# 7 Current production and use of mercury

## 7.1 Overview

### Origin of mercury

538. Mercury is a natural component of the earth, with an average abundance of approximately 0.05 mg/kg in the Earth's crust, with significant local variations. Mercury ores that are mined generally contain about one percent mercury, although the strata mined in Spain typically contain up to 12-14 percent mercury. While about 25 principal mercury minerals are known, virtually the only deposits that have been harvested for the extraction of mercury are cinnabar. Mercury is also present at very low levels throughout the biosphere. Its absorption by plants may account for the presence of mercury within fossil fuels like coal, oil and gas, since these fuels are conventionally thought to be formed from geologic transformation of organic residues.

### Sources of mercury to the market

539. The mercury available on the world market is supplied from a number of different sources, including (not listed in order of importance):

- Mine production of primary mercury (meaning extracted from ores within the earth's crust):
  - either as the main product of the mining activity,
  - or as by-product of mining or refining of other metals (such as zinc, gold, silver) or minerals;
- Recovered primary mercury from refining of natural gas (actually a by-product, when marketed, however, is not marketed in all countries);
- Reprocessing or secondary mining of historic mine tailings containing mercury;
- Recycled mercury recovered from spent products and waste from industrial production processes. Large amounts ("reservoirs") of mercury are "stored" in society within products still in use and "on the users' shelves";
- Mercury from government reserve stocks or inventories;
- Private stocks (such as mercury in use in chlor-alkali and other industries), some of which may later be returned to the market.

540. The mining and other mineral extraction of primary mercury constitute the human mobilisation of mercury for intentional use in products and processes. Recycled mercury and mercury from stocks can be regarded as an anthropogenic re-mobilisation of mercury previously extracted from the Earth.

### Continued mining of primary mercury

541. Despite a decline in global mercury consumption (global demand is less than half of 1980 levels), supply from competing sources and low prices, production of mercury from mining is still occurring in a number of countries. Spain, China, Kyrgyzstan and Algeria have dominated this activity in recent years, and several of the mines are state-owned. Table 7.1 gives information on recorded global primary production of mercury since 1981. There are also reports of small-scale, artisanal mining of mercury in China, Russia (Siberia), Outer Mongolia, Peru, and Mexico. It is likely that this production serves robust local demand for mercury, often for artisanal mining of gold[8]. Such mercury production would require both accessible mercury ores and low-cost labor in order for it to occur despite low-priced mercury available in the global commodity market.

---

[8] In some countries, such as China, the artisanal mining of mercury or gold – or both – are illegal, but the enforcement of such legislation varies depending on many local factors.

*Table 7.1 Recorded global primary production of mercury since 1981, metric tons/year.*

| **Period** | **1981-1985** | **1986-1989** | **1990-1995** | **1996** | **1997** | **1998** | **1999** | **2000** |
|---|---|---|---|---|---|---|---|---|
| Recorded annual, global primary production (in metric tons) | 5500-7100 | 4900-6700 | 3300-6100 | 2600-2800 | 2500-2900 | 2000-2800 | 2100-2200 | 1800 |

Sources: See section 7.2.1.

### Large supplies of recycled mercury may be marketed

542. Large quantities of mercury have come onto the market as a result of ongoing substitution and closing of mercury-based chlor-alkali production in Europe and other regions. Market analysis indicates that 700 - 900 metric tons per year of recycled mercury (corresponding to about 30 percent of the recorded primary production) has been marketed globally since the mid-1990's, of which the majority originated from chlor-alkali production facilities (see section 7.3.1). However, to the extent there remains a legitimate demand for mercury, the re-use and recycling of mercury replaces the mining and smelting of virgin mercury, which would involve additional releases and would result in mobilising new mercury into the market and the environment.

543. The preference for reuse and recycling of mercury over mining - especially in the context of large mercury inventories coming onto the market - is complicated by the generally accepted economic rule that an **excess** supply of mercury drives the market price lower, which in turn encourages additional use or waste of mercury. For this reason, certain precautions are being taken, as described below.

544. Within the current decade and beyond, vast supplies of mercury will become available from conversion or shutdown of chlor-alkali facilities using the mercury process, as many European countries[9] press for a phase-out of this process before 2010. From the European Union alone, this may introduce up to 13,000 metric tons of additional mercury to the market (equal to some 6-12 years of primary mercury production; see section 7.4.1 on chlor-alkali production). In response to this potential glut of mercury, Euro Chlor, which represents the European chlor-alkali industry, has signed a contractual agreement with Miñas de Almadén. The agreement provides that Miñas de Almadén in Spain will buy the surplus mercury from West-European chlor-alkali plants and put it on the market in place of mercury Almadén would otherwise have mined. All EU members of Euro Chlor have agreed to sell their surplus mercury to Almadén according to this agreement, and Euro Chlor believes most of the central and eastern European chlorine producers will also commit to this agreement. While this agreement clearly represents an effort by all parties to responsibly address the problem of surplus mercury, some people have the view that there are not yet adequate controls on where this mercury would be sold or how it would be used.

545. Similarly, large reserve stocks of mercury held by various governments have become superfluous, and are subject to future sales on the world market if approved by the relevant national authorities. This is the case in the USA, for example, which holds a 4,435 metric ton inventory of mercury. The sale of this mercury has been suspended since 1994, awaiting a determination of its potential environmental and market impacts. Prior to that, however, the sale of some of these stocks contributed significantly to the supply of mercury on the domestic US-market, and to exports as well. US government sales were equivalent to 18 to 97 percent of the domestic US demand for mercury in the years 1990-94 (US EPA, 1997; Maxson and Vonkeman, 1996).

### Uses of mercury

546. The element mercury has been known for thousands of years, fascinating as the only liquid metal, and applied in a large number of products and processes utilising its unique characteristics. Being liquid at room temperature, being a good electrical conductor, having very high density and high sur-

[9] Including most of the parties to the OSPAR and HELCOM Conventions. OSPAR recommends a phaseout of the mercury cell chlor-alkali process within the territories of its parties. Most OSPAR and HELCOM countries are member states of the European Union.

face tension, expanding/contracting uniformly over its entire liquid range in response to changes in pressure and temperature, and being toxic to micro-organisms (including pathogenic organisms) and other pests, mercury is an excellent material for many purposes.

547. In the past, a number of organic mercury compounds were used quite broadly, for example in pesticides (extensive use in seed dressing among others) and biocides in some paints, pharmaceuticals and cosmetics. While many of these uses have diminished in some parts of the world, organic mercury compounds are still used for several purposes. Some examples are the use of seed dressing with mercury compounds in some countries, use of dimethylmercury in small amounts as a reference standard for some chemical tests, and thimerosal (which contains ethylmercury) used as a preservative in some vaccines and other medical and cosmetic products since the 1930's. As the awareness of mercury's potential adverse effects to health and the environment has been rising, the number of applications (for inorganic and organic mercury) as well as the volume of mercury used have been reduced significantly in many of the industrialised countries, particularly during the last two decades.

**Examples of uses of mercury**

As the metal (among others):

- for extraction of gold and silver (for centuries)
- as a catalyst for chlor-alkali production
- in manometers for measuring and controlling pressure
- in thermometers
- in electrical and electronic switches
- in fluorescent lamps
- in dental amalgam fillings

As chemical compounds (among others):

- in batteries (as a dioxide)
- biocides in paper industry, paints and on seed grain
- as antiseptics in pharmaceuticals
- laboratory analyses reactants
- catalysts
- pigments and dyes (may be historical)
- detergents (may be historical)
- explosives (may be historical)

548. The submissions received for the Global Mercury Assessment have confirmed, however, that many of the uses discontinued in the OECD countries are still alive in other parts of the world. Several of these uses have been prohibited or severely restricted in a number of countries because of their adverse effects on humans and the environment. Furthermore, while this chapter provides a good general picture of mercury production and use around the world, it also shows that it is crucial to gain an even better understanding of global mercury markets and flows in order to assess demand, to design appropriate pollution prevention and reduction measures, and to monitor progress towards specific objectives.

549. Parts of the descriptive text in this chapter were based on the submission from the Nordic Council of Ministers (sub84gov).

## 7.2 Global production

### 7.2.1 Production of primary mercury

550. Estimates for global primary production of mercury, as reported by the US Geological Survey, are given in table 7.2. Reese (1999) notes, however, that most countries do not report their mercury production, resulting in a high degree of uncertainty on the presented world production numbers.

Sznopek and Goonan (2000) quote alternative production estimates from Gobi International (1998). For 1990, global production was estimated at 4100 metric tons according to USGS and 5356 metric tons according to Gobi. For 1996, the USGS reported the production as 2795 metric tons and Gobi reported it as 3337 metric tons. The causes for these deviations are not known, but they indicate that the real production numbers may be higher than those presented in table 7.2. It may also be possible that recycled mercury, mercury recovered as a by-product or marketing from stocks have influenced the higher set of numbers.

551. Lawrence (2000) has estimated that on a worldwide basis, the amount of by-product mercury might be as much as 400 metric tons.

552. At the US EPA-sponsored Mercury Conference in Boston in May 2002, Lawrence (2002, as quoted by USA; comm-24-gov) estimated current supply to the world market at about 2000 metric tons, of which virgin mercury extraction (including by-product) accounted for about 1,000 metric tons annually, and another approximately 1,000 metric tons comes from other sources). In the current situation with low – and possible poorly reported - production numbers, such estimates may be highly uncertain.

*Table 7.2 Estimated world production of primary (mined) mercury (metric tons), as reported by the US Geological Survey (Jasinski, 1994; Reese, 1997; 1999; unless noted; aggregation as presented in the Submission from the Nordic Council of Ministers, sub84gov) and by Hylander & Meili (2002) for the year 2000.*

| **Country** | **1981-1985 *1** | **1986-1989 *1** | **1990** | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Algeria | 386-877 | 587-764 | 637 | 431 | 476 | 459 | 414 | 292 | 368 | 447 | 224 | 200 | 240 |
| China | 800 | 850-1200 | 1000 | 760 | 580 | 520 | 470 | 780 | 510 | 830 | 230 | 200 | 200 |
| Finland ***2** | 65-130 | 135-160 | 141 | 74 | 85 | 98 | 89 | 90 | 88 | 63 | 80 | 80 | 45 |
| Kyrgyzstan | - | - | - | - | 300 | 1000 | 379 | 380 | 584 | 610 | 620 | 620 | 600 |
| Mexico | 221-394 | 124-651 | 735 | 340 | 21 | 12 | 12 | 15 | 15 | 15 | 15 | 15 | 25 |
| Russia | - | - | - | - | 70 | 60 | 50 | 50 | 50 | 50 | 50 | 50 | - |
| Slovakia /Cz | 144-158 | 131-168 | 126 | 75 | 60 | 50 | 50 | 0 | 0 | 0 | 20 | 0 | 0 |
| Slovenia | - | - | - | - | 7 | ? | 6 | 0 | 5 | 5 | 5 | 0 | 0 |
| Spain | 1416-1560 | 967-1471 | - | - | - | 643 | 393 | 1497 | 862 | 863 | 675 | 600 | 237 ***3** |
| Tajikistan | - | - | - | - | 100 | 80 | 55 | 50 | 45 | 40 | 35 | 35 | 40 |
| Ukraine | - | - | - | - | 100 | 50 | 50 | 40 | 30 | 25 | 20 | - | - |
| USA | 570-962 | 140-520 | 562 | 58 | 64 | w | w | w | 65 | w | - | - | 15 |
| USSR | 1600-1700 | 1500-1650 | 800 | 750 | - | - | - | - | - | - | - | - | - |
| Yugoslavia | 0-88 | 51-75 | 37 | 9 | - | - | - | - | - | - | - | - | - |
| Other countries | 200-400 | 100-200 | - | - | - | - | 223 | 200 | - | - | 830 | 380 | 448 |
| Totals for reported activity (rounded) | 5500-7100 | 4900-6700 | 4000 | 2500 | 1900 | 3000 | 2200 | 3400 | 2600 | 2900 | 2800 | 2200 | |
| Derived by Hylander & Meili (2002) | 5600-6100 | 6100-6600 | 6100 | 3700 | 3100 | 3000 | 2000 | 3300 | 2800 | 2500 | 2000 | 2100 | 1800 |

Notes and legend:

w Withheld in the references

\- Not relevant or not available

/Cz Up to 1992 as part of Czechoslovakia

1 Reference: Metallgesellschaft (1992), as cited by OECD (1994). This reference's totals for 1990 and 1991 were 400-900 metric tons higher than the presented totals from USGS.

2 Numbers for Finland from 1990-1997 are from Finnish Environment Institute (1999).

3 Spain has reported a production in 2000 of 237 metric tons from the Spanish mercury mines.

### 7.2.2 Recycling of mercury

553. Recycled mercury has played an important role on the global market in recent decades. In 1982, the OECD estimated that the secondary production could be as much 40 percent of the primary production (OECD, 1985). Masters (1997) stated that 700 - 900 metric tons (20,000-25,000 "flasks"[10]) of mercury are recycled globally every year, of which some 200-400 metric tons originate from spent mercury-containing products, and the rest come mainly from chlor-alkali facilities. As mentioned in section 7.2.1 above, recent estimates (Lawrence, 2002) indicate that as much as 50 percent of the global supply may originate from secondary sources (sources other than virgin mercury extraction).

554. A large "reservoir" of mercury is known to be contained in products still in use, and "on the users' shelves" in society. If properly collected, recycled and managed, this reservoir could be the source of all of society's needs for mercury for many years into the future. Attempts have been made to quantify these reservoirs of mercury in Sweden, the Netherlands and Denmark.

555. In 1996, recycling of mercury in the USA, by itself, was greater than reported industrial usage in the same country (372 metric tons), and almost in the same range as the amount entering applications (417 metric tons; source: Sznopek and Goonan, 2000). Reported recycling numbers increased steadily from about 100 metric tons in 1990 to about 400 metric tons in 1996/97 (US EPA, 1997; USGS at www.usgs.gov; more recent trends were not investigated here).

556. German recycling of mercury has been quantified by Rauhaut (1996) for the period 1972-1993. In the years 1986-1993 (for which consumption is presented in the reference), the amounts of mercury re-refined for recycling in Germany were equivalent to 3-53 percent of the domestic mercury consumption in that country. During this period, recycling increased slightly (from 7 metric tons in 1986 to 36 metric tons in 1993), while German consumption decreased from 222 metric tons in 1986 to 67 metric tons in 1993. Recycling reached a maximum of 205 metric tons/year in the late 1970's. Reduced consumption and dropping mercury prices appear to have been among the possible reasons for the decrease in German recycling since the 1970's (Rauhaut, 1996).

557. For Denmark, an average of 3.5-4 metric tons of mercury was sent abroad for recycling per year in the years 1992-93 (Maag *et al.*, 1996).

558. In the Netherlands, 93 metric tons of mercury was recovered/recycled in 1995, including 2 tons product waste from Dutch use of amalgam fillings, 6 tons from Dutch gas sludge/waste, and 85 tons of mercury from imported sludge/waste (Maxson and Vonkeman, 1996; Annema *et al.*, 1995; DHV, 1996). One should note that recovery of mercury from, for example, gas sludge is not the same as recycling of spent mercury in products; rather it is a treatment of waste from resource extraction. When the mercury is marketed, it is equivalent to the by-product mercury produced during gold or zinc mining.

559. In an assessment of mercury in wastes in France, it was estimated that recycled mercury in that country was only about 2.8 metric tons/year. However, potentially significant wastes from chlor-alkali production, electrical contacts and laboratories, among others, were not included in the assessment (Groupe de travail de l'AGHTM, 1999).

560. Switzerland recovers about 15 metric tons recycled mercury/year (Swiss submission, sub38gov).

### 7.2.3 Price levels for metallic mercury

561. According to the US Geological Surveys' Mineral Yearbooks of various years (Reese, 1997; 1999; and others), mercury metals prices (i.e. selling prices quoted by dealers to customers) fluctuated quite dramatically during the early 1990's, averaging about 190 US$ per "flask" during the period 1990-1996 (range 122-262 US$). As one "flask" equals 34.5 kg, the average price per kg was 5.5 US$ at that time. During the years 1997-2000 the market price appeared stable at around 140-160 US$/flask (aver-

[10] Named for the leather container in which mercury was originally traded. Each flask (nowadays in fact a steel container) contains 34.5 kg of mercury.

age 148 US$/flask or 4.3 US$/kg). The highest mercury prices in the 20th century were about 500 US$/flask during the last half of the 1960's. When expressing prices as adjusted for inflation in the US$, market prices in 1998 were only about one-tenth of the price in the late 1960's (Scoullos *et al.*, 2000).

## 7.3 Current use patterns

### 7.3.1 Global consumption

562. The global consumption equals the amount of mercury originating from the sources listed in section 7.1 above to final users/consumers, corrected for intermediate stock changes. No precise data on the total global consumption and its distribution among countries and applications is available. A great deal of mercury use in developing countries takes place beyond mainstream society, and therefore beyond the classical compilation of economic statistics - principally in small-scale, artisanal mining of gold and silver. Yet this use may be among the largest on a global basis. Thus, estimates of total world use of mercury must rely in part on uncertain estimates from very incomplete data. Data on use in OECD nations is more precise, yet as the market in these nations has shrunk with increasing public scrutiny, this information is both diminishing in relative importance and becoming less reliable.

563. Submitted data on national consumption are presented in table 7.3. Many governments did not submit data on consumption, although their submissions indicated consumption of mercury within a number of applications and uses. In cases where actual consumption data were not submitted, data on imports and/or production were presented here as rough indicators of consumption levels. It should be noted, however, that import and production data may not always mirror consumption levels, as other factors may influence the numbers. A more thorough analysis of these aspects would be valuable, but could not be accomplished for use in this report due to time and resource limitations.

*Table 7.3 Submitted national data on consumption (or imports and production data, if consumption data were not available). Note that the basic assumptions and quality of data behind these numbers varies, and not all contributions are reported in all cases. Metric tons/year unless noted.*

| Country | Reported annual consumption (or import) Metric tons/year unless noted | Year(s) | Reference |
|---|---|---|---|
| Australia | >30 tons metallic mercury imported<br>+ 5 tons produced as by-product<br>+ 4 tons import of mercury compounds | 1996 | National submission, sub63gov |
| Canada | 2.8-2.9 tons consumption, metallic mercury<br>(of 9.4-11.4 tons imported) | 1998-1999 | National submission, sub42gov |
| Denmark | 1.5 tons total consumption (including with products, domestic and imported) | 2000/2001 | Submission from the Nordic Council of Ministers, sub84gov |
| Finland | App. 10 tons comsumption<br>(mercury produced as by-product, see table 7.2) | 1991 | National submission, sub44gov |
| France | 45 tons net import averaged over 3 years<br>(2, 112 and 20 tons respectively) | Averaged over 1998, 1999 and 2000 (individual years in brackets) | Comments from France, comm-10-gov |
| India | 170-190 tons imports of metallic mercury | Not mentioned (presumably relatively recent estimate) | National submission sub71govatt1 |
| Norway | 0.8-1.4 tons consumption with products only, additional consumption as metallic mercury | 1995/1999 | Submission from the Nordic Council of Ministers, sub84gov |
| Peru | 30-45 tons import of metallic mercury<br>+ 19-48 tons produced as by-product<br>+ small import of compounds | 1998-2000 | National submission, sub47gov |

| Country | Reported annual consumption (or import) Metric tons/year unless noted | Year(s) | Reference |
|---|---|---|---|
| Philippines | 55.658 tons import of metallic mercury<br>26.169 tons import of metallic mercury<br>19.100 tons import of metallic mercury | 1999<br>2000<br>2001 | National Statistics Office & Bureau of Export Trade Promotion, DTI Philippines (comm-4-gov) |
| Sweden | 2 tons consumption with products only, additional consumption as metallic mercury | 1997 | Submission from the Nordic Council of Ministers, sub84gov |
| Switzerland | 30 tons import (uncertain estimate) | "Late 1990's" | National submission, sub38gov |
| Thailand | 12,1 tons import of metallic mercury<br>17.2 tons import of metallic mercury<br>5.8 tons import of metallic mercury<br>(mostly for fluorescent lamp production, and a little for dentistry and lab analysis) | 2000<br>2001<br>Jan.-June 2002 | National submission, sub53gov, www.customs.go.th (2805.40) |
| Turkey | 4.5 "of mercury and its compounds imported" | 2000-2001 | National submission, sub34gov |
| USA | 372 tons consumption, including with products produced in the USA (not imports) | 1996 | Sznopek and Goonan, 2000 |

564. Regarding the geographical distribution of global mercury consumption, Scoullos *et al.* (2000) quotes Lawrence (1994) for the information presented in table 7.4 on world mercury consumption and its distribution over various countries/regions.

*Table 7.4 Estimated world mercury consumption in 1993 in metric tons, according to Lawrence (1994).*

| Country/region | Consumption |
|---|---|
| CIS | 1379 |
| USA | 558 |
| Europe | 448 |
| People's Republic of China | 345 |
| India | 345 |
| Iran * | 414 |
| Others | 345 |
| Total | 3834 |

CIS - Commonweath of Independent States (former Soviet Union minus Baltic States).

* According to Hylander (2001), the large consumption by Iran in 1993 was due to the restarting of a chlor-alkali plant destroyed during the war - consumption was not so large in other years.

## Estimated global distribution of consumption among regions and uses

565. Sznopek and Goonan (2000, as quoted in the submission from the Nordic Council of Ministers, sub84gov) have developed estimates of the likely distribution of global consumption and uses of mercury among diverse regions and uses. According to this analysis, the industrialised countries are still by far the largest users of mercury, in agreement with the numbers presented by Lawrence in table 7.4.

566. An estimate of the distribution of global mercury consumption by application group is shown in table 7.5. Taken together with table 7.4, this table shows that Western Europe and North America accounted for about 60 percent of the mercury consumed by worldwide chlor-alkali production, although these numbers were extrapolated from consumption ratios for this industry in the USA in the early 1990's, and no longer show a realistic picture of the actual situation. Based on data reported to their

respective governments by the industry, US- and OSPAR-region[11] (refer to section 9.3.2 for further details concerning OSPAR) chlor-alkali facilities consumed in 1999/2000 about 170 metric tons of mercury per year: 28 metric tons in the USA, and 145 metric tons in the OSPAR countries. Based upon diverse reports from other parts of the world, total mercury consumption by the chlor-alkali industry in the rest of the world is significantly higher.[12]

567. Western Europe, North America and Northeast Asia together accounted for about 80 percent of the global amount of mercury used for manufacturing of products. The calculations for product manufacturing are deemed indicative only (in submission from the Nordic Council of Ministers, sub84gov), as they were based on US consumption patterns in 1990 and 1996, and the assumption that consumption can be described as a function of "economic sophistication". That is, the numbers were not based on any actual observations of mercury consumption in product manufacturing in countries other than the USA.

568. Finally, as mentioned in the notes to table 7.5, mercury consumption for gold extraction in the table was estimated only for Brazil. The notes provide indications of the magnitude of global consumption.

*Table 7.5 Estimates of global mercury consumption by application category in 1990 and 1996 respectively, according to Sznopek and Goonan (2000, as presented in the submission from the Nordic Council of Ministers, sub84gov).*

| **Application category** | **1990** | **1996** |
|---|---|---|
| Chlor-alkali production | 2003 | 1344 ***3** |
| Use in products | 1818 | 1061 |
| Small-scale gold mining in Brazil***1** | 200 | 100 |
| Addition to stocks ***2** | 1335 | 832 |
| **Total** | **5356** | **3337** |

Notes: 1 One estimate of global mercury releases (obviously related to gold production, which is in turn related to gold demand) from small-scale gold mining was up to 460 metric tons per year for the late 1980's/early 1990's (Lacerda, 1997a). An estimate for global consumption of mercury was 350-450 metric tons/year for 1996 (Maxson and Vonkeman, 1996 – as cited by Scoullos *et al.*, 2000). A more recent small-scale mining estimate for global consumption of mercury was at least 500 metric tons, and possibly 1000 metric tons per year.[13]

2 It was assumed by Sznopek and Goonan that this category also includes amounts for which the use is unknown ("buffer category" in the calculated global mercury balance).

3 Recent estimates of global mercury consumption by the chlor-alkali industry (note that consumption is not equivalent to emissions) are significantly lower, as indicated in the text above. See also section 7.4.1.

[11] OSPAR member countries are Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom, although Denmark and Luxembourg have no chlor-alkali production, and Ireland and Norway have no mercury-cell chlor-alkali production. Of European Union member states, only Austria, Greece and Italy are not Parties to the OSPAR Convention.

[12] It should be noted that chlor-alkali mercury "consumption" figures should not be taken as equivalent to releases to the environment. This is because some of the mercury "consumption" (i.e. purchases corrected for inventory change) can ultimately be recovered from sludge wastes during normal operation, plant equipment and structures during major maintenance and, especially, when the mercury cellrooms are decommissioned (see also section 7.3.2. below). There is concern, however, that in some countries this recovery is inadequate.

[13] MMSD ("Case studies," 2002) calculated global gold mine production in 2000 as 2574 metric tons, and estimated that 20 percent of this comes from artisanal and small miners, most of them using a mercury process to recover gold. This is consistent with Gold Fields Mineral Service Limited (World gold production, 1998) estimate of global gold production by artisanal miners of 500 to 800 tons. Since artisanal miners on average use between one and two kilograms of mercury for each kilogram of gold produced (Lacerda, 1997b), this suggests world mercury use in gold mining of at least 500, and possibly 1000 tons per year. If one were to include artisanal mining of silver as well, the estimate of mercury use would be considerably higher.

### 7.3.2 Uses of mercury

569. Table 7.6 gives an overview of identified intentional applications of mercury and the available information on their current use. The applications marked as "general" in the table were mentioned in many of the submissions, as well as in current reviews. For applications that differ from the general pattern or were considered largely abandoned, the countries mentioning such uses are listed in the table. For some applications, the submitted information on bans and restrictions (see table 7.7) is the best available indication of current use. Applications that are known to have been used historically, but for which no confirmation of their current use was provided in submissions, are marked "no confirmation of current use". Finally, for some applications, less certain indications of current use were added, based on the background knowledge of the authors.

570. It is important to note that this list of uses also indicates where to search for mercury sources nationally or locally, for example in an effort to identify and reduce or eliminate specific sources of mercury in environmental media, waste or waste water. All of these uses gives rise to mercury releases in one or more of the phases of their life cycles: mercury extraction, product manufacturing, use, disposal, recovery and intermediate transport.

571. It is important to investigate national and global use patterns further - for example, in order to better assess patterns in global consumption of mercury, as a basis for possible international initiatives. However, this has not been possible within the time and resource constraints imposed on this phase of UNEP's mercury assessment process.

572. Examples of the relative contributions of different uses to total mercury consumption is given for selected countries in tables 7.8 and 7.9 in section 7.3.3 below.

*Table 7.6 Identified mercury applications, and indications of their current use. (This table attempts to reflect the actual situation in the countries listed, although it should not be assumed to be exhaustive or complete.)*

| **Application** | **Indications of current use** |
|---|---|
| **Chlor-alkali production (chlorine and caustic soda)** | General |
| **Dental amalgam** | General |
| **Artisanal gold and silver mining** | Australia, Burundi, Brazil, Burkina Faso(?), China, Costa Rica, Colombia, Côte d'Ivoire(?), Ecuador, Colombia, French Guyana, Ghana, Indonesia, Mongolia, Panama, Papua New Guinea, Peru, Philippines, Russia, Tanzania, Venezuela, Vietnam, Zimbabwe |
| **Batteries** | In use, but banned or restricted in many countries |
| **Measuring and control equipment** | See below |
| Medical thermometers | General, but banned or restricted in a few countries |
| Other thermometers (marine engine control, laboratory) | General, but banned or restricted in a few countries |
| Blood pressure gauges (sphygmomanometers) | General, but banned or restricted in a few countries |
| Industrial and meteorological manometers | Most likely general, but banned or restricted in a few countries |
| Pressure valves (district heating systems, industry) | Banned or restricted in a few countries |
| Gyroscopes | Banned or restricted in a few countries |
| **Electric and electronic switches** | Banned or restricted in a few countries |
| Level switches (sewer pumps, door bells, railway signals, car boot lids, refrigerators, freezers, fall-alarms for the elderly, etc.) | Banned or restricted in a few countries |
| Multiple poled switches (for example in excavation machines) | Banned or restricted in a few countries |

| **Application** | **Indications of current use** |
|---|---|
| Mercury-wetted microelectronic switches | Most likely general |
| Thermo-switches | Banned or restricted in a few countries |
| Switches in sports shoes with lights in soles | Banned or restricted in a few countries |
| **Discharge lamps** | General |
| Fluorescent lamps | General |
| Other mercury-containing lamps | General |
| **Laboratory chemicals, electrodes and apparatus for analysis** | General |
| **Pesticides (seed dressing and/or others)** | Australia, Belarus, Benin (unspecified), Burkina Faso (unspecified), Côte d'Ivoire, Ghana, Guinea (unspecified), India (unspecified), Ireland |
| **Biocides for different products and processes** | Cameroon (unspecified industrial production), Ireland |
| Paints (latex paints and possibly others) | Australia, Ghana, Guinea, India, Ireland, Samoa, Thailand (substitution ongoing), Trinidad and Tobago (subst. ongoing or completed recently) |
| **Slimicides for paper production** | Morocco, |
| **Pharmaceuticals (biocide or systemic functions)** | Czech Republic (unspecified), Ghana (unspecified), India, Australia (unspecified and for horses), Switzerland |
| Preservatives in vaccines | In use |
| Preservatives in eye drops | Most likely still in use |
| Disinfectants, e.g. in hospitals | Burkina Faso (unspecified) |
| Herbal medicine, "folk" medicine, "street pharmacies" | India (some herbal medicines), Lesotho (metallic mercury) |
| **Catalytic mercury compounds** | India |
| Catalysts for polyurethane/other polymer production | Finland, Australia, Ireland |
| Catalysts in acetylene-based production of vinyl chloride monomer, vinyl acetate, and acetalydehyde | (Used previously in a large number of factories worldwide) No confirmation whether or not this use continues. |
| **Cosmetics (creams, soaps)** | Benin (unspecified), Ireland (unspecified) |
| Skin lightening creams and soaps | In common use, restricted in some countries |
| Biocides in eye cosmetics | Possibly in use, restricted in some countries |
| **Lighthouses (marine use; for stabilising lenses)** | Canada (possibly general – mentioned in the literature) |
| **Production of counterfeit money** | Cameroon (no details on how mercury is used in the process) |
| **Religious ceremonies "superstitious" activities** | USA and possibly Caribbean regions (US ATSDR, 1999), Lesotho |
| **Pigments** | No confirmation of current use |
| **Tanning** | Ireland |
| **Browning and etching steel** | Ireland |
| **Colour photograph paper** | Australia |
| **Explosives, fireworks** | No confirmation of current use |
| **Airbag activators and anti-lock braking system (ABS) mechanisms in cars** | No confirmation of current use |
| **Artisanal diamond production** | Guinea ("to clean stones and improve physical quality") |
| **Recoil softeners for rifles** | Ireland |
| **Arm and leg bands (e.g. for "tennis elbow")** | Ireland |
| **Executive toys** | Ireland |
| **Surfacing material used in running tracks in sports stadiums ("Tartan" tracks)** | Historical use in Switzerland |
| **Ammunition** | Historical use in Switzerland |

*Table 7.7 Information on national actions, both regulatory and voluntary, to eliminate or restrict uses of mercury presented in table 7.6 (derived from a separate appendix to this report: "Overview of existing and future national actions, including legislation, relevant to mercury").*

| **Application** | **Import, sale and/or use banned or restricted nationally** (see separate appendix) |
|---|---|
| **Chlor-alkali production (chlorine and caustic soda)** | Japan |
| **Gold extraction** | Brazil, China, Philippines |
| **Mercury-containing products in general (with some exemptions)** | Denmark, Sweden, Switzerland |
| **Dental amalgam** | Denmark, France, New Zealand, Norway, Sweden, Switzerland |
| **Batteries** | Canada, China, Estonia, European Union countries*, Hungary, Mauritius, Norway, Slovak Republic, Switzerland, Turkey, USA, |
| Mercury-oxide batteries | European Union countries*, Japan |
| Alkaline batteries | Canada, European Union countries* |
| Other batteries (zinc-oxide, silver-oxide, mainly button cell formats) | Canada, European Union countries* |
| **Measuring and control equipment** | Sweden (in general) |
| Medical thermometers | Canada, Denmark, France, Norway, Sweden, |
| Other thermometers (marine engine control, laboratory) | Denmark, Sweden |
| Blood pressure gauges | |
| Industrial and meteorological manometers | Denmark |
| Pressure valves (district heating systems, industry) | Denmark |
| Gyroscopes | Denmark |
| **Electric and electronic switches** | Denmark, Sweden, Switzerland |
| Level switches (sewer pumps, door bells, railway signals, car back lids, refrigerators, freezers, fall-alarms for old people, etc.) | Denmark, Sweden |
| Multiple poled switches (for example in excavation machines) | Denmark |
| Mercury-wetted microelectronic switches | |
| Thermo-switches | Denmark |
| Switches in sports shoes with lights in soles | Denmark |
| **Discharge lamps** | |
| Fluorescent lamps | Canada, Sweden, European Union countries* from 1 July 2006 |
| Other mercury-containing lamps | Denmark, Sweden |
| **Laboratory chemicals, electrodes and apparatus for analysis** | Denmark, Sweden |
| **Pesticides** | |
| Seed dressing and/or other agricultural uses | Armenia, Burundi, Canada, China, Colombia, Cuba, Czech Republic, European Union countries*, Hungary, Japan, Latvia, Lesotho, Lithuania, Mauritius, Norway, Samoa, Switzerland, Tanzania, USA |
| **Biocides for different products and processes** | Denmark, Japan, Sweden, Switzerland |
| Paints (latex paints and possibly others) | Cameroon, Costa Rica, European Union countries*, Japan, Norway, Switzerland, USA |
| **Preservation of wood** | European Union*, Norway |
| **Pharmaceuticals (biocide or systemic functions)** | Austria, Canada, Costa Rica, Denmark, Japan, Mauritius, |

| **Application** | **Import, sale and/or use banned or restricted nationally** (see separate appendix) |
|---|---|
| | Sweden, Switzerland, USA |
| Preservatives in vaccines | |
| Preservatives in eye drops | |
| Disinfectants, e.g. in hospitals | Denmark |
| Herbal medicine, "folklore" medicine, "street pharma-cies" | Denmark |
| **Catalytic mercury compounds** | |
| Polyurethane (PUR) **and other polymer production | |
| **Cosmetics (creams, soaps)** | China, European Union countries*, Norway |
| Skin lightening creams and soaps | Cameroon, Denmark, USA, Zimbabwe |
| Biocide in eye cosmetics | |
| **Production of counterfeit money** | |
| **Religious ceremonies and so-called "superstitious" activities** | |
| **Pigments** | Denmark |
| **Explosives, fireworks** | Denmark |
| **Airbag activators and anti-lock braking system (ABS) mechanisms in cars** | European Union countries* |
| **Artisanal diamond production** | |
| **Packaging and packaging waste** | European Union countries*, Norway |

Note - * This implies that there is European Community legislation that applies to all member States of the European Union, namely Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom.

### 7.3.3 Examples of national consumption distributed among uses over time

*Table 7.8 Consumption of mercury (metric tons/year) in deliberate applications in Denmark at present, 10 years ago and 20 years ago (as described in the submission from the Nordic Council of Ministers, sub84gov).*

| **Year/use** | **1982/83 *1** | **1992/93 *1** | **2000/2001 *1** |
|---|---|---|---|
| Chlor-alkali production | 3.00 | 2.50 | 0 |
| Dental amalgam | 3.1 | 1.80 | 0.9 |
| Mercury-oxide batteries | 2.40 | 0.36 | 0 |
| Other batteries | 2.30 | 0.28 | 0 ***2** |
| Measuring and control equipment | 0.53 | 0.50 | 0.3 |
| Electric and electronic switches | 0.34 | 0.30 | 0 ***2** |
| Light sources (lamps) | 0.14 | 0.17 | 0.17 |
| Medical thermometers | 0.75 | 0.05 | 0 |
| Other thermometers | 1.55 | 0.10 | 0 |
| Laboratory chemicals | 0.50 | 0.09 | 0.09 |
| Other intentional uses | 1.48 | 0.03 | 0.03 |
| Total, intentional uses | 16.09 | 6.18 | 1.5 |

Notes:

1 Includes mercury in net imports of products. 1982/83 numbers are from Hansen (1985) and 1992/93-numbers from Maag *et al* (1996). 2001-numbers are rough estimates based on background knowledge and knowledge of elimination of uses in response to the Danish mercury ban by Heron (2001) and Maag in the submission from the Nordic Council of Ministers, sub84gov.

2 Some mercury may be present in button cell batteries, and in micro-switches in some types of electronics.

*Table 7.9 Reported consumption ***1** of mercury in the USA in 1990 and 1996 (metric tons/year; Jasinski, 1994, and Sznopek and Goonan, 2000). ***3***

| **Application** | **1990** | **1996** |
|---|---|---|
| Dental | 44 | 31 |
| Laboratory | 32 | 20 |
| Measurement and control devices | 108 | 41 |
| Wiring devices and switches | 70 | 49 |
| Electric lighting | 33 | 11 |
| Paint | 14 | 0 |
| Batteries | 105 | 0 |
| Chlor-alkali production ***2** | 247 | 136 |
| Other | 58 | 84 |
| Total | 711 | 372 |

Notes: 1 Imports and exports of mercury incorporated in products were not included in the numbers. Except for wiring devices and switches, which may be of some importance to the actual materials balance, Sznopek and Goonan (2000) deem that imports and exports are approximately equivalent or negligible.

2 Mercury consumption in the US chlor-alkali sector during 2001 was reported by industry at 28 metric tons (31 short tons), a 75 percent decline from consumption levels recorded during 1990-96.

3 Updated and more detailed information on use and mobilisation of mercury can be found in Stone (2002).

## 7.4 Particulars on chlor-alkali production and gold extraction

### 7.4.1 Chlor-alkali production and residual mercury

573. Chlor-alkali production has been among the largest intentional uses of mercury in the world (Sznopek and Goonan, 2000; see section 7.3.1), although emissions controls and, in particular, closing and converting facilities to non-mercury technology have led to a steady decrease in the consumption and releases of mercury in this industrial sector. In one of the three common processes for chlor-alkali production - the mercury cell process - large quantities of mercury serve as a liquid cathode in the electrolytic process. The process releases mercury to the environment with air emissions, water discharges and the sodium hydroxide (NaOH) and hydrogen products[14], and mercury-containing solid and liquid process wastes are generated that are carefully disposed of in some countries (mercury recovery, hazardous waste landfill), and less carefully in others (at the production site, normal landfill). Some of the mercury in the solid wastes is recovered and recycled to the production process – often as an on-site integrated part of the production facility. However, mercury must be periodically added to the process to replenish losses. Eventually, when mercury cellrooms close or are converted to a non-mercury process, large inventories of mercury may be recovered from process equipment and structures.

574. In recent decades, releases from the remaining mercury process chlor-alkali plants in Western Europe and the US have been reduced substantially, as a result of pollution-limiting efforts in a continued dialog between environmental authorities/international organisations and the industry. Little information has been found that suggests similar improvements in other parts of the world. Even after these improvements, the use of mercury in chlor-alkali production remains a significant source of mercury releases to the environment. Data provided by industry and reported by the US Toxic Release Inventory for 2000 (US EPA TRI Explorer report for chemicals facilities SIC 28, available at http://www.epa.gov), and the OSPAR Parties for 1999 (OSPAR, 2001b), indicated that total emissions (not including mercury in wastes) from these sixteen countries (which together account for approximately 62 percent of global mercury cell chlor-alkali capacity) amounted to about 16 metric tons per year during 1999/2000. Less detailed data is available from other regions, as mentioned below.

[14] In poorly managed facilities, mercury in untreated hydrogen (often sent as fuel to on-site power stations) has been a major source of chlor-alkali mercury releases to the atmosphere, whereas mercury contamination of NaOH tends to be minor.

575. As one example, Qi *et al.* (2000) reported that mercury releases (including mercury in wastes – it is not described how these wastes were treated) from Chinese chlor-alkali plants decreased significantly from 500-1400 g of mercury/ton of sodium hydroxide production before 1977, to 160-180 g of mercury/ton of sodium hydroxide production in 1997, but were still much higher than in some other countries. Specifically, these 1997 Chinese releases were more than 4 times greater per ton of production, than OSPAR releases (including mercury wastes, which were stored or treated according to relevant legislation) at that time. However, most chlor-alkali plants in China use the diaphragm process, which does not use mercury, and plans for converting or closing the few remaining mercury-cell chlor-alkali facilities in China (we know of only one, owned by the Tianjin Chemical Company, with a capacity of 50 thousand metric tons chlorine per year) were mentioned in the presentation (Qi *et al.*, 2000).

576. In a second example, the Mexican submission indicated that mercury releases from Mexican mercury-cell chlor-alkali plants (three sites identified, with a capacity of about 170 thousand metric tons chlorine per year) are also considerably higher than in similar plants in the USA.

577. Adequate and mature cleaner technology in the form of the non-mercury membrane chlor-alkali process is readily available and widely used all over the world. A third technology is available and in use, called the diaphragm process, but has been deemed slightly less beneficial than the membrane process. Scoullos *et al* (2000), EIPPCB (2000) and Lindley (1997) give comprehensive descriptions and discussions of the chlor-alkali mercury-process and its implications.

578. According to worldwide chlor-alkali production capacity statistics (see table 7.10), the regions of West and Central Europe have the highest relative percentage of mercury-cell chlorine production capacity in the world (61 and 66 percent in 1997, respectively), according to Sznopek and Goonan (2000), citing CMAI (1999). At the same time, the world average of mercury-based production was 24 percent of total production capacity, according to the same source, including about 15 percent in North America. According to updated information from the USA (comm-24-gov), mercury-cell production in 2001 has further decreased to 10 percent of the total US chlorine production. In Japan, all mercury chlor-alkali production has long ago been replaced by non-mercury technologies (CMAI, 1999; Maxson, 1999, as cited by Scoullos *et al.*, 2000). As about three-fourths of the entire global chlorine production capacity is situated in Western Europe, North America and Northeast Asia, it is clear that a large part of the mercury at work in the world's chlor-alkali plants is located in Europe, although a large part of the mercury consumption and releases remain in less developed nations. Based on actual records of easily recoverable mercury from decommissioned chlorine production facilities in the EU and the US, it can be roughly estimated that about half (12,000-13,000 metric tons[15]) of the mercury inventories associated with chlor-alkali production in the world (roughly estimated at 20,000 - 30,000 metric tons[16]) is situated within the EU.

579. In 1990, a total phase-out of the mercury process for chlor-alkali production by the year 2010 was recommended by the Parties to the OSPAR Convention of the North European region (PARCOM Decision 90/3 of 14 June 1990; see section 9.3.2). Chlor-alkali facilities that come under the responsibility of OSPAR, most of whose Parties belong to the European Union, currently hold more than half of the mercury amounts working in European chlor-alkali production. Decision 90/3 recommending mercury cell phase-out was reviewed in 1999-2001, but no changes were made. Implementation of this recommendation is at the discretion of the national regulatory authorities of the various Parties to the OSPAR Convention. Therefore, conversions and closures of mercury-cell chlor-alkali plants are being carried out faster in some OSPAR countries than in others, but at a pace that will see most of these facilities phased out by 2020 (Maxson and Verberne, 2000).

---

[15] Calculated by Maxson and Verberne (2000).

[16] Global mercury-based chlorine production capacity in 1997 was about 11,640,000 metric tons/year (Euro Chlor, 1998). Based on the data collected by Maxson and Verberne (2000) showing about 1,8 kg Hg (in cells) per metric ton of chlorine capacity, and another 10-15 percent easily recoverable from other parts of the plant, global mercury inventories associated with chlor-alkali production amount to over 25,000 metric tons. The range of 20,000-30,000 metric tons reflects some uncertainty, such as possibly lower efficiency rates in some regions.

580. The releases of mercury from chlor-alkali production are not the only issue of concern in relation to this use. Among OSPAR countries and in the EU there has been considerable discussion about the possible impacts the re-marketing of the mercury from decommissioned chlor-alkali facilities will have on the global mercury market. From the OSPAR countries this will amount to more than half of the 12,000-13,000 metric tons mentioned above. This mercury is virtually "pure" and therefore easily marketable, although there has been some debate as to whether this mercury should technically be considered to be "waste" and therefore covered by the transport restrictions imposed by the Basel Convention (see section 9.3.4). According to a very recent legal determination (European Commission, 2002), "the decommissioned mercury is not automatically governed by the Community waste legislation or by the requirements of the Basel Convention." This means that each member state of the EU, "according to individual circumstances," will determine whether or not this mercury is a "waste". Where such decisions find that the mercury is waste, the material will be covered by all applicable international agreements. In passing, the referenced document notes that final disposal of this mercury would be the "optimal solution" from an environmental point of view, and considers this solution to be the only sustainable approach.

581. Sweden has decided that such residual pure mercury should be considered as waste and is subject to Swedish legislation prohibiting exports of mercury waste. The OSPAR countries have proposed that safe measures for the disposition of this residual mercury should be discussed at the EU level, because individual national initiatives would affect trade parameters and waste handling policies within the Union, and would probably hinder the operation of the common market within the EU.

582. It is feared that large market releases of recycled mercury may render low-priced mercury more abundant on the world market and encourage more extensive or even revived use of mercury (in certain applications) in countries with less restrictive legislation, fewer enforcement possibilities and/or special social and economic circumstances. One example might be a slow-down in efforts to use mercury more efficiently in small-scale gold mining in the Amazon and other regions of the world (see below), which has been, at least partly, based on mercury imports from OECD countries (Maxson and Vonkeman, 1996, as cited by Scoullos *et al.*, 2000). Another specific example was the export of a complete, old chlor-alkali production plant, including mercury, from Denmark to Pakistan. The intervention of the Danish Minister of the Environment prevented the factory from actually being assembled in Pakistan, and the facilities were returned for disposal. Subsequently, in 1999 all West European chlor-alkali producers presented the authorities with a voluntary commitment, one clause of which commits them not to sell or transfer mercury cells after plant shutdown to any third party for re-use.

583. All these considerations parallel the discussions in the US, where concern for the environmental consequences led to a suspension of US federal mercury sales from government stocks in 1994 – a suspension still in effect (US EPA, 1997; Snopek and Goonan, 2000, as cited by Scoullos *et al.*, 2000).

584. In order to address the same issue of market disruption, as well as social responsibility, the European chlorine industry association (Euro Chlor) signed an agreement with the state-owned Miñas de Almadén of Spain, one of the world's most important mercury producers and marketers. This agreement stipulates that Miñas de Almadén will accept all surplus mercury from western European chlorine producers, under the condition that it displaces, ton for ton, mercury that would otherwise have been newly mined (referred to as "prime") and smelted to satisfy legitimate uses. All western European members of Euro Chlor have agreed to transfer their surplus mercury to Almadén (or, so as to honor free trade and competition, an alternative European mercury producer). Euro Chlor believes that central and eastern European producers may also be convinced to join the agreement. While this agreement clearly represents an effort by all parties to responsibly address the problem of surplus mercury, some people have the view that there are not yet adequate controls on where this mercury would be sold or how it would be used.

585. The World Chlorine Council has pointed out that this agreement is closely linked to the voluntary commitments presented in 1999 to the authorities by all West European chlor-alkali producers. The companies recognise that the pure mercury from cellrooms that close or are converted is best used in a manner that minimises the need for adding mercury to the global circulation by mining and extract-

ing virgin mercury. The companies also recognise that if in the future it appears that the supply of mercury from the chlor-alkali industry exceeds the legitimate remaining demand for mercury, storage options will need to be discussed.

586. As indicated, use of mercury for chlor-alkali production is not confined to the western world. For historical reasons, this technology is still used world-wide, though the relative share of the mercury technology is lower in other regions than in Europe. Table 7.10 gives an impression of the global and regional chlorine production capacity, and the relative share thereof based on mercury technology.

*Table 7.10 Global and regional chlorine production capacity in 1992 and 1997, and the relative share thereof based on mercury technology (chlorine production capacity in metric tons; table from Sznopek and Goonan, 2000, citing CMAI, 1999).*

| | **Total World** | **North America** | **South America** | **West Europe** | **East Europe** | **FSU** | **Africa** | **Middle East** | **India Pakistan** | **N.E. Asia** | **S.E. Asia** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| All Cells | | | | | | | | | | | |
| 1992 | 45,394<br>100% | 13,575<br>30% | 1,696<br>4% | 11,223<br>25% | 1,896<br>4% | 3,773<br>8% | 535<br>1% | 800<br>2% | 1,523<br>3% | 9,706<br>21% | 667<br>1% |
| 1997 | 49,437<br>100% | 14,686<br>30% | 1,787<br>4% | 10,640<br>22% | 1,791<br>4% | 3,676<br>7% | 584<br>1% | 1,294<br>3% | 2,135<br>4% | 11,794<br>24% | 1,050<br>2% |
| CAGR | 1.72 | 1.59 | 1.05 | (1.06) | (1.13) | (0.59) | 1.77 | 10.10 | 6.99 | 3.94 | 9.50 |
| Hg-Cell | | | | | | | | | | | |
| 1992 | 12,625<br>100% | 2,016<br>16% | 460<br>4% | 6,984<br>55% | 1,437<br>11% | 248<br>2% | 295<br>2% | 263<br>2% | 898<br>7% | 0<br>-- | 5<br>nil |
| 1997 | 11,640<br>100% | 1,809<br>16% | 424<br>4% | 6,445<br>55% | 1,174<br>10% | 248<br>2% | 222<br>2% | 276<br>2% | 916<br>8% | 50<br>nil | 5<br>nil |
| CAGR* | (1.61) | (2.14) | (1.62) | (1.59) | (3.94) | 0 | (5.53) | 0.97 | 0.40 | nil | 0 |
| % Hg-Cell | | | | | | | | | | | |
| 1992 | 28 | 15 | 27 | 62 | 76 | 7 | 55 | 33 | 59 | 0 | 1 |
| 1997 | 24 | 15 | 24 | 61 | 66 | 7 | 38 | 21 | 43 | nil | nil |

*CAGR=Compound Annual Growth Rate. Numbers in parentheses are negative.

587. Chapter 8 provides information on possibilities for substitution of mercury in chlor-alkali production, as well as technical possibilities for reduction of mercury releases from mercury-based chlor-alkali plants.

### 7.4.2 Revived mercury use in gold mining

588. An example of a revived application of mercury is the mercury amalgamation process for gold extraction, which has caused great worry among people concerned about mercury's global environmental impact. Lacerda (1997a) has described and reviewed the use of this technique and its resulting mercury burden to environment from both ancient and present-day exploitation. Mercury has been used in gold and silver mining since Roman times. With the invention of a refining method – the "patio" process – in Spanish colonial America, silver and gold were produced in large scale in America as well as in Australia, Southeast Asia and even in England. Mercury released to the biosphere due to this ancient activity may have reached over 260,000 metric tons in the period from 1550 to 1930, after which easily exploitable silver reserves were nearly exhausted, and the mercury amalgamation process was partly replaced by the more efficient large scale cyanidation process, enabling extraction of gold even from low-concentration ores. After this development, mercury amalgamation virtually disappeared as a significant mining technology until the 1970's.

589. Exceptional increases in gold prices, and the prevailing difficult socio-economic situation in the 1970's, resulted in a new gold rush, especially in the southern hemisphere, involving more than 10 million people on all continents. Presently, mercury amalgamation is used as the major artisanal technique for gold extraction in South America (especially the Amazon), China, Southeast Asia and some African countries. In Brazil mercury amalgamation was used for the production of 5.9 metric tons of gold in

1973. In 1988, this figure had increased to over 100 metric tons per year. During the 1990's this figure decreased again due to falling gold prices and exhausted deposits (Uppsala University; comm-3-ngo).

590. Although alternative extraction methods existed, the amalgamation method was probably chosen as the one requiring the lowest start-up investments and very little technical know-how.

591. The list of countries where the mercury amalgamation process is reportedly used for gold extraction in recent years includes Brazil, Venezuela, Bolivia, French Guyana, Peru, Ecuador, Colombia, Philippines, Indonesia, Vietnam, China (Lacerda, 1997a), Panama, Papua New Guinea, Ghana, Zimbabwe (Maxson, 1999, as cited by Scoullos *et al.*, 2000), Tanzania (Appel *et al.*, 2000), and Russia (Laperdina *et al.*, 1996). From information submitted as comments to drafts of this report (see table 7.6), the following countries can be added to the list: Australia, Burundi, Burkina Faso, Costa Rica, Côte d'Ivoire, India, Kyrgyz Republic, Mali, Mexico, Mongolia, Mozambique, South Africa and Suriname.

592. In China, over 200 small mines were said to have been opened since 1992 in one province after permission to form individual enterprises was granted. This induced an increment in gold production of 10 percent, according to Yshuan (personal communication, in Lacerda, 1997a). This may be one explanation for the relatively high mercury imports to China pointed out by Sznopek and Goonan (2000), and Scoullos *et al.* (2000). During the last couple of years, however, all artisanal mining of gold (and mercury) has been forbidden by the Chinese authorities.

593. Lacerda (1997a) has estimated the yearly global releases of mercury to the environment from gold extraction at up to 460 metric tons/year in the late 1980's/early 1990's, equivalent to about 10 percent of the total global anthropogenic releases. Certain areas of the Amazon basin are extensively contaminated with mercury as a result of small-scale gold mining. The gold amalgam from the extraction process releases mercury as vapour when heated in one of the steps in the purification. Mercury is found not only in mine tailings at extraction sites and at trading posts, but also in soil, plants, sediments and waterways. It was estimated in the early-mid-1990's that at least 95 percent of the mercury used was lost to the environment, where it contributed to the continuing global atmospheric re-mobilisation and cycling of mercury (Maxson and Vonkeman, 1996, as cited by Scoullos *et al.*, 2000). Cited by the same authors, Greenpeace (1994) estimated the total world-wide consumption of mercury for gold mining at 400-500 metric tons/year in 1993-94, but some industry observers consider this estimate too high, and suggest that the 1996 consumption may have been 350-450 metric tons/year. Other well-informed analysts (MMSD, 2002) consider the number too low, and suggest that at present 500 to 1000 metric tons annually may be consumed by artisanal gold and silver miners, of which a very high percentage is lost to the environment. Maxson and Vonkeman (1996), as cited by Scoullos *et al.* (2000), have noted that considerable amounts of this mercury have been supplied from or via Europe over the years.

594. During 1989, gold miners in Brazil released at least 168 metric tons of mercury into the environment. This corresponds to 80 percent of the total loss of mercury in Brazil in 1989 (estimated at 210 metric tons). The second largest source, Brazilian chlor-alkali production, was responsible for 8 percent of the releases. The final destination of another 67 metric tons is not known, and according to Hylander *et al* (1994), citing CETEM (1992), it is possible that this amount also ended up in the gold mining process, hence increasing the possible total loss of mercury from this source to 277 metric tons in 1989.

595. Maxson and Vonkeman (1996), as cited by Scoullos *et al.* (2000), noted that the sale and use of mercury for gold mining are officially banned in Brazil, but this ban is clearly difficult to enforce in the Amazon. According to this source, mercury imports for this use still continue, mainly from neighbouring countries like Colombia and Venezuela, but from Europe as well (mercury is traded globally). In recent years mercury use for this purpose is reported to be falling, mostly because the reserves of gold accessible to small-scale gold mining ("garimpeiro") techniques seem to be disappearing (Mercury as a Global Pollutant, 1999). According to data produced by Brazil's National Department of Mines and Prospecting, Brazil produced 112.5 metric tons of gold in 1988, of which small-scale gold miners were responsible for 90 metric tons. In 1995 the total gold output was reported at only 63 metric tons, of which 20 were produced by small-scale gold miners. Maxson and Vonkeman (1996), as cited by Scoullos *et al* (2000) caution that such numbers should be interpreted loosely, as many of these activities are

beyond government control. Maxson and Vonkeman (1996), as cited by Scoullos *et al.* (2000), cited CETEM (1993) for import numbers for mercury estimated at 250 metric tons in 1992, of which 150 metric tons were used in mining. This figure is thought to have declined to approximately 100 tons in 1996 in combination with a lower gold price than during the 1980's.

596. Maxson and Vonkeman (1996), as cited by Scoullos *et al.* (2000), noted that the mercury price is clearly not the determining factor in its use in artisanal gold mining. The price would need to be considerably higher to stimulate any wide-spread use of mercury-saving technology in small-scale mining.

597. In several South American countries, there are examples of programmes to promote less polluting mercury-based extraction equipment, raise awareness of mercury's hazardous qualities and provide other help and information regarding environmental and social aspects, business administration etc. Some projects are also assessing or trying to enhance the authorities' (and other interested parties') possibilities and capabilities to enforce environmental regulation in small-scale gold mining areas (based on Mercury as a Global Pollutant, 1999). A UNIDO-GEF global action plan to remove barriers to the introduction of cleaner artisinal gold mining technologies is also being implemented in a number of countries on three continents, see section 9.4.6.

598. According to Uppsala University of Sweden, an additional environmental hazard may often follow after gold extraction by the relatively inefficient amalgamation practices used by most artisanal miners. Since considerable amounts of gold remain on mining sites after amalgamation, e.g. in Brazil, the leftovers are often reprocessed using the cyanide process (Hylander, 2001). Cyanide is also an environmental toxin, but possesses one important advantage over mercury as it is degradable and does not bioaccumulate.

599. Chapter 8 provides information on possibilities for preventing or reducing mercury releases from artisanal gold extraction.