrous Smelters

The iron and steel industry is comprised of five major producers and a group of smaller plants known under the generic name of "*acerías*" (steel foundries). Total combined steel production in Mexico was of 14,213,000 tons in 1998.

TABLE 4.7 STEEL PRODUCTION BY COMPANY.
(Thousands of metric tons)

COMPANY	1993	1994	1995	1996	1997	1998 P/
Total	**9 199**	**10 260**	**12 147**	**13 172**	**14 128**	**14 213**
Altos hornos de México, S.A.	2 584	2 490	3 103	3 393	3 505	3 677
Hierro y Láminas, S.A.	2 007	2 181	2 463	2 722	3 060	2 797
Ispat Mexicana, S. A.	1 354	1 761	2 254	2 426	2 867	3 123
Siderúrgica Lázaro Cárdenas-Las Truchas, S.A.	1 165	1 345	1 439	1 337	1 459	1 283
Tubos de Acero de México, S.A.	391	427	550	737	746	721
Acerías	1 678	2 056	2 338	2 557	2 581	2 612

P/ Preliminary
Source: INEGI: *El Sector Siderurgico en Mexico, 2000* from CANACERO, *Diez años de Estadística Siderúrgica,* 1989- 1998

In 1999, Mexico produced 2,219,845 tons of coke, imported 292,929 tons and exported 692 tons of coke *(23)*, for a resultant usage of 2,512,081 tons of coke in 1998.

TABLE 4.8 METALS AND SIDERURGICAL MATERIALS PRODUCTION.
(Metric tons)

METALS AND SIDERURGICAL MATERIALS	1994	1995	1996	1997	1998	1999 P/
Mineral Coal b/ c/	6 392 937	7 391 059	8 779 518	8 509 976	7 832 227	8 767 000
Coke b/	1 984 730	2 147 602	2 184 363	2 139 376	2 202 558	2 227 531
Iron *a/*	5 516 193	5 625 110	6 109 453	6 279 783	6 334 257	6 885 217
Manganese a/	91 272	140 661	173 380	192 825	187 103	169 107

a/ By metal content b/ Mineral production c/ Non-for-coke coal
P/preliminary
Source: INEGI: *EL Sector Siderurgico en Mexico, 2000*

For estimating mercury emissions from ferrous smelters in Mexico, it is assumed that mercury is emitted only from the combustion processes during production of primary iron ("arrabio"). Assuming EPA's coke emission factor of 2.724×10^{-5} (*17*), mercury emissions from ferrous smelters in Mexico are estimated to be **0.086 ton/yr**.

4.5 Oil Refining

There are six PEMEX's oil refineries in Mexico. These are generally basic refineries that produce a fairly high percentage of heavy oil. It is likely that the majority of the Hg present in the crude oil processed by these refineries is concentrated in the heavy oil, due to the relatively high boiling point of Hg, ~670 ^{o}F, though significant fractions of the total Hg present in the feedstock could also be present in the distillate oil fraction (diesel), as well as the refinery fuel gas produced in the atmospheric fractionation tower. Refinery fuel gas is typically burned as fuel in refinery heaters and boilers. If insufficient fuel gas is generated for all refinery heaters and boilers, heavy oil or crude oil is typically used as supplemental fuel in the heaters and boilers. As a result, any Hg present in the feedstock crude oil that does not remain in the heavy oil or distillate product would probably be emitted in the exhaust gases produced by refinery heaters and boilers.

Mexico produces two general grades of crude oil, a light sweet crude that is primarily exported to the U.S. and a heavy, high sulfur crude (Maya) that is processed in domestic refineries. Maya crude is also imported by a number of U.S. refiners in the Houston area that have the capability to remove and recover the sulfur and to crack the heavy oil components to form valuable gasoline and distillate range products. Maya crude samples were not available for analysis of mercury in Mexico because there is no analytical capability to perform this type of test in crude oil and refined products. For that reason, arrangements were made with ITS Caleb-Brett laboratory from Houston to analyze two Maya crude oil samples on hand. *Combustoleo* and diesel samples taken from the kiln feed system of a cement plant were also sent to ITS Caleb-Brett for mercury analysis. Results of these analysis are summarized in Appendix G. Samples were collected and tested for reference purpose only and are not of statistical value. Robert Kelly, crude oil assay manager of ITS Caleb-Brett has encountered mercury concentrations as high as 2 ppm in crude oils, though he has relatively little confidence in the accuracy of the EPA analytical method used to quantify mercury in Petroleum products.

TABLE 4.9 PEMEX: CRUDE OIL PROCESSED
(Thousands of barrels per day)

	1995	1996	1997	1998	1999
Total	**1 243**	**1 283**	**1 228**	**1283**	**1228**
Cadereyta	176	167	110	167	110
Madero	138	148	150	148	150
Minatitlán	176	181	174	181	174
Salamanca	195	185	178	185	178
Salina cruz	281	307	309	307	309
Tula	277	295	308	295	308

Source: PEMEX: Annual Statistics (several years).

No estimate of mercury emissions from petroleum refining was made in the EPA's Mercury Study Report to Congress. The EPA cited insufficient data on Hg concentrations in the crude oil feedstock and refined products to develop a credible emission factor. The EPA has recommended that more analyses of oils and refinery stack emissions are needed to determine the significance of petroleum refineries as a source of Hg emissions, but considered 3.5 ppb as the best typical value so far for mercury in crude oil *(16)*. However, for the purpose of estimating mercury emissions from oil refineries, the project team will use the average value of 13.5 ppbwt of Hg content in crude oil as determined by ITS Caleb-Bret laboratory.

By assuming that mercury that does not remain in the heavy oil (446,000 barrels/day) *(36)* or distillate product (290,000 barrels/day) is emitted in the exhaust gases produced, mercury emissions from crude oil refineries will then be estimated as **0.680 tons/yr**.

4.6 Cement Plants

There are 31 cement plants in Mexico, 28 of which are operated by three cement manufacturing group: Cementos Apasco, Cementos Mexicanos y Cementos Cruz Azul. 25 of the Mexican cement plants are authorized to burn "alternate" fuels, including hazardous waste equaling from 5 percent up to 30 percent of the total heat input required by the process *(20)*. A number of the cement plants located in Mexico have taken advantage of this authorization, burning both waste combustible liquid and solid hazardous waste.

AyA project team members had access to emission test reports of four of the cement plants that are burning "alternate" fuel. The following emissions of mercury were reported for each of these plants: 1) 0.0003 kg/hr burning tires and plastic from battery cases; 2) 0.00096 kg/hr, nature of alternate fuel was not disclosed; 3) 0.0021 kg/hr burning waste oil; and 4) 0.0092 kg/hr and 0.14 kg/hr from oily wood chips and other undisclosed alternate fuel. Mercury content in feedstock was not reported and not all plants reported feed rate of alternate fuel used during the emission tests.

TABLE 4.10 AUTHORIZED CEMENT PLANTS TO BURN ALTERNATE FUELS

PLANT	STATE	CITY	%*
Cementos Apasco, S.A. de C.V.	Coahuila	Ramos Arizpe	10-30
Cementos Apasco, S.A. de C.V.	Veracruz	Ixtaczoquitlán	10-30
Cementos Apasco, S.A. de C.V.	Guerrero	Acapulco	10-30
Cementos Apasco, S.A. de C.V.	Edo. De México	Apaxco	10-30
Cooperativa La Cruz Azul	Hidalgo	Tula de allende	10-30
Cooperativa La Cruz Azul	Oaxaca	Lagunas	10-30
Cementos Mexicanos, S.A. de C.V.	Coahuila	Torreón	10-25
Cementos Mexicanos,S.A. de C.V.	Hidalgo	Huichapan	10-30
Cementos Guadalajara, S.A. de C.V.	B.C.	Ensenada	5
Cementos Maya, S.A. de C.V.	Yucatán	Mérida	5
Cementos Portland Moctezuma	Morelos	Juitepec	25
Cementos Apasco, S.A. de C.V.	Colima	Tecomán	10-30
Cementos de Chihuahua, S.A. de C.V.	Chihuahua	Samalayuca	5
Cementos del Yaqui, S.A. de C.V.	Sonora	La Colorada	5
Cemento Portland Nacional, S.A. de C.V.	Sonora	Hermosillo	5
Cooperativa La Cruz Azul, S.C.L.	Hidalgo	Tula de Allende	5
Cementos del Yaqui, S.A. de C.V.	Edo. De México	Tlanepantla	5
Preconcreto de Alta Resistencia, S.A. de C.V.	Jalisco	Tlaquepaque	5
Cementos Mexicanos, S.A. de C.V.	S.L.P	Tamulín	5
Cementos Tolteca, S.A. de C.V.	Puebla	Tepeaca	5
Cementos Mexicanos, S.A. de C.V.	N. L.	Monterrey	5
Cementos Apasco, S.A. de C.V.	Tabasco	Macuspana	5
Cementos Tolteca, S.A. de C.V.	Jalisco	Zapotiltic	5
Cemento Portland Blanco de México, S.A. de C.V.	Hidalgo	Atotonilco de tula	5
Cementos Tolteca, S.A. de C.V.	Hidalgo	Atotonilco de tula	5
Cementos Mexicanos, S.A. de C.V.	S.L.P.	Valles	5

* % of energy requirements replaced by alternate fuels

Source: INE: DGMRAR

AyA had access to the annual emission inventory reports of 17 of the cement plants operating in 1999 *(55)*. These reports include cement production and fuel used by type of fuel. Total cement production for these 17 plants in 1999 was 19,330,136 tons with a consumption of 989, 320 m^3 of heavy fuel oil, 4,930 m^3 of Diesel and 221,160 tons of a variety of alternate fuel. These figures are used to extrapolate fuel consumption for the other 14 plants based on rated production capacity, resulting in mercury emissions of **0.0105 tons/yr**. Since cement production often is lower than installed capacity, this assumption may over estimate mercury emissions for this source.

4.7 Lime Plants

There are 80 registered lime plants in Mexico with a total rated capacity of 5,102,323 tons of hydrated lime and one plant with 140,000 tons of quick lime *(55, 57)*. The majority of these plants operate vertical or shaft kilns. Only a few utilize a rotary kiln for intermediary quick lime production. Only Mexicana de Cobre lime plant in Agua Prieta in the state of Sonora produces quick lime as its final product. All others commercialize hydrated lime.

AyA had access to records of 22 of the lime plants operating in Mexico and obtained data on lime production and fuel consumption for each *(55, 60)*. Emissions inventory for these 20 plants reviewed contained data only on gases of combustion and some on particles, but none on heavy metals. Some of the plants operating rotary kilns have cyclones for dust collection. Dust is either disposed on site or sold as a soil aggregate for agricultural purposes.

Total lime production for these 22 plants in 1999 was 801,117 tons of hydrated lime with a consumption of 68,084 m^3 , 723 m^3 of Diesel and 21,769,070 m^3 of natural gas and 119,300 tons of quick lime consuming 30,667 m^3, 3.5 m^3 of Diesel and 33,979,895 m^3 of natural gas. No alternate fuel usage was reported. These figures are used to extrapolate fuel consumption for the other 58 plants based on rated production capacity. Using this approach, mercury emissions from lime plants are estimated as **0.003 ton/yr**. Since lime production often is lower than installed capacity, this assumption may over estimate mercury emissions for this source. Also, fuel efficiency depends heavily on the type of kiln in operation. Vertical kilns are much more fuel efficient than rotary kiln. One of AyA team members worked in the lime industry for several years and recorded efficiencies as low as 310 liters of fuel oil per ton of quicklime produced in rotary kilns with no heat recovery, while as high as 140 liters of fuel oil per ton of quick lime produced in vertical or shaft kilns. Degree of calcinations (quick lime quality) also plays a role in fuel efficiency.

4.8 Solid/Hazardous Waste Incinerators

In Mexico there are no incinerators of municipal solid waste. Except for two incinerators of expired pharmaceutical products authorized since 1993 and 1995, most incinerators of hazardous (HW) in Mexico started operation very recently. The number of operating incineration facilities in Mexico is changing constantly: there were 11 HW incinerators authorized in 1999; 17 in 2000 and the most recent list includes 14 of these plants operating with a total incineration capacity of 103,000 tons of hazardous waste per year *(20)*.

AyA reviewed records of all the 17 HW incinerators actually operating in Mexico. Only six of these plants have submitted emission tests data *(55)*. Three reported mercury concentration in their exhaust gases and the other three combined cadmium and mercury content as one single figure. INE is in the process of developing an electronic database of annual emission inventory records. At present, no records of hazardous waste incinerator facilities have been loaded yet

Since no data is available regarding actual amount of hazardous waste incinerated, mercury content in feedstock to incinerators as well as results of emission tests, no attempts are made to estimate mercury emissions from this source. In the INE's *Diagnóstico del Mercurio en México, 2000* *(21)*, it was assumed that actual amount of hazardous waste incinerated was only 10% of total incineration capacity and used a mercury emission factor of 3.0 g/ton. Using these assumptions results in an estimated mercury emission of **0.020ton/yr**, not including in these figures hazardous waste burnt in cement plants as alternate fuel.

TABLA 4.11   AUTHORIZED HAZARDOUS WASTE INCINERATORS
(TON/YR)

Plant	Hazardous waste	Rated capacity
Tecnología Especializada en Reciclaje, Tepeji del Río, Hgo.	Medical waste and industrial hazardous waste	7,500
Ciba Geigi Mexicana, Atotonilco, Jal.	Hazardous waste from its own facility and from other pharmaceutical companies.	2,075
Kodak de México, Zapopan, Jal.	Hazardous waste from the production process of photographic film, filter paper, activated sludge, dross and sludge from silver recovery processes.	613
Bayer de México, Ecatepec, Edo. de Méx.	Hazardous waste from its own facility.	1,752
Aceros Nacionales, Tlalnepantla, Edo. de Méx.	Wood chips, rags, gloves and metal chips impregnated with oil and grease.	183
Siderúrgica Lázaro Cárdenas. Las Truchas, Lázaro Cárdenas, Mich.	Rags, gloves impregnated with oil, solvent and grease.	22
Laboratorios Julián de México, Jiutepec, Mor.	Hazardous waste from its own facility.	20,000
Sintex, Jiutepec, Mor.	Expired and out of specification pharmaceutical products.	840
Hylsa, San Nicolás de Los Garza, N.L.	Waste oil.	246
Síntesis Orgánica, Xalostoc, Tlax.	Distillation bottoms of phtalic anhydride	2,160
Pemex-Petroquímica, Coatzacoalcos, Ver.	Streams containing heavy chlorohydrocarbons	30,000
Total Rated Capacity		**65,391**

Source: *INE, DGMRAR*. 2000

4.9 Medical Waste Incinerators

Of the 27 incinerators of medical waste (MW) authorized in Mexico, 24 are actually operating. With few exceptions, most started operations in 1997 and 1998. AyA reviewed mercury emission records of 21 of these MW incineration facilities *(55)*. Most data reported combined emissions of cadmium and mercury as one single figure, since INE established a maximum emission limit of 0.2 mg/m^3 of Cadmium and Hg. A new proposed standard for medical waste incinerators (NOM-ECOL-098/99) sets a maximum emission limit of 0.07 mg/m^3 of mercury.

TABLE 4.12 MEDICAL WASTE INCINERATORS IN MEXICO

Plant	State	Capacity (Kg/hr)
Tradem.	Distrito Federal	1000
Control de Desechos Ind. y Monit. Amb.	Coahuila	200
Tradem.	Estado de México	500
Sterimed.	Estado de México	109
Soluciones Ecológicas Integrales.	Estado de México	1400
Protección Integral del Medio Ambiente.	Estado de México	45
Desechos Biológicos.	Estado de México	250
Proterm-JV de México.	Estado de México	350
Proterm-JV de México.	Estado de México	200
Tecnología Especializada en Reciclaje.	Hidalgo	1000
Alicia Chávez González.	Jalisco	360
Ciba Especialidades Químicas México.	Jalisco	588
Servicios de Tecnología Ambiental.	Nuevo León	350
Bio-System Technology.	Nuevo León	270
Ecotérmica de Oriente.	Puebla	350
Marepel.	Sinaloa	200
Secam.	Tamaulipas	220
Ecología del Mayab.	Yucatán	270
Incineradores, Mantenimiento y Equipo.	Jalisco	420
Centro Ambiental.	San Luis Potosí	90
Bio-Tratamientos.	Estado de México	340
Ameq de México.	Coahuila	112.5
Técnicas Especiales Reducción de Altamirano.	Tamaulipas	250
Control Ambiental del Bajío.	Guanajuato	83
Total Plants: 24		**8,957.5**

Fuente: Dirección General de Materiales, Residuos y Actividades Riesgosas. Reporte Interno. Marzo, 2000. (Taken from INE *Diagnóstico del Mercurio en México, 2000*)

The majority of mercury emissions were reported in mg/m^3 but no information was provided regarding volumetric gas flow that would have allowed to calculate mass emission rate. Since composition of medical waste incinerated varies greatly as well as incinerator type and capacity, gas flow rate from each incinerator could not be estimated. In the INE's *Diagnóstico del Mercurio en México, 2000* *(21)*, it was assumed that actual amount of medical waste incinerated was 40% of total incineration capacity and used a mercury emission factor of 0.96 g/ton. Using these assumptions results in an estimated mercury emission of **0.007 ton/yr**.

4.10 Chlor-Alkali Plants

There are five chlor-alkali plants in Mexico with a combined production of 447,000 tons per year of chlorine gas. 147,000 tons of chlorine per year are produced with the mercury cathode technology in three of these plants that utilize the mercury cell production process (*5*).

TABLE 4.13 CHLOR-ALKALI PLANTS IN MEXICO

STATE & CITY	PRODUCER	YEAR BUILT	CELL TYPE	CHLORINE PRODUCTION/ Hg CELLS
Jalisco El Salto	Mexichem, S.A. de C.V.	1976	OxyTech DS45 diaph	None
Mexico Santa Clara	Mexichem, S.A. de C.V.	1958	De Nora 14TGL, 14x3F merc Mathiesen E11 merc. '66	18,000
Monterrey Nuevo Leon	Industria Química del Itsmo, S.A.	1958	Mathiesen E8 merc	29,000
Veracruz Coatzacoalcos	Industria Química del Itsmo, S.A.	1967	De Nora 18X4, 18H4'72 merc	100,000
Pajaritos	Cloro de Tehuantepec S.A. de C.V.	1980	Glanor 1144 diaph.	none

Source: The Chlorine Institute (*47*) and INE (*21*) with data from ANIQ (*5*).

According to information provided to INE's DMT by the *Asociación Nacional de la Industria Química, ANIQ* (National Chemical Industry Association), plants with mercury cell technology have a total of 120 cells, anode being of titanium. Each cell contains 2,287 Kg. of mercury as an average, resulting in a mercury inventory in operation of about 275 tons. Plants are operating at over 90 percent of total production capacity and there are no plans to increase actual installed capacity.

Mercury emissions from Mexican chlor-alkali industry in 1998 were estimated by INE as 5.658 tons equal to the yearly amount of mercury purchased by chlor-alkali plants based on ANIQ's estimates (*21*). This estimate results in an emission factor of 41.2 grams of mercury per ton of chlorine produced, considerably much higher than the 1994 emission factor of 3.5 g/ton estimated by EPA for U.S. chlor-alkali plants (*17*). However, USGS estimates that about 74 percent of mercury used by chlor-alkali plants is "unaccounted", calling this amount, the "missing" mercury, addressing EPA concern about this unaccounted mercury (*49*).

TABLE 4.14 CHLOR-ALKALI PLANTS PRODUCTION

(tons)

YEAR	Cl_2 WITH Hg CELLS	Cl_2 TOTAL	Hg USED
1995	121 846	390 255	5.258
1996	131 211	415 159	5.174
1997	134 786	415 080	5.403
1998	141 446	447 500	5.658
1999	133 352	456,120	5.767

Source: INE: DGMRAR from data provided by ANIQ

By assuming that all mercury added to replace losses is emitted to the air, the mercury emission factor of 41.2 g/ton in Mexico may be overestimated, since mercury is also lost in wastewater discharged, in sludge sent to landfill and as an impurity in sodium hydroxide by-product; however, it can not be as low as 3.5 g/ton. In absence of information, EPA's Frank Anscombe considers a safe bet to assume that half of mercury losses are to the atmosphere (*6*). Team members met with environmental managers of three mercury-cell plants to review information previously given to INE regarding mercury flow in the chlor-alkali plants and to obtain updated information regarding mercury emissions estimates as well as mercury transferred to products and waste. Information did not arrive by the time of writing this report.

USGS estimates that 14 % of mercury replaced in a chlor-alkali plant is transferred to landfills in the sludge from wastewater treatment, 5 % is internally recycled and 1 % is lost with NaOH product *(49)*. With these USGS figures and 5.767 tons of mercury replaced, estimated mercury emissions in Mexican chlor-alkali plant were **4.902 tons** in 1999.

A sixth chlor-alkali plant was located in a pesticide plant in Salamanca in the state of Guanajuato. It used to produced chlorine for manufacturing organochloride pesticides such as DDT, BHC and others (*2, 10*). Mercury was contained within masonry walls. This plant exploded in September last year and since than more than 1000 tons of mercury-containing waste have been removed to be landfilled (*40*). According to PROFEPA the sites is being remediated. For this reason, this site will not be included in this inventory as an active emission source.

4.11 Carbon Black Plants

There is one carbon black plant located in Tampico, Tamaulipas with an annual production capacity of 122,000 tons/year. The EPA's Mercury Study Report to Congress *(17)* indicates that carbon black plants may be a source of significant atmospheric Hg emissions. This project has been unable to obtain information regarding type of pollution control equipment installed in this plant, but most probably it is for particles control. Using EPA's emission factor of 1.5x10-4 kg/ton, results in 18.3 kg/yr or **0.0183 ton/yr**.

4.12 Pulp and Paper Plants

There are six pulp and paper plants in Mexico that produced 544,100 tons of pulp in 1999, representing 71.8 percent of total pulp installed capacity *(8)*. At present, only five of these plants are in operation *(46)*. Because of economic reasons, capacity of pulp production per year has decreased from 1,139,000 tons in 1990 to 758,000 tons in 1999. During that same period, imports of pulp have increased over 50 percent, while exports have practically been reduced to zero.

The majority of the production from these mills is produced using the kraft process or soda process *(8)*. The EPA's Mercury Study Report to Congress *(17)* indicates that essentially all Hg emissions from the pulp and paper industry are emitted from recovery boilers used in kraft and soda pulp mills. Pulp produced in Mexico by chemical process amounted 97.4 percent of total pulp production, but reduced to 91.1 percent in 1999. It is expected that during 2000-2001 chemical pulp production will represent less than 50 percent of all pulp produced in Mexico *(46)*.

TABLE 4.15 PULP PRODUCTION BY TYPE .
(Metric tons)

TYPE	1991	1992	1993	1994	1995	1996	1997	1998	1999
Total	**705 111**	**559 783**	**343 571**	**276 320**	**420 525**	**511 307**	**442 121**	**442 121**	**544 126**
Chemical pulp from Wood	359 444	280 272	208 799	159 581	278 356	324 124	302 337	330 185	300 819
Chemical pulp from Plants	237 117	240 177	121 390	116 739	122 593	153 956	134 194	182 144	194 705
Mechanic pulp	108 550	39 334	13 382	--	19 576	33 227	5 590	13 915	48 602

Source: CNICP, *Memoria estadística 2000*

EPA estimated mercury emissions from U.S. pulp and paper plants by assuming an emission factor of $1.95x10^{-5}$ Kg/Mg based on firing range of recovery furnaces. This assumption resulted in a mercury emission of 1.7 tons/yr. No information is available as of the firing rate capacity of the Mexican plants producing pulp by chemical means. For this reason, to estimate mercury emissions from pulp plants in Mexico, the following approach is used:

Chemical pulp production in the United States is over 54,000,000 tons per year, more than 80 times of pulp produced in Mexico by chemicals processes *(8)*. A simple extrapolation can be done, assuming that 80 percent of pulp produced in the United States is from kraft and soda processes *(17)* and that no pollution control system is in place in Mexican pulp plants (which adds 21 % more to the emissions figures). Applying the emission rate calculated with this approach to Mexican pulp production, results in **0.0240 Ton/yr** of mercury emitted to the atmosphere by the pulp and paper industry in Mexico.

TABLE 4.16 1999 PULP PRODUCTION BY TYPE AND BY STATE
(Metric Tons)

STATE	PULP FROM WOOD	PULP FROM PLANTS	MECHANIC PULP	TOTAL
Total	**300 819**	**194 705**	**48 602**	**544 126**
Chihuahua*	128 552	-	-	128 552
Jalisco	83 557	-	-	83 577
Michoacán	88 690	137 867	-	226 557
Oaxaca	-	-	48 602	48 602
Veracruz	-	56 838	-	56 838

Source: CNICP, *Memoría Estadística 2000*
* No pulp production during 2000-2001

1.13 Metallurgical Coke Production

Mexico has an installed capacity for the production of metallurgical coke of 4,240,150 tons in three main regions: Monclova and Sabinas in Coahuila, and Lazaro Cardenas in Michoacan *(23)*. In 1999 Mexico produced 2,227,531 tons of coke *(24)*. Practically all coke produced is used as a primary feedstock for the iron and steel industries.

For the estimate of mercury emissions from coke manufacturing processes, EPA assumed an emission factor of 0.025 g of mercury per ton of coke produced, based on an emission factor from Germany *(16)*. Using this factor for Mexico, results in an estimated emission of mercury of **0.055 ton/yr**.

4.14 Instruments and Electrical Apparatus Manufacturing

4.14.1 Fluorescent Lamps:

The EPA's <u>Mercury Study Report to Congress</u> *(17)* did not identify mercury emissions from fluorescent lamp manufacturing facilities, but included only emissions from lamp recycling. No attempts were made either to account for mercury emitted by lamp breakage. In Mexico, there is no recycling of fluorescent lamps or of any other mercury containing electric device.

TABLE 4.17 MERCURY CONTENT PER TYPE OF LAMP

Year	Lamp Type	Production (pcs.)	Hg/lamp	Total Hg Content	% Produced in Mexico
1997	Fluorescents	25 Millions	40 mg	1000 Kg	95%
	Compacts (112/T8)	5 Millions	10 mg	50 Kg	20%
1998	Fluorescents	27 Millions	35 mg	945 Kg	80%
	Compacts (112/T8)	6 Millions	10 mg	60 Kg	20%
1999	Fluorescents	30 Millions	30 mg	900 Kg	75%
	Compacts (112/T8)	7 Millions	5 mg	35 Kg	20%

Source*: Information provided by CANAME on 2/7/2000. Taken from INE's Diagnóstico*

INE estimated that 25 % of the mercury contained in a tube lamp is emitted to air at the time a lamp breaks and that about 98 % of all lamps in used breaks during one year *(21)*. Using these figures, it was estimated that mercury atmospheric emissions from fluorescent lamp breakage in Mexico were **0.229 tons/yr**.

Mercury emissions estimated this way, may be underestimated because no consideration is given to emissions generated during the lamp manufacturing itself.

TABLE 4.18 MERCURY EMISSIONS BY LAMP TYPE

Year	Lamp Type	Production (pzs)	Hg/lamp	Hg Emissions ton/yr

1997	Fluorescents	25 Millions	40 mg	0.25
	Compacts (112/T8)	5 Millions	10 mg	0.01
1998	Fluorescents	27 Millions	35 mg	0.24
	Compacts (112/T8)	6 Millions	10 mg	0.02
1999	Fluorescents	30 Millions	30 mg	0.22
	Compacts (112/T8)	7 Millions	5 mg	0.01

Source: Information provided by CANAME on 2/7/2000. Taken from INE's Diagnóstico

4.14.2 Thermometers:

There are several types of thermometers each containing different amount of mercury. The most common thermometers in used are those clinical thermometers for measuring body temperature containing about 0.61 grams of mercury each *(17)*. EPA assumed an emission factor of 9 Kg of mercury emitted for every ton of mercury used in thermometers manufacturing *(17)*.

In absence of information on thermometers produced in Mexico, INE estimated emissions based on the calculated number of thermometers broken each year in hospitals and assuming a breakage rate of one thermometer per four hospital beds per week *(21)*. For purpose of estimating mercury emission from the manufacturing of thermometers, the number of thermometers broken within a year can be used as a surrogate for thermometers produced per year. This assumption may underestimate resulting emissions, since an undetermined amount of mercury-containing thermometers produced in Mexico are exported to other countries. According to statistics from Mexican Health Department, in 1999 there were 251,656 beds in hospital and clinics in Mexico *(43)*. Using the above figures and EPA's emission factor gives a mercury emission estimate of **0.0179 ton/yr** for thermometers manufacturing.

4.14.3 Other Manufacturing Sources:

Mercury is also used in the manufacturing of a diverse range of instruments, apparatus and devices, such as sphygmomanometers, electrical switches, thermal and electrical sensors, and batteries, among others. Tendency is to reduce the use of mercury in these items. Although emissions of mercury from breakage of these instruments and apparatus may be important, it is expected that most of the mercury emitted will come from the operations involved in manufacture of these devices. At present, there is no information on production figures for these items. Official figures available for each of these instruments, apparatus and devices group together the several types of the same device produced, not differentiating those that contain mercury from those that do not. Also, most of these manufacturing plants are not under INE's jurisdiction, but report their emission, as well as material usage and production, to the environmental agency of the state were each plant is installed. Anyway, as in other Pollutant Release and Transfer Register, emissions reported are only those regulated: combustion gases and particles.

However, mercury emissions form manufacturing sources may be relevant: according to the *Consejo Nacional de la Industria Maquiladora de Exportacion A.C (*National Council of the Export Maquiladora Industry*)*, in 1999 there were 1,120,303 workers in Mexico, at 4420 "*maquiladora*" assembly plants in Mexico; a number that has increased since that time *(57)*. The majority of "*maquiladoras,*" are dedicated to the production of electronic components (such as wiring harnesses), switches, and a wide variety of electrical devices for U.S. and Asian corporations. In many of these operations, mercury is involved as a "direct" material, meaning it is incorporated into the final product.

Other researchers have estimated air emissions in Mexico based on figures from U.S. statistics for the same source being evaluated, either adjusting resulting emissions downward based on differences in wages or salaries *(41)* or by taking one half of the per-capita emission rate estimated for the U.S. *(34)*. Without discussing the merits of these approaches, they can not be applied in the present case because for example, the evolution in technology to replace mercury in many applications in the US may not have occurred in Mexico or at least not at the same rate. Also, production figures from *maquiladora* plants are included in Mexico statistics, but manufactured goods are exported and then not used/discarded in this country. Situations like these two previous may prevent indirect approaches to estimate mercury emissions in Mexico from manufacturing sources.

Mercury distributors or suppliers to manufacturing facilities may be also an important source of mercury emissions. Most mercury is received "as is" from the Zacatecas recovery plants *(3)* and has to be cleaned before being sold for instruments and dental/medical applications. Cleaning method involves removing dust and debris with a rag and consecutive washings with a 5% nitric acid solution, acetone and hexane *(29)*. Mercury cleaned this way is called "*triplestilado*" (triple-distillate). During this cleaning practice, mercury may be transferred to rags and water, as well as emitted to the atmosphere. No data was available as to estimate the quantity of mercury that is cleaned each year and the emission factors for this activity.

4.15 Dental Amalgams:

Mercury is emitted from dental amalgam during amalgam formulation operations and from spills and scrap in the dentist offices during dental preparation. No information has been compiled regarding amount of dental amalgam formulated in Mexico. Amalgam is prepared by several private laboratories *(11)* as well as in dentist offices. According to the Mexican Dental Association, 70 % of dentists still formulate their own amalgam *(7)*. Typical amalgam formulation has the following composition: 34.65 % Silver, 8.95 % Tin; 5.90 % Copper; 0.5 % Zinc and 50.0% of Mercury *(14)*.

According to USGS estimates, 90 % of mercury used in dental applications is formulated in amalgams. From this, additionally 8 % is lost in the dental office during the first year, assuming a life time of 10 years for amalgams. INE estimated that in Mexico 1.51 tons of mercury are discarded from dental amalgam each year *(21)* and EPA reported that 2 percent of mercury used in dental amalgam is emitted into the atmosphere *(17)*. Using these figures, it is estimated that mercury emissions from amalgam during dental preparation/removal are **0.378 tons/yr**.

4.16 Sewage Sludge Incineration Facilities

There are no sewage sludge incineration facilities known to be operating in Mexico at this time *(20)*.

4.17 Crematories

In Mexico crematories are regulated by state's environmental agencies *(58)*. As such, emissions reported are only those regulated: particles and combustion gases. Number of human bodies cremated are not necessarily reported. Figures on cremation of human bodies are available only for Mexico City. Hence, the project will not attempt to estimate emissions from crematories. However, it must be stated that mercury emissions from crematories in Mexico may not be of significance if it is considered that EPA estimated in 1995 that mercury emissions from crematories in the US were $4.6x10^{-4}$ tons/yr *(17)*. It is estimated that there are about 50 to 60 crematories in Mexico *(59)*. In 1995, there were 1,155 crematories in the United States *(17)*.

4.18 Geothermal Power Plants

There are five geothermal power units in México capable of generating 750 Mwatts per year *(24)*. No information is available regarding mercury content in vapor or water nor on emission factors from geothermal plants.

5.0 Summary of Estimates of Atmospheric Mercury Emissions in Mexico

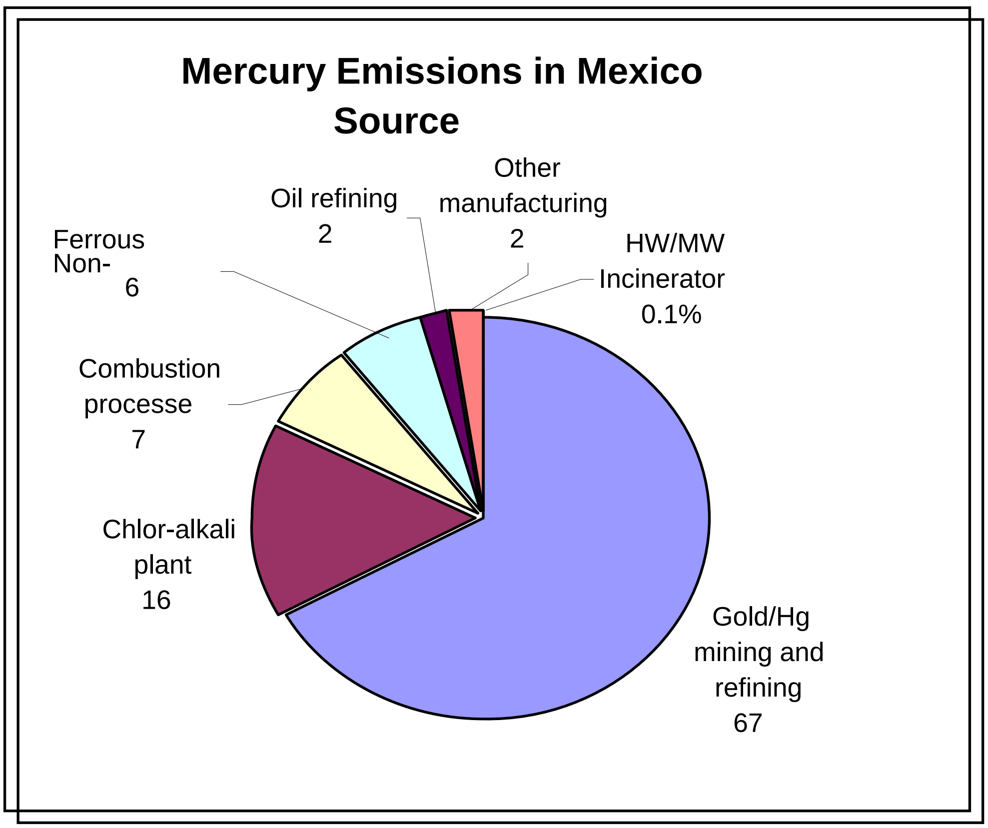
Table 5.1: Estimated Emissions of Mercury in Mexico (1999)

Source of emission	GIS compatible database	Hg: tons/yr
Thermoelectric plants	HgAirMex_PowerFinal	0.1263
Carboelectric plants	HgAirMex_PowerFinal	0.7855
Industrial commercial boilers	None	0.0954
Residential Wood Combustion	None	1.168
Gold mining and refining	HgAirMex_AuFinal	11.270
Mercury mining/refining	HgAirMex_SecHgFinal	9.666
Copper smelters	HgAirMex_NonFerFinal	1.543
Primary Lead and Zinc smelters	HgAirMex_nonFerFinal	0.208
Secondary Lead and Zinc smelters	None	---
Ferrous smelters	HgAirMex_FSmltFinal	0.086
Oil refineries	HgAirMex_OilFinal	0.680
Cement plants	HgAirMex_CemnTFinal	0.0105
Lime plants	HgAirMex_LimeFinal	0.003
Hazardous waste incinerators	HgAirMex_HWFInal	0.020
Medical waste incinerators	HgAirMex_MWFinal	0.007
Chlor-alkaly plants	HgAirMex_ChlAlkFinal	4.902
Carbon black plants	HgAirMex_CBCokeFinal	0.0183
Pulp and paper plants	HgAirMex_PulpFinal	0.024
Coke manufacturing	HgAirMex_CBCokeFinal	0.055
Fluorescent lamp	None	0.229
Thermometers	None	0.018
Amalgams	None	0.378
Crematories (not determined)	None	---
Total mercury emissions estimated		**31.293**

Table 5.2 Mercury Emissions in Mexico by Source Category 1999

Source category	Ton/yr	%
Gold/Hg mining and refining	20.936	66.9
Chlor-Alkali plants	4.902	15.7
Combustion processes	2.189	7.0
Ferrous and Non-ferrous smelters	1.892	6.0
Oil refining	0.680	2.2
Other manufacturing	0.667	2.1
HW/MW Incinerators	0.027	0.1

Figure 5.1 Mercury Emissions in Mexico by Source Category 1999



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Appendices

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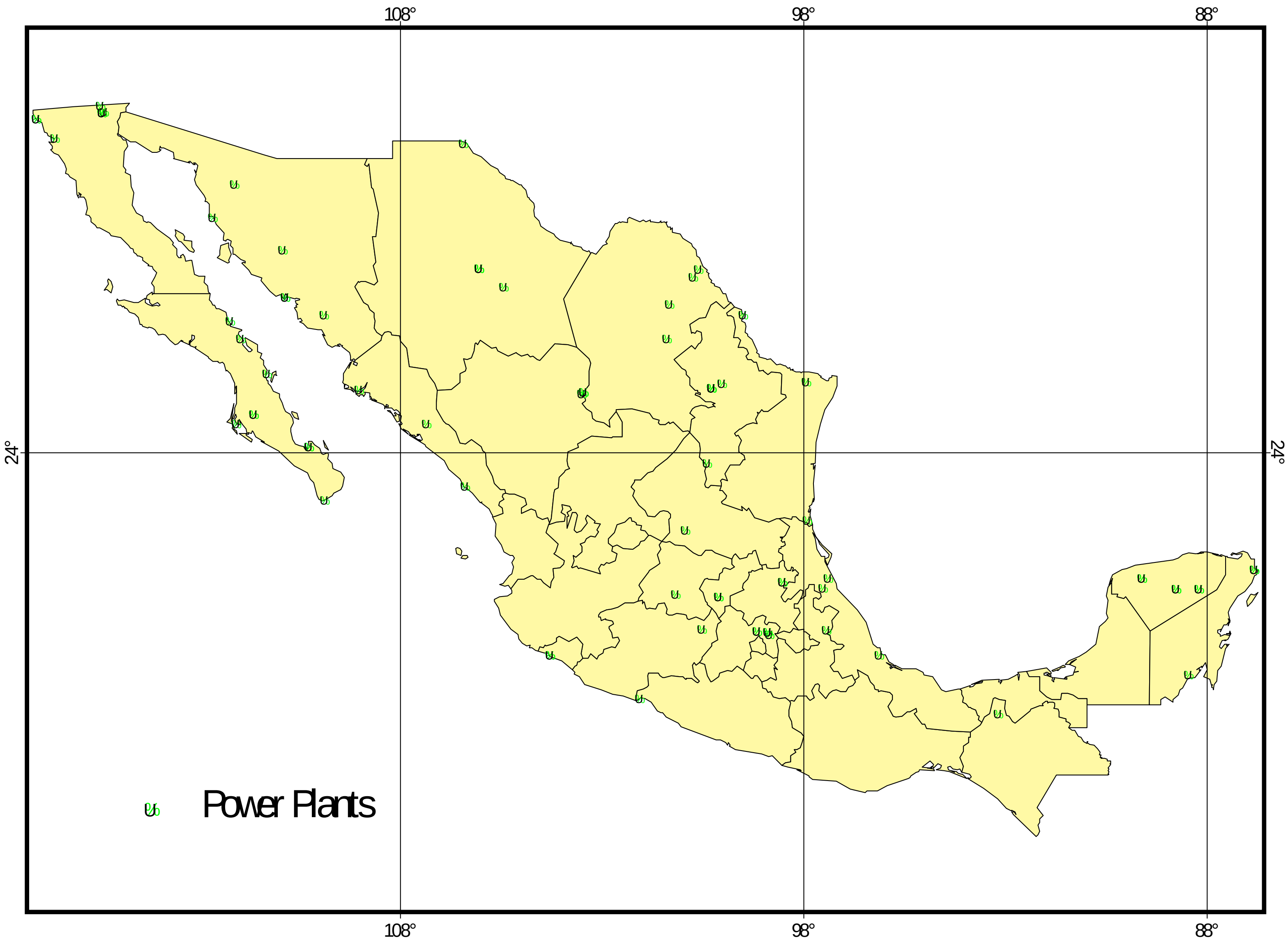
Appendix A

Maps of Sources of Mercury Emissions by Source Type

Appendix A: Maps of Sources of Mercury Emissions by Source Type



Map 1 Hg emission sources: Power Plants.

Map 2 Hg emission sources:Gold Mining and Refining.

Map 3 Hg emission sources: Secondary Production of Hg

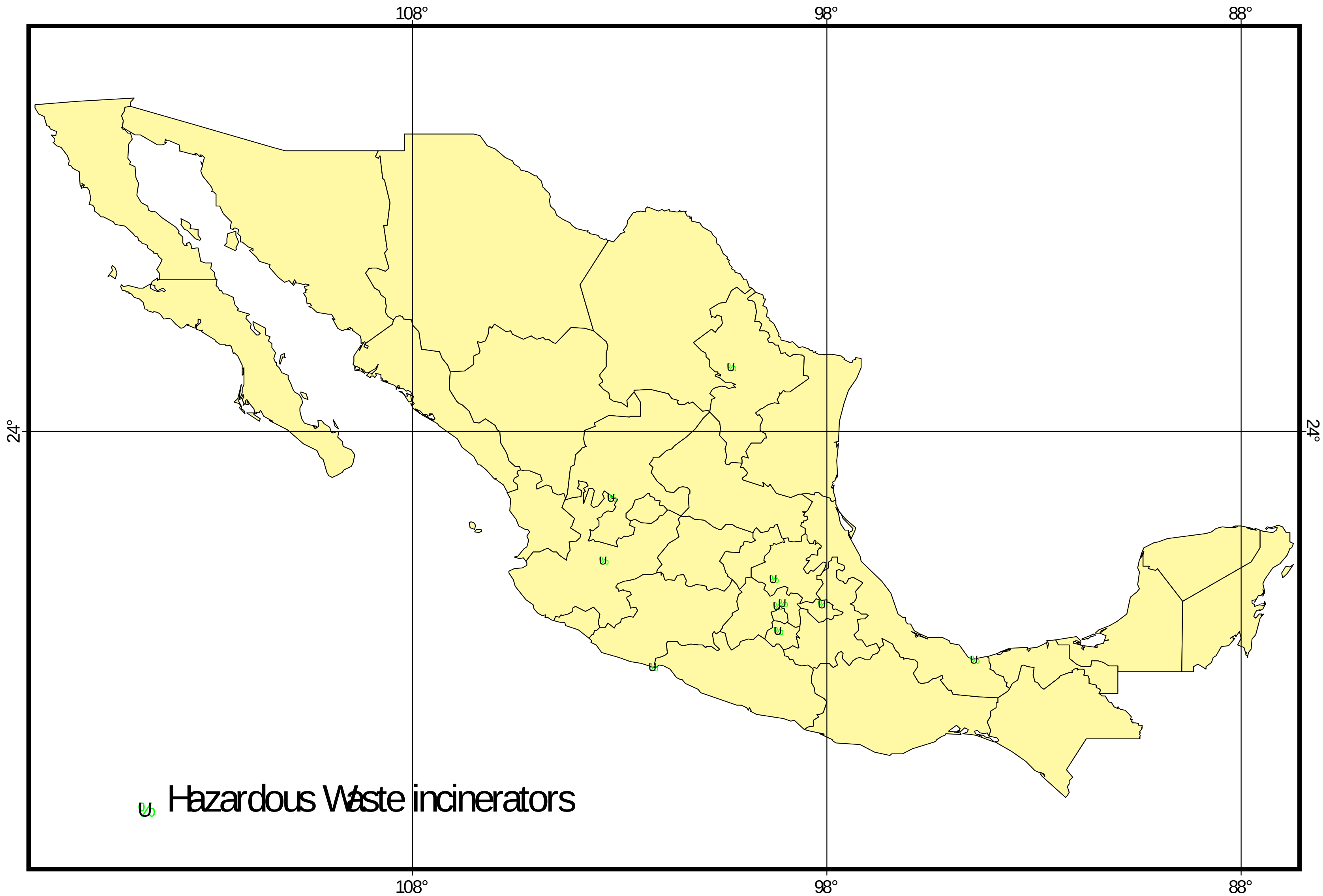
Map 4 Hg emission sources: Non Ferrous Smelters.

Map 5 Hg emission sources: Ferrous Smelters

Map 6 Hg emission sources: Oil Refineries.

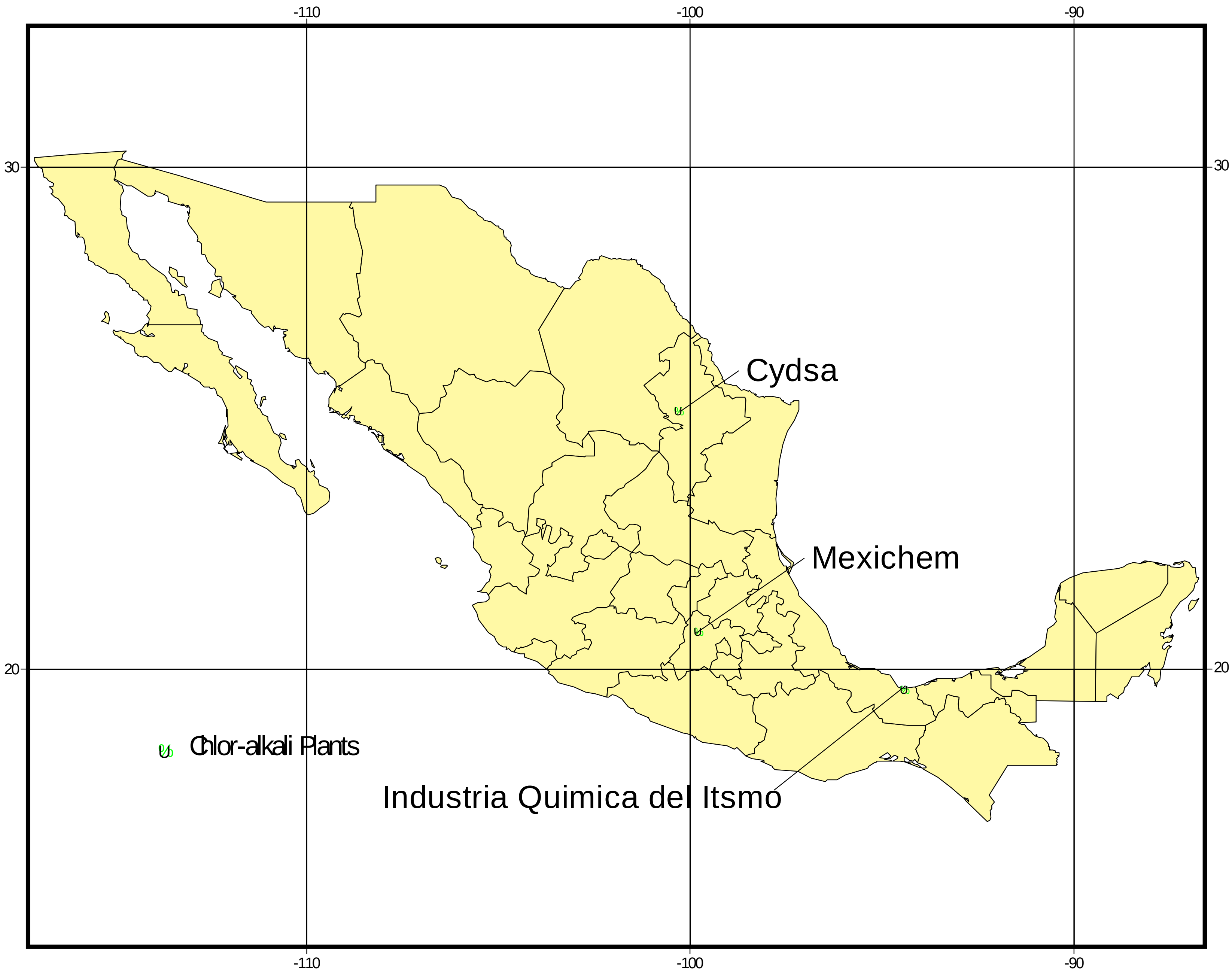
Map 7 Hg emission sources: Cement Plants.

Map 8 Hg emission sources: Lime Plants.



Map 9 Hg emission sources: Hazardous Waste Incinerators.

Map 10 Hg emission sources: Medical Waste Incinerators.



Map 11 Hg emission sources: Chlor-Alkali Plants.

Map 12 Hg emission sources: Pulp and Paper Plants.

Map 13 Hg Source: Carbon Black and Coke Plants.

Appendix B

Cement Plants: Data/Sources

Appendix B - Cement Plants: Data/Sources

Table B.1: Fuel Usage and Cement Production

1999

Plant	m^3		Alternate Fuel (ton)	Cement (ton)
	Heavy Oil	Diesel		
Cemento Portland Nacional Hermosillo, Sonora	69559	842	6.95	849,959
Cementos del Yaqui La Colorada, Sonora	54000	1724.00	84811.00	1,306,313
Cementos Apasco Ramos Arizpe, Coahuila	71322	982.00	8474.00	1,252,818
Cementos Mexicanos Hidalgo, Nuevo Leon			9440.00	487,984
Cementos Mexicanos Cd. Valles, San Luis Potosi	85453			820,283
Cementos Apasco Tecoman, Colima	19480.00	385.46	116712.00	1,256,603
Cementos Mexicanos Huichapan, Hidalgo	160258			2,647,800
Cemento Portland Blanco Atotoniclo de Tula, Hidalgo	117497			3,033,383
Cementos Tolteca Tepeaca, Puebla	194639	94.70		2,702,361
Cementos Moctezuma Jiutepec, Morelos	62683	856.82		852,267
Cementos Moctezuma Tepetzingo, Morelos	33169	45.49	89.87	433533
Cementos del Yaqui Tlalnepantla, Edo. De Mexico	12330			1,272,827
Cementos Apasco Acapulco, Guerrero	25213		882.50	1,649,642
Cementos Maya Merida, Yucatan	83717		743.82	764,363
Totals	**989,320.00**	**4,930.47**	**221,160.14**	**19,330,136**

Source: *INE's Dirección General de Gestión e Información Ambiental and Direccion General de Materiales, Residuos y Actividades Riesgosas*

Assumption: Since alternate fuel used by the various cement plant is of diverse nature, no single heat value can be assigned to this type of fuel. For simplicity, it will be assumed as if this alternate fuel is equivalent to heavy fuel oil.

Table B.2: Fuel used by ton produced

Fuel rate	(m^3/ton)
Heavy Fuel Oil	0.06262
Diesel	0.00026

(From Table B.1)

Using above determined fuel consumption per ton of cement (Table B.2), and from total rated capacity of each cement plant listed in the inventory database, the total fuel consumption is calculated.

Table B.3: Mexico's Total Fuel Usage and Cement Production

Mexico's totals	
Cement (ton)	42,626,062
Heavy Fuel Oil (m3)	2,669,303.59
Diesel (m3)	10,872.48

Appendix C

Lime Plants: Data/Sources

Appendix C - Lime Plants: Data/Sources

Table C.1: Fuel Usage and Lime Production
1999

Plant	M^3			Hydrated Lime (ton)
	Heavy Oil	Diesel	N. Gas	
Cal de Aguascalientes Aguascalientes, Aguascalientes		16.8		102312
Cal Apasco Apaxco, Estado de Mexico		24	27344270	256978
Calteco Tecolotlan, jalisco	20228.5	391.454		68000
Caleras Xiutepec y anexas Xitepec, Morelos	5038.715			45290
Cales Hidratadas de Teposcolula Teposcolula, Oaxaca	4075			3000
Calera María Luisa Izucar de Matamoros, Puebla	1490			13200
Cales Teziutecas Teziutlan, Puebla	2633.37			21757.32
Cal San Antonio Queretaro, Queretaro	3200			20000
Calera Bernal Queretaro, Queretaro	7600	51		75600
Calhidra de Sonora Hermosillo, Sonora	4431.6	240	4424800	90000
Industrias Hersan Izucar de Matamoros, Puebla	13546.93	0	0	53480
Materiales Calfin Merida, Yucatan	5840			51500
Total	**68084.115**	**723.254**	**31769070**	**801117**.32

Source: *INE's Dirección General de Gestión e Información Ambiental and Direccion General de Materiales, Resiudos y Actividades Riesgosas.*

Table C.2: Fuel used by ton produced

Fuel rate	(m^3/ton)
Heavy Fuel Oil	0.0850
Diesel	0.0009
Natural Gas	39.6560

(From Table C.1)

Table C.3: 1999 Quick Lime Production

Plant	m^3			Quick Lime (ton)
	Heavy Oil	Diesel	N. Gas	
Mexicana de Cobre Agua Prieta, Sonora	30,667	3.5	33,979,895	119,300

Using above determined fuel consumption per ton of hydrated lime (Table C.2), and from total rated capacity of each lime plant listed in the inventory database, the total fuel consumption is calculated.

Table C.4: Mexico's Total Fuel Usage and Lime Production

Mexico's totals	
Hydrated lime(ton)	5,102,323
Quick lime (ton)	119,300
Heavy Fuel Oil (m3)*	464,295.3
Diesel (m3)*	4,609.9
Natural Gas (m3)*	236,317,371.1

* *Including Mexicana de Cobre*

Appendix D

Medical Waste Incinerators: Data/Sources

Appendix D - Medical Waste Incinerators: Data/Sources

Table D.1: Medical Waste Incinerators in Mexico 1999

Plant	State	Date of Test	Emission Tests Hg+Cd (mg/m³)
Tradem.	Distrito Federal	6/99	0.147
Control de Desechos Ind. y Monit. Amb.	Coahuila	9/99	0.010
Tradem	Estado de Mexico	11/96 12/98	0.4 1.23(*)
Steriderm	Estado de México	2/99 9/99	0.0368 0.015
Soluciones Ecológicas Integrales.	Estado de México	1/99 1/99 1/99 1/99	0.0447 0.0491 0.0798 0.1234
Proterm-JV de México.	Estado de México	7/99	0.1
Proterm-JV de México.	Estado de México	7/99	0.1
Tecnología Especializada en Reciclaje.	Hidalgo	4/99	0.14
Alicia Chávez González.	Jalisco	1/99	0.1
Ciba Especialidades Químicas México.	Jalisco	11/97 12/98 5/99 11/99 12/99 12/99	0.0429 0.005 0.015 0.038 0.079 0.085
Servicios de Tecnología Ambiental.	Nuevo Leon	8/98	0.15
Bio-System Technology.	Nuevo León	1/99 1/99	0.056 0.073
Ecotérmica de Oriente.	Puebla	4/99 4/99 9/99 9/99	0.0624 0.19 0.06 0.19
Marepel.	Sinaloa	‘96 ‘97 ‘98 ‘99	0.03 0.1217 0.07105 0.25
Secam.	Tamaulipas	4/97 4/97	0.00425 0.002904
Incineradores, Mantenimiento y Equipo	Jalisco	4/98	0.04 0.126
Centro Ambiental.	San Luis Potosí	6/99	0.0352
Ameq de México.	Coahuila	10/99 3/00	0.012(*) 0.012(*)
Control Ambiental del Bajío.	Guanajuato	8/99	0.07(*)

Source: *INE's Dirección General de Materiales, Residuos y Actividades Riesgosas.*
(*) Only Hg

Appendix E

Non-Ferrous Smelters: Data/Sources

Appendix E - Non-Ferrous Smelters: Data/Sources

Table E.1: Non-Ferrous Smelters: 1999

Plant	Concentrate Processed (ton)		Source	Hg (ppm)	Source
Mexicana de Cobre	Cu	1,080,000	INE's DGGIA, DGMRAR(*), *(62)*	-	-
Industrial Minera Mexico	Cu	22,500	INEGI's Directorio de la Minería Mexicana, 2000	1.4	Dr. Francisco Martinez Gonzalez, IMMSA's EHS Mngr. Test done at INE's request.
	Zn	122,000		-	-
Peñoles	Pb	340,540	INE's DGGIA, DGMRAR(*)	20-25	Ing. Camilo Valdez, Peñoles' EHS Mngr., based on Hg routine analysis.
	Zn	240,359		5-10	

(*) *Dirección General de Gestion e Informacion Ambiental and Dirección General de Materiales, Residuos y Actividades Riesgosas. (62): Minería, Vol. X Num. 8, October-December 2000.*

Appendix F

Mercury Emission Estimates

Appendix F – Mercury Emission Estimates

Note: Unless otherwise specified, all data are for year 1999.

I.- THERMOELECTRIC.

1.- FUEL CONSUMPTION:

Generation Technology	GWh Generated (1)	Heavy fuel oil (2)		Diesel (2)		Natural Gas (2)	
		Mm^3	Mm^3/Gwh	Mm^3	Mm^3/Gwh	MMm^3	MMm^3/Gwh
Vapor	85 104	18 469	0.2170	11	0.0004	3510	0.0412
Internal Combustion	381	49	0.1286	45	0.1181	--	0
Turbo Gas	2 077	--	0	365	0.1757	504	0.2427
Combinated Cycle	15 526	157	0.0101	81	0.0052	3826	0.2464
Dual	11 234	2 613	0.2236	5	0.0004	--	0
Total		**21 288**		**507**		**7 840**	

Source: (1) *INEGI: El Sector Energetico en Mexico, 2000 Table 2.41* (2) *Ibid, Table 3.5.1.2*
GWh: Giga watts-hour ; Mm^3: thousands of cubic meters; MMm^3: Millions of cubic meters.

2.- SPECIFIC GRAVITY: (from PEMEX)

Heavy Fuel Oil = 0.98 ton/m^3
Diesel = 0.86 ton/m^3

3.- Hg EMISSION FACTOR: (See Section 4.1)

HO = 0.004 ppm
Diesel = 0.010 ppm
NG = 5 $\mu g/m^3$

4.- ESTIMATE OF Hg EMMISSIONS:

Hg from HO = 21 288 (m^3/yr) x 0.98 (ton/m^3) x 0.004 (g/ton) x 10^{-6} (ton/g) = 0.083 (ton/yr)
Hg from Diesel = 507 (m^3/yr) x 0.86 (ton/m^3) x 0.010 (g/ton) x 10^{-6} (ton/g) = 0.004 (ton/yr)
Hg from NG = 7 840 x 10^{-6} (m^3/yr) x 5 x 10^{-12} (ton/m^3) = 0.0392 (ton/yr)

__Hg emissions__ = 0.083 + 0.004 + 0.0392 = __**0.1263 (ton/yr)**__

II.- CARBOELECTRIC:

1.-FUEL CONSUMPTION

GWh Generated	Coal		Diesel	
	Mton	Mton/Gwh	Mm^3	m^3/GWh
18 251	9 468	0.51876	27	1.4793

Source: *INEGI: El Sector Energético en México, 2001, Table 3.5.1.2*

2.- Hg EMISSION FACTOR: (See Section 4.1)

Coal = 0.105 ppm
Diesel = 0.010 ppm

3.-ESTIMATED Hg EMISSIONS:

Hg from C = 9.468 (MMt) x 0.105 (ton/MMt) = 0.9941 (ton/yr)

Hg from Diesel = $27 \times 0.86 \times 0.010 \times 10^{-6}$ = 0.0002 (ton/yr)

Uncorrected Hg emissions = 0.9941 + 0.0002 = 0.9943
Assuming 21% reduction by pollution control system = 0.9943x0.79

Hg emissions = 0.7855

III. ESTIMATE OF EMISSIONS FOR EACH THERMOELECTRIC STATION

a) Data Sources: INEGI, El Sector Energético en México, 2000.

(1) GWh generated by each technology: table 2.4.1, page 84
(2) Fuel consumption by each type of technology, table 3.5.1.2, page 207
(3) GWh generated by each station: table 2.5.3, pages 101-103

b) Calculations:

b.1 For each type of technology, determine the amount of each fuel used per GWh generated (Mm^3/GWh).
b.2 For each type of station, multiply GWh generated by (Mm^3/GWh) for each type of fuel, to obtain amount of each fuel used by each station.
b.3 Apply the Hg emission Factor for each fuel used per station.

c) *Note:*

There is a sligth difference between total GWh generated from table 2.4.1 and total GWh generated from table 2.5.3 in INEGI, El Sector Energético en México, 2000 . This difference reflects also in different emissions figures estimated, depending on what source is used. For the purpose of this inventory, data from figure 2.4.1 is used.

IV.- BOILERS (1998):

1.- HEATING VALUES:

HO = 10 120 Kcal/Kg (PEMEX)

Diesel = 7 969 Kcal/Kg (PEMEX)

NG = 36×10^{-6} Joules/ m^3 (Perry' Chemical Eng. Handbook, 6^{th}. Ed))

2.- FUEL USAGE:

$$HO = \frac{[167\,108 \times 10^{12} \text{ (Joules)} \times 10^{-9} \text{ (MMt/Kg)}]/}{[4\,186.8 \text{ (Joules/Kcal)} \times 10\,120 \text{ (Kcal/Kg)}]} = 3.944 \text{ (MMt)}$$

$$Diesel = \frac{[84\,340 \times 10^{12} \text{ (Joules)} \times 10^{-9} \text{ (MMt/Kg)}]/}{[4\,168.8 \text{ (Joules/Kcal)} \times 7\,969 \text{ (Kcal/Kg)}]} = 2.528 \text{ (MMt)}$$

$$NG = \frac{[390\,883 \times 10^{12} \text{ (Joules)}]/}{[36 \times 10^{6} \text{ (Joules/m}^{3]}} = 10857.86 \text{(MMm}^3\text{)}$$

3.- MERCURY EMMISSIONS:

Hg from HO = 3.944 (MMt/yr) x 0.004 (ton/MMt) = 0.0158 (ton/yr)

Hg from Diesel = 2.528 (MMt/yr) x 0.010 (ton/MMt) = 0.0253 (ton/yr)

Hg from NG = 10 857.86 $MMm^3 \times 5 \times 10^{-6}$ (tons/MMm^3) = 0.0543 (ton/yr)

Hg emissions = 0.0158 + 0.0253 + 0.0543
= 0.0954 (ton/yr)

NOTE: Emissions from coke are negligible

V.- RESIDENTIAL WOOD COMBUSTION:

1.- WOOD USAGE: 243.913 x 10^{15} Joules (INEGI: El Sector Energetico en Mexico, 2000)

2.- CONVERSION FACTOR: 1 Joule x 9.480 x 10^{-4} = 1 Btu (Perry's Chemical Engineering Handbook, 6th. Ed)

3.- MEAN HEATING VALUE: 8 989 Btu / lb (Combustion Fossil Fuel Power Systems; Joseph G. Sinaer, Editor, Combustion Engineering, Inc.)

4.- WOOD USAGE: (INEGI)

$$W = \frac{[243.913 \times 10^{15} \text{ (Joules)} \times 9.48 \times 10^{-4} \text{ (Btu/Joule)} \times 0.454 \text{ (Kg/lb)} \times 10^{-3} \text{(ton/Kg)}]/}{[8\,989 \text{(Btu/lb)}]} = 11.679\text{x } 0^{6} \text{ (ton/yr)}$$

5.- Hg EMISSION FACTOR: 0.1 (g/ton) (Emission Factors Manual Parcom-Atmos: Emission factors for air pollutants; Netherlands, 1992)

6.- Hg EMISSIONS

Hg emissions = 11.679 x 10^{6} (ton/yr) x 0.1 (g/ton) x 10^{-6} (ton/g)

Hg emissions = 1.168 (ton/yr)

VI.- GOLD/SILVER MINING & REFINERY:

1.- ORE PROCESSED: 11 679 723 (ton/yr) (From Table 4.5)

2.- EMISSION FACTOR: 0.965 (g/ton of ore) (See Section 4.4.1)

3.- Hg EMISSIONS:

Hg emissions = 11 679 723 (ton/yr) x 0.965 x 10^{-6} (ton/ ton of ore) = 11.270 (ton/yr

Hg emissions = 11.270 ton/yr

VII.- MERCURY MINING & REFINERY:

1.- Hg RECOVERED FROM TAILINGS: 29 tons (from Semarnat-Zacatecas)

2.- Hg CONDENSATION EFFICENCY: 75 % (See Section 4.4.2)

3.- Hg EMISSIONS:

Hg emissions = 29 x (0.25/.75) = 9.666 (ton/yr)

Hg emissions = 9.666 ton/yr

VIII.- COOPER SMELTERS:

1.- CONCENTRATE PROCESSED:

Mexicana de Cobre	= 1 080 000 (ton)	(55, 62)
IMMSA	= 22 500 (ton)	(Directorio de la Minería Mexicana, 1999)

2.- Hg CONTENT IN CONCENTRATE: 1.4 ppm (IMMSA actual tests) (Assumed for M de C)

3.- Hg IN CONCENTRATE:

Mexicana de Cobre	$= 1\ 080\ 000 \times 1.4 \times 10^{-6}$	= 1.512 (ton)
IMMSA	$= 22\ 500 \times 1.4 \times 10^{-6}$	= 0.0315 (ton)

4.- POLLUTION CONTROL EFICCIENCY:

Mexicana de Cobre = 98 % (2 % to Air; 98% to Sludge sent to IMMSA)

IMMSA = 0 %

NOTE: M de C Sludge is sent to IMMSA

5.- Hg EMISSIONS:

Mexicana de Cobre	= 1.512 X 0.02	= 0.0302 (ton/yr)
IMMSA	= (1.512 x 0.98) + 0.0315	= 1.513 (ton/yr)

Hg emissions = 1.543

IX.- PRIMARY LEAD & ZINC SMELTERS:

1.- CONCENTRATE PROCESSED PER YEAR:

(Lead)	Peñoles	= 340 540 (ton)	(55, 60)
(Zinc)	Peñoles	= 240 359 (ton)	(55, 60)
(Zinc)	IMMSA	= 122 000 (ton)	(60)

2.- Hg CONTENT IN CONCENTRATE:

(Lead)	Peñoles	= 22.5 ppm	(Peñoles' EHS)
(Zinc)	Peñoles	= 7.5 ppm	(Peñoles' EHS)
(Zinc)	IMMSA	= 7.5 ppm	(Assumed from Peñoles)

3.- Hg in CONCENTRATES:

(Lead)	Peñoles	= 340 540 x 22.5 x 10^{-6}	= 7.662 (ton)
(Zinc)	Peñoles	= 240 359 x 7.5 x 10^{-6}	= 1.803 (ton)
(Zinc)	IMMSA	= 122 000 x 7.5 x 10^{-6}	= 0.915 (ton)

Total Hg in concentrates = 10.380 (ton)

4.- POLLUTION CONTROL EFICCIENCY: 0.98%

5.- Hg EMISSIONS:

Hg emissions = 10.380 x 0.02 **= 0.208 (ton/yr)**

X.- FERROUS SMELTERS:

1.-FUEL CONSUMPTION:

HO	= 23.933 (Petajoules)	(INEGI)
Diesel	= 1.282 (Petajoules)	(INEGI)
Coke	= 2 512 081.6 (ton)	(INEGI)
NG	= 109.272 (Petajoules)	(INEGI)

Converting from Petajoules: See conversion factors in section III of this appendix

HO = 0.565 MMt

Diesel = 0.038 MMt

NG = 3035.3 MMm^3

2.- Hg EMISSIONS FACTORS:

HO = 0.004 ppm

Diesel = 0.010 ppm

Coke = 2.724×10^{-5} (Kg/ton coke); Source (*17*)

NG = 5 $\mu g/m^3$

3.- Hg EMISSIONS / YR:

Hg from HO	=	0.565 MMt	= 0.068 (ton)
Hg from Diesel	=	0.038 MMt	= 0.0004 (ton)
Hg from Coke	=	$2\,512\,081.6 \times 2.724 \times 10^{-5}$	= 0.00226 (ton)
Hg from NG	=	$3035.3 \times 5 \times 10^{-6}$	= 0.0152 (ton)

Hg emissions = 0.086 ton/yr

XI.- OIL REFINERIES:

1.-FUEL USAGE:

Crude oil	= 1 228 000 bpd
HO	= 426 000 bpd
Diesel	= 272 000 bpd

Bpd = barrels per day

2.- CONVERSION FACTORS: (From PEMEX)

1 barrel = 0.15899 m^3
1 barrel = 42 gallons

3.- SPECIFIC GRAVITY:

Crude oil	= 0.98
HO	= 0.98
Diesel	= 0.86

4.- HgEMISSION FACTOR:

Crude oil	= 0.0135 ppm (ITS Caleb-Brett)
HO	= 0.004 ppm
Diesel	= 0.010 ppm

NOTE: 1 ppm = (1 ton / MMt)

5.- Hg EMISSIONS:

a) Mercury from Crude Oil:

Crude Oil	= 1 228 000 (b/d) x 0.15899 (m^3/b) x 0.98 (ton/m^3)	= 0.191335 (MMt/d)
Hg in Crude Oil	= 0.191335 (MMt/d) x 0.0135 (ton/MMt)	= 2.5827 x 10^{-3} (ton/d)

b) Mercury in Heavy Oil

Heavy Oil	= 426 000 x 0.15899 x 0.98	= 0.0664 (MMton/d)
Hg in Heavy Oil	= 0.0664 x 0.004	= 0.2656 x 10^{-3} (ton/d)

c) Mercury in Diesel

Diesel	= 272 000 x 0.15899 x 0.86	= 0.0372 (MMton/d)
Hg in Diesel	= 0.0372 x 0.010	= 0.372 x 10^{-3} (ton/d)

Hg emissions = Hg from CO – Hg from HO –Hg from D = 1.945 x 10^{-3} (ton/d)

Assuming = (350 d/yr)

Hg emissions = 0.680 (t/yr)

XII.- CEMENT PLANTS:

1.-FUEL USAGE: (From Table C.3, Appendix C)

HO = 2 669 303.6 m^3
Diesel = 10 872.5 m^3

2.- Hg EMISSIONS:

Hg from HO = 2 669 303.6 (m^3/yr) x 0.98 (ton/m^3) x 0.004 (g/ton) x 10^{-6} (ton/g) = 0.0105 (ton/yr)

Hg from Diesel = 10 872.5 (m^3/yr) x 0.86 (ton/m^3) x 0.010 (g/ton) x 10^{-6} (ton/g) = 9.35 x 10^{-5} (ton/yr)

<u>Hg emissions = 0.0105 (ton/yr)</u>

XIII.- LIME PLANTS:

1.-FUEL USAGE: (from Table D.4 Appendix D)

HO = 464 295.3 m^3
Diesel = 4 609.9 m^3
NG = 236 317 317 .1 m^3

2.- Hg EMISSIONS:

Hg from HO = 464 295.3 (m^3/yr) x 0.98 (ton/m^3) x 0.004 (g/ton) x 10^{-6} (ton/g) = 0.0018 (ton/yr)

Hg from Diesel = 4 609.9 (m^3/yr) x 0.86 (ton/m^3) x 0.010 (g/ton) x 10^{-6} (ton/g) = 4.5 x 10^{-5} (ton/yr)

Hg from NG = 236 317 317.3 x 10^{-6} (m^3/yr) x 5 x 10^{-12} (ton/m^3) = 0.0012 (ton/yr)

<u>Hg emissions = 0.0030 (ton/yr)</u>

XIV.- HAZARDOUS WASTE INCINERATORS:

1.-TOTAL INCINERATION CAPACITY: 65 391 (ton/yr)

2.- ASSUMPTIONS[(1)] : 10 % of capacity was used in 1999
Hg emissions factor = 3.0 g/ton

(1) INE: Diagnóstico del Mercurio en México, Junio 2000.

3.- Hg EMISSIONS:

Hg Emissions = 65 391 (ton/yr) x 0.10 x 3.0 (g/ton) x 10^{-6} (ton/g) = 0.020 (ton/yr)

Hg Emissions = 0.020 (ton/yr)

XV.- MEDICAL WASTE INCINERATORS:

1.-TOTAL RATED CAPACITY: 8 975 (Kg/hr)

2.- ASSUMPTIONS[(1)] : 260 days/yr @ 8 hr/day
40 % of capacity was used in 1999
Hg emissions factor = 0.96 g/ton

(1) INE: Diagnóstico del Mercurio en México, Junio 2000.

3.- Hg EMISSIONS:

Hg Emissions = 8.9755 (ton/hr)x260 (days/yr)x8 (hr/day)x0.40x0.96 (g/ton)x10^{-6} (ton/g) = 0.007 (ton/yr)

Hg Emissions = 0.007 (ton/yr)

XVI.- CHLOR-ALKALI PLANTS:

1.-TOTAL Hg USAGE: 5. 767 (ton/yr) (INE's Diagnóstico del Mercurio en Mexico)

2.- Hg LOSSES: 14 % to Sludge (USGS: The Materials Flow of Mercury in the Economies of the United States and the World, Circular 1197, June, 2000)
1% to NaOH

3.- Hg EMISSIONS:

Hg Emissions = 5 767(ton/hr) x (1-0.14-0.01) = 4.902 ton/yr

Hg Emissions = 4.902 ton/yr

XVI.- PULP AND PAPER PLANTS:

1.- ASSUMPTIONS: Pulp production in US = 54 000 000 (ton/yr) (CNICP)
80 % of pulp produced in US is from Chemical Processes:
(EPA: Report to Congress, 1997) ($54 \times 10^6 \times 0.8 = 43.2 \times 10^6$)
Hg emissions from pulp plants in the US = 1.7 ton/yr
Hg emission per ton of pulp = $1.7/43.2 \times 10^{-6} = 0.0393 \times 10^6$ (ton Hg /ton pulp)

2.- PULP PRODUCTION FROM CHEMICAL PROCESSES IN MEXICO: 495 524 (ton)
NOTE: No pollution control , add 21%

3.- Hg EMISSIONS:

Hg Emissions = $495\,524 \times 0.0393 \times 10^{-6} \times 1.21$ = 0.024 (ton/yr)

Hg Emissions = 0.024 (ton/yr)

XVIII.- FLUORESCENT LAMPS:

1.- Hg USED IN LAMPS: 935 Kg/yr (INE)

2.- Hg EMISSIONS FACTOR : 25 % of mercury used (INE)

3.- Hg EMISSIONS:

Hg Emissions = 935 (Kg/yr) x 0.25 x 0.98 = 0.229 (ton/yr)

Hg Emissions = 0.229 (ton/yr)

XIX.- THERMOMETERS:

1.- No. OF HOSPITAL BEDS : 251 656 (INE & SSA)

2.- ASSUMPTIONS[(1)] : 1 thermometer per 4 beds per week (INE & SSA)
0.61g Hg per thermometer (EPA, Report to Congress)
9 Kg Hg emitted per ton of Hg used (EPA, Report to Congress))

3.- Hg EMISSIONS:

Hg Emissions = [251 656 / 4] x 52 pcs/yr x0.61 (gr/pcs) x 9 (Kg/ton) x 10^{-6} (ton/g) = 17.9 (Kg/yr)

Hg emissions = 0.018 (ton/yr)

XXI.- AMALGAMS:

1.- ASSUMPTIONS: 8 % of amalgams used is lost in dental offices (USGS, Idem)
1.51 (ton/yr) of Hg discarded (INE)
2 % Hg used in amalgams is lost to air (EPA Report to Congress)

2.- Hg EMISSIONS:

Hg Emissions = [1.51 / 0.08] x 0.02 = 0.378 (ton/yr)

Hg Emissions = = 0.378 (ton/yr)

Appendix G

Laboratory Results

Appendix G: Laboratory Results

Hard copies of laboratory results are attached to the printed report, according to the following:

TABLE G.1   LABORATORY RESULTS

Laboratory	Sample	Sample ID No.	Hg Content ppb
ITS Caleb-Brett	Maya Crude Oil	004830-DRPK-007	18
		007047-DRPK-006	16
		Astro Antares 01-0932	< 10
		000352-DRPK-007	< 10
	Heavy Fuel Oil	0022078-DRPK-002	< 10
	Diesel	0022078-DRPK-001	< 10
AOL/ITS Caleb-Brett	Heavy Fuel Oil	002078-DRPK-004	< 100
	Diesel	002078-DRPK-003	< 100
Commercial Testing and Engineering	Unwashed carbon (Rio Escondido vein)	UW-1	120
	Washed carbon (Rio Escondido vein)	W-1	60
	Coke	CK-1	20
	Carbon for coke (La Colorada, Son. vein)	CS-1	80
Severn Trent Laboratory	Unwashed carbon (Rio Escondido vein)	UW-2	883
	Washed carbon (Rio Escondido vein)	W-2	369
	Coke	CK-2	53.5
	Carbon for coke (La Colorada, Son. vein)	CS-2	119