

2.1 Topography

The HLL factory site is located at an elevation of approximately 2,180 m. The site (see Figure 1) is irregular in shape and occupies an area of approximately 85,000 square meters. The southern boundary of the site slopes steeply into the Pambar Shola Forest, a protected nature sanctuary of the Tamil Nadu Government.

Meteorological records are available for the six year period 1995 to 2000 and have been used to construct a monthly average rainfall chart (Figure 2) and wind rose (Figure 3). The dominant wind directions are northeast/north northeast, northwest/north northwest and southeast, consistent with the prevailing direction of the monsoon winds. Mercury vapour in air will therefore disperse initially in the direction of the air exhaust fan discharge and then predominantly to the northwest/north northwest, northeast/north northeast and to the southeast. Topography and vegetation will also have an influence on mercury dispersion in air.

The access road to the site, St. Mary's Road, forms the drainage divide between the Pambar River subcatchment to the south, which includes the factory site, and the Kodai Lake catchment to the north. Drainage across the site is primarily via a small stream, termed the main stream, which originates at the northeastern corner of the site and flows in a southwest direction prior to discharging to the precipitous slopes which fall 1,300 m from the southern boundary to the Pambar River. There is a second smaller drainage termed the minor stream which traverses the western part of the site, and also a number of seepage areas. Details of the site features, facilities and access roads are illustrated on Figure 4. The topography of the site and its surroundings are provided on Figure 5.

The general land use to the north and east of the site is largely low density private residential properties along St Mary's Road. A few squatter cottages and St Mary's Church are located to the west. A large television broadcast antenna tower is located about 200 meters to the east of the site. The Pambar River (approximately 0.5 km to the south) is the nearest surface water body to the site within the factory site catchment, flowing in a southwest direction to the Kumbakarra Falls about 7 km to the southeast, thence draining eastward across the Tamil Nadu Plain. Kodai Lake is 500m to the north of the site but within a different catchment area.

The whole site is underlain by shallow Archaean bedrock, mainly granite gneiss and charnockite, which is impermeable apart from limited fracture porosity related to vertical and subhorizontal joints and exfoliation joints in the uppermost weathering profile down to 5 or 6 m depth. Two shallow wells on site which are blasted into the rock, have limited supplies which decline markedly in the summer season. There is also a spring in the central/lower part of the site adjacent to the main stream, and this again becomes dry during summer. The soil profile is very thin, and comprise a few centimetres of predominantly sandy material in the upper part of the site grading down into densely vegetated peaty soils in the south. Maximum thickness of soil intersected across the site is approximately 1.5 m. A narrow access path, the Levange Path, is in the Forest Reserve immediately to the south of the site boundary and can be traversed on foot with the approval and presence of the Forestry Department in Kodaikanal. This path lies immediately above the precipitous slopes and is primarily on bedrock with only a thin veneer of

soil. Access to the slopes below the Levange Path and to the Pambar River as far as the Kumbakarra Falls is extremely difficult and hazardous.

Several photographs taken at various locations of the site and its surrounds are provided in Plates 3 through 12 in the Plates section of the report.

2.2 Factory Layout and Operations

2.2.1 General

The thermometer manufacturing process in the factory had been divided into two main areas:

- Non Mercury Area; and
- Mercury Area.

Mercury was also handled in the crushing and distillation rooms and the glass scrap storage areas.

The Mercury and Non Mercury areas were physically separated by partitions and walls.

2.2.2 Non Mercury Area

This is where glass-forming operations were carried out before mercury was filled into thermometers and covered departments 1 and 2. Various processes that were carried out in this area included:

- Stem cutting;
- Bulb cutting;
- End opening;
- End cutting; and
- Bulb forming.

Glass scrap from this area is termed 1 & 2 scrap and does not contain mercury.

2.2.3 Mercury Area

This is where all operations from mercury fill through to final thermometer manufacturing operations were carried out and covered departments 3 and 4. Various processes that were carried out in this area included:

- Mercury filling;
- Top chambering;
- Annealing;
- Contracting;

- Airpassing;
- Test for shake;
- Scale setting;
- Grading; Screening;
- Baking;
- Top making;
- Final inspection;
- Quality assurance; and
- Packing.

Glass scrap from this area is termed 3 & 4 scrap and contains mercury.

Information on mercury in thermometers are presented in Appendix A.

2.3 Scrap Handling and Disposal

It should be noted that under Waste Category No. 4 of the Hazardous Waste (Management and Handling) Rules of 1989 any operation that generates more than 5 kg per year of mercury must ensure proper collection, reception, treatment, storage and disposal. The Hazardous Waste Rules were updated on 6 January 2000 (Rule 3i(b) of Schedule 2) and classifies mercury and mercury compounds as Hazardous Waste (Class A6) if the concentration exceeds 50 mg/kg.

Glass scrap from the Non Mercury Area 1 and 2 was packed in corrugated cartons and has either been disposed or is held in the Custom Bonded Storage area on site. Approximately 45 tonnes of mercury free scrap was also buried in four shallow pits on site.

The glass scrap from the Mercury Area contained residual mercury and since 1984 until 1990 was stored on site in the old bakery building. This non-treated scrap contains an estimated 5.97% of residual mercury by weight.

Mercury recovery commenced in 1990 using a crusher and twin recovery ovens, which operated until 1998. Approximately 68 tonnes of 3 and 4 glass have been processed during this period, however this operation was not considered particularly efficient as the grinder was unable to crush the glass to the desired level. After treatment the residual mercury in the scrap is estimated to be 1.04%.

At the beginning of 1999, a new crusher and vacuum activated mercury recovery plant was commissioned and continued in operation until March 2001. This new plant was able to process and recover mercury from 80-100 kg per day of scrap glass on a round the clock basis. Residual mercury in the scrap treated this way is estimated to be 0.15%.

Sale of glass scrap commenced in 1992. A total of 98.3 tonnes was sold during 1992-1999 and comprised 49.4 tonnes of 1 & 2 glass scrap, 43.6 tonnes of mercury-recovered 3 & 4 glass scrap (1.04 % residual

mercury) and 5.3 tonnes of enhanced mercury recovery 3 & 4 glass scrap (residual mercury 0.15%). Details of these sales including dates, purchaser names and material quantities are provided in Table 2.

The last sale in November 1999 of 5.3 tonnes of mercury recovered 3&4 glass scrap was made to a scrap dealer in Moonjikal area in Kodaikanal (which is the material referred to by Greenpeace) and this material lay in the dealer's yard (see Plates 1 and 2 in Plates section of report) until it was removed in June 2001 (see Appendix B for details).

HLL has approached the Ministry of Environment, New Delhi for permission to send the accumulated glass scrap 3&4 and the retrieved glass scrap to Bethlehem Apparatus Company, a Mercury Recycler in the USA.

3.1 Regulatory Controls

A description of the Regulatory Controls in India which are pertinent to the Kodaikanal thermometer factory is given in Appendix C.

Of particular importance is the Indian Occupational Health and Safety Regulation (Tamil Nadu Factory Rules) for air quality in the workplace. This specifies a maximum time weighted average of 0.05 mg/m^3 of Hg. There are no regulations or guidelines for mercury emissions in air.

The factory operated under valid consent under section 21 of the Air (Prevention and control of Pollution) Act, 1981, as amended in 1987 and consent for discharge of Sewage and Trade Effluents granted by the Tamil Nadu Pollution Control Board (TNPCB). In addition, the factory had authorisation from the TNPCB for collection/storage of hazardous wastes under Rule 3(c) and 5(5) of The Collection/Storage of Hazardous Waste (Management and Handling) Rules 1989 enacted under the Environmental Protection Act 1986. This licence was for sludge derived from treatment of industrial effluent containing heavy metals and was renewed in April 2000 with a validity of two years. An application for extension of this licence was submitted to TNPCB in March 2002.

3.2 Indoor Air Monitoring

When the Plant was in operation, the mercury concentration in air area was monitored using a gold film mercury vapour analyser with a self-calibrating facility. Fifteen to twenty two air monitoring locations were spread across the Mercury Area, the Non Mercury Area, Distillation Room, Crushing Room and external to the workplace. The intention was for the mercury in the atmosphere to be controlled to less than 0.05 mg/m^3 of air by adopting the following measures:

- Total of 25 exhaust fans fitted along the southeastern wall of the Mercury Area to turnover the air in the $15,145 \text{ m}^3$ of open area every 45 minutes for 16 hrs per day, 310 days per year;
- Provision of vacuum cleaners equipped with water seals to collect broken thermometers when breakage occurred in the factory;
- Scrubbing and washing of the factory floor once a day with water to remove traces of mercury. This water was treated in the Effluent Treatment Plant (ETP) and reused for floor washing;
- Total of 6 exhaust fans along the northeastern wall of the mercury crusher building for an air change of the 288 m^3 of area every 5 minutes for 24 hrs per day, 310 days per year;
- Total of 5 exhaust fans along the southeastern wall of the mercury distillation building for an air change of the 166 m^3 of area every 4 minutes for 8 hrs per day, 310 days per year.

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The following additional safety measures were also adopted:

- Natural ventilation was adopted in the Non Mercury Area;
- Mercury levels in urine were measured monthly for each employee (ie 5 to 10 employees per day); and
- Operators in the Mercury Area were provided with safety masks to filter out mercury vapours. This was backed by an emergency procedure when the mercury vapour exceeded 0.05 mg/m^3 . This included opening all windows and cleaning the entire floor with water after which the water was brushed into the ETP.

Records of mercury vapour levels have been maintained for the period 1984 to 2001, measured daily at the 15 to 22 different locations within and adjacent to the Mercury and Non-Mercury Areas. During this time there have been some recorded exceedances of the 0.05 mg/m^3 criterion. The records for the period between 1994 and 1997 have not been sighted.

3.3 Medical Surveillance

In accordance with Company policy, medical surveillance comprised an annual medical checkup of all employees and monthly monitoring of mercury in urine. The annual medical check up consisted of physical examinations with special attention to mouth, gums, skin, teeth, hair and neurological symptoms such as tremors or unsteady gait. The medical tests comprised blood tests (haemoglobin estimation, total white blood cell counts, differential white blood cell counts) and routine urine examinations for albumen, red blood cells, casts, crystals and sugar. Records of these examinations for 130 employees are available from 1988. The medical records of 184 employees / casuals / contract workers who left the company and of others whose services were terminated in the recent past are also available. These results indicate that all levels monitored were within acceptable recommended WHO / ILO limits.

The monthly urine examinations of all employees were done for mercury and compared to the maximum regulated level (WHO recommended acceptable upper limit) of 100 micrograms of mercury per litre ($\mu\text{g/L}$) of urine. Employees whose mercury levels exceeded 100 $\mu\text{g/L}$ level were deployed from the Mercury Area. In all such cases mercury levels of the re-deployed staff reduced to acceptable levels (less than 100 $\mu\text{g/L}$) in one to two months. The urine monitoring results are available with HLL.

Group mean mercury levels in urine for employees over the period 1988 to 2001 are provided in Table 4. They show an annual range between about 13 and 32 $\mu\text{g/L}$. WHO recommends that on a group basis the mercury level in urine should not exceed 50 $\mu\text{g/L}$.

Results of the most recent urine examinations conducted in March 2001 indicate that the mercury concentrations in the urine of all employees, ex-employees and scrap dealers are well below the WHO recommended acceptable upper limit of 100 $\mu\text{g/L}$. Of the 255 included in the survey, 3% of those surveyed had between 40 and 60 $\mu\text{g/L}$ of mercury in urine, another 3% between 30 and 40 $\mu\text{g/L}$ and the remaining 94% had mercury levels of less than 30 $\mu\text{g/L}$ of urine. A further survey was undertaken in May 2001 and the results of the study are presented in Appendix D. Medical records comprising the urine

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analysis results, annual medical surveillance and comprehensive occupational health surveillance done in March/May 2001 have been given to the individual employees.

This comprehensive occupational health surveillance done in March/May 2001 (clinical protocol, biological monitoring, results and conclusions) has been reviewed and validated by Dr Tom van Teunenbroek of TNO, Netherlands and his report is provided in Appendix E. Independent reviews carried out by the All India Institution of Medical Sciences and Indian Association of Occupational Health are also provided in Appendix E.

A mercury balance has been prepared in order to estimate the total unaccounted losses of mercury over the 18 years life of the operation. These unaccounted losses comprise dispersion of airborne mercury and accumulation in soil, lichen and vegetation both onsite and offsite, mercury in soil and sediment hotspots derived from accidental spillages, mercury recovered from drains and other areas of mercury accumulation adjacent to Mercury Processing Areas, and mercury discharging offsite with suspended sediment southwards to Pambar Shola.

Several of the key components of the mercury balance have been subjected to detailed review and audit as part of the risk assessment. These components are described below:

- Thermometers in the factory were manufactured from imported glass and imported mercury. The mercury used in thermometers was triple distilled (99.999%) and its importation required clearances from the Ministries of Commerce and Finance of the Government of India. Entry of glass or mercury on to site and dispatch off site of finished products and wastes have been carried out under certification by the customs official posted at the Factory and recorded in the Annual Bond Account. A proportion (12%) of the imported mercury was sourced from other Indian importers from 1993 to 1998 and this has been recorded in the Daily Materials Receipts Register at the time of purchase. A detailed description of this important component of the balance is given in Appendix A and indicates that a total of 165,178,795 thermometers were exported from site containing an aggregate of 119,067 kg mercury.
- The calculated weight of mercury expelled to air from the Mercury Area (operated from 1984 to 2001), the Crusher Building (constructed in 1990) and the Distillation Building (mercury purification from 1984 to 1986 then distillation until 2001) can be estimated using the frequency of air changes nominated for each area, the period of operation and an average (conservative) mercury concentration in air of 0.03 mg/m^3 . The total aggregate is 64 kg as follows:
Mercury Area = 54 kg, Crusher Building = 8 kg, Distillation Building = 2 kg.
- It is recognised (refer Encyclopaedia of Occupational Health and Safety, International Labour Office, Geneva, 1998) that mercury in urine bears a reasonably constant relationship to mercury in air. The correlation factor between mercury in air, measured as mg/m^3 to mercury in urine measured as $\mu\text{g/L}$ is $1.2 \text{ to } 2.0 \times 10^3$. The NIOSH time weighted average mercury concentration in air of 0.05 mg/m^3 therefore equates to between 60 and $100 \mu\text{g/L}$ in urine. An average urine concentration of $32 \mu\text{g/L}$, the maximum average annual value recorded, therefore equates to an air concentration of between 0.026 and 0.016 mg/m^3 . This lends credibility to the adoption of a mean air concentration of 0.03 mg/m^3 for estimation of mercury emissions to air. The above data for monitoring carried out at the HLL Plant is provided in Table 3 and illustrated on the associated chart.
- Scrap handling has been discussed in Section 2.3 of the report. In summary, glass scrap from the Mercury Area (3&4) scrap is in three forms – unrecovered with approximately 5.97% of mercury; partially recovered with an estimated 1.04% of mercury; and enhanced recovery with approximately 0.15% of mercury. Glass scrap which was sold off site and has either been repurchased by HLL or had been recycled has also been tabulated and considered to contain between 0.15% and 1.04% of mercury.

Mercury Balance

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The elements of the mercury balance are:

$$MI = TE + GSS + GSO + ETP + ST + WIP + \Delta U, \text{ where,}$$

- MI:** Mercury imported to site in containers directly from the USA and Spain or via Indian importers. The customs bond and local purchase registers record a total of 136,486 kg.
- TE:** Mercury exported from site in thermometers. HLL has made an exhaustive review and collation of the recorded numbers and types of thermometers dispatched from site and their contained mercury. The total number of thermometers was 165,178,795 with a total mercury content of 119,067 kg.
- GSS and GSO:** This represents glass scrap stored onsite (GSS) and glass scrap disposed offsite (GSO). GSS has been calculated from tabulated records of unrecovered 3 & 4 glass (160,051 kg @ 5.97% residual mercury), 3 & 4 partially recovered (9,858 kg @ 1.04% mercury), and 3 & 4 enhanced recovery (58,511 kg @ 0.15% mercury). These amounts have been assessed by sampling each batch of unrecovered glass scrap in GSS and measuring mercury recovery. GSO is based on the glass scrap disposed offsite (43,577 kg @ 1.04% and 5,327 kg @ 0.15%).
- ETP** Mercury in stored sludge (17,542 kg) from the industrial ETP, estimated to be 593 kg. This figure is based on analysis of total mercury in fifteen composite samples drawn from 145 drums containing ETP sludge and analysing them in the TNPCB Laboratory. The average concentration of fifteen composite samples is 3.38%, which translates into 593 kg.
- ST and WIP:** Mercury in stock (ST) and work in progress (WIP) are based on audited inventories.
- ΔU :** Unaccounted Losses.

Based on the above information the mercury balance can be expressed as follows:

MI	=	TE	+	GSS	+	GSO	+	ST	+	WIP	+	ETP	+	ΔU
136,486	=	119,067	+	9,746	+	461	+	2,983	+	1,605	+	593	+	ΔU

Unaccounted losses, ΔU , therefore total 2,031 kg.

The unaccounted mercury losses can also be expressed as the following equation:

$$\Delta U = SSR + LLD + MPA + PS$$

where:

- SSR

=

Mercury contained in soil and sediment which will be remediated ie at concentrations in excess of 10 mg/kg, namely Areas A, B, C (C1 and C2). SSR is estimated to be 291 kg (Table 9). This has been based on the mercury concentration contours derived from the results of the sampling program (and assuming a soil density of 1800 kg/m³).
- LLD

=

Low level dispersion at concentrations of between 0.1 and 10 mg/kg in soil and sediment both onsite and offsite. The onsite component of this is estimated to be 75 kg. The offsite component is estimated to be approximately 30 kg.
- MPA

=

Mercury recovered from the Mercury Area Drains (see Figure 4) inside the factory (76 kg), the Vacuum Distillation Unit (16 kg), the Bakery Floor (52 kg with soil) and the Distillation Room Sump (138 kg with soil). Sampling of the main drain predominantly along the south wall of the Mercury Area and two shorter sections of drains perpendicular to the main drain revealed the presence of free mercury. This prompted the investigation of other areas adjacent to mercury processing areas as summarised above.
- PS

=

Discharge offsite to the south to Pambar Shola.

PS

=

ΔU

2,031

-

SSR

291

-

LLD

105

-

MPA

282

=

1353 kg

Therefore, estimated offsite discharge to the Pambar Shola is approximately 1,350 kg. This estimate will be further refined after site remediation has been completed and the volume of mercury contained in the ETP sludge is subject to detailed analysis as well as actual content of mercury in GSS and GSO, to be advised after recycling is completed.

This estimate indicates unaccounted losses of about 75 kg annually over the 18 year life of the operation equivalent to 200 g/day or approximately 15 mL/day.