THE CHLORINE INSTITUTE, INC.

Pamphlet 125

Guidelines - Medical Surveillance And Hygiene Monitioring Practices For Control Of Worker Exposure To Mercury In The Chlor-Alkali Industry

A LEGACY OF 1924 since SAFETY STEWARDSHIP

A RESPONSIBLE CARE® PARTNER ASSOCIATION

Edition 4 • January 2004

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Scope

These guidelines highlight potential safety and industrial hygiene concerns and provide guidance for medical surveillance and industrial hygiene exposure assessment and control practices for worker exposure to mercury. As used in this pamphlet, mercury refers to elemental mercury or inorganic mercury compounds.

This pamphlet combines information contained in the prior edition of this pamphlet as well as information contained in the current edition of Pamphlet 156, *Guidelines to Physicians in ConductingMedical Surveillance Programs,* which is now being withdrawn. The combination of these two pamphlets allows for information to be provided to physicians or other qualified medical professionals, employers, and employees in a single document. The recommendations contained in this pamphlet should apply to all persons based on the potential for exposure to mercury regardless of whether they are employees of the company operating the facility or contractors at the site.

1.2 Background

This pamphlet is the fourth edition of Institute recommendations pertaining to medical surveillance and industrial hygiene practice for chlor-alkali employees exposed to mercury. The first edition was issued in 1972. In addition to a review of numerous articles dealing with mercury, the Institute has reviewed the recommendations by other organizations such as the American Conference of Governmental Industrial Hygiene (ACGIH) pertaining to mercury exposure.

1.3 Responsible Care

The Institute is an American Chemistry Council (ACC) Responsible Care[7] Partnership Association. In this capacity, the Institute is committed to: Fostering the adoption by its members of the Codes of Management Practices; facilitating their implementation; and encouraging members to join the Responsible Care [7] initiative directly.

Chlorine Institute members who are not ACC members are encouraged to follow the elements of similar responsible care programs through other associations such as the National Association of Chemical Distributors: (NACD) Responsible Distribution Program or the Canadian Chemical Manufacturers Association's Responsible Care[7] Program.

1.4 Definitions

ACGIH — American Conference of Governmental Industrial Hygienists - The ACGIH is a non government organization based in Cincinnati, Ohio that issues exposure guidelines or recommendations to assist in the control of workplace health hazards.

AIHA — American Industrial Hygiene Association; A non profit organization focusing on industrial hygiene issues

Ceiling — The concentration that should not be exceeded during any part of the working exposure

CNS	Central nervous system
EPA	Environmental Protection Agency (USA government regulatory body)
g	grams
Hg	Chemical symbol for mercury
IDLH	An atmosphere that poses an immediate threat to life, would cause irreversible adverse health effects, or would impair an individual's ability to escape from a dangerous atmosphere.
Mercury	As used in this pamphlet, mercury refers to elemental mercury or inorganic mercury compounds.
NIOSH	National Institute for Occupational Safety and Health (U. S. Department of Health and Human Services)
OSHA	Occupational Safety and Health Administration (USA government regulatory body; part of the U. S. Department of Labor)
PEL	Permissible Exposure Limit (Regulations established by OSHA) - The maximum concentration that a worker can be exposed to for a prescribed period of time (TWA; STEL; Ceiling).
PPE	Personal Protective Equipment
STEL	Short Term Exposure Limit - The concentration to which a worker can be exposed continuously for a short period of time (typically 15 minutes).
TLV	Threshold Limit Value (guidelines developed by ACGIH) (TWA; STEL; Ceiling) - The exposure level to which it is believed that nearly all workers may be repeatedly exposed, day after day or short term, without adverse effect.
TWA	Time Weighted Average (based on 8 hour work day and a 40 hour work week)
U-Hg	Urinary mercury
g/g crt	Micrograms per gram of creatinine
g/L	Micrograms per liter
g/m3	Micrograms per cubic meter

1.5 Disclaimer

The information in the pamphlet is drawn from sources believed to be reliable. The Institute and its members, jointly and severally, make no guarantee and assume no liability in connection with any of this information. Moreover, it should not be assumed that every acceptable procedure is included or that special circumstances may not warrant modified or additional procedures.

The user should be aware that changing technology or regulations may require a change in the recommendations herein. Appropriate steps should be taken to ensure that the information is current when used. These recommendations should not be confused with federal, state, provincial, municipal or insurance requirements, or with national safety codes.

1.6 Approval

The Institute=s Mercury Issues Management Steering Committee approved Edition 4 of this pamphlet on October 27, 2003.

1.7 Revisions

Suggestions for revision should be directed to the Secretary of the Institute.

1.8 Reproduction

2. EXPOSURE POTENTIAL FOR MERCURY

2.1 Occupational Exposure

In the mercury-type electrolytic cell, flowing mercury serves as one electrode and as a medium for the amalgamation of sodium or potassium formed (along with chlorine) from the electrolysis of brine. In a separate unit, the amalgam is reacted with water to form co-products sodium or potassium hydroxide and hydrogen. The mercury is subsequently recycled back to the electrolytic cell.

There is a potential for exposure to liquid mercury, mercury vapor, and chlorides of mercury through interaction with chlorine produced using mercury cells.

In the workplace, mercury on skin and/or clothing can vaporize, possibly resulting in potential exposure to employees. Contaminated clothing should be removed at the end of tasks involving significant contact with liquid mercury or at the end of the work shift and the skin and hair should be thoroughly washed.

2.2 Non Occupational Exposure

The following are among the non-obvious “off the job” sources of mercury:

- **Inadvertent Contamination within Home**

  Inadvertent contamination of households (e.g., carpets, furniture), can result from contaminated street clothes or work clothes and shoes. Contamination of households can also result from the misuse of mercury taken home from the job.

- **Fish diet**

  Fish is a dominant source of human exposure to organic mercury; this is a source of interference when testing mercury in blood unless inorganic and methyl mercury are analyzed separately since methyl mercury concentrates in red blood cells while inorganic mercury concentrates in plasma. Methyl mercury excretion in urine is very limited so its contribution to the overall body burden may be less apparent when considering only urinary excretion.

- **Dental fillings**

  Silver amalgam contains approximately 40% mercury. Amalgam capsules are marketed to dentists in three different sizes (#1, #2, and #3). The mercury content in each is 368 mg., 550 mg., and 731 mg., respectively. Mercury is released from amalgam restorations in the mouth as vapor. Ingestion is increased by chewing and is correlated with the number of dental fillings. After insertion or removal of multiple fillings, urinary mercury may increase over the next several weeks.

- **Skin lightening creams and soaps**

  Although they are no longer allowed in the United States, they may still be encountered. They have been applied overnight to give dark skin a lighter tone by pigment inhibition. Such soaps contain 3% mercuric iodide creams may contain 1-5% ammoniated mercury.

- **Therapeutic agents**

  Some therapeutic agents (e.g., preservatives for nose drops and certain vaccines, diuretics (obsolete), antiseptics, soft contact lenses solutions (e.g., thimerosal)), may contain mercury. There are still some uses for antiseptic mercury ointment in selected dermatological conditions.

- **Other Categories**

  Although some of these other uses may be restricted or prohibited within the United States or elsewhere, the use of mercury in these applications may still be encountered.

  * Medical instruments - e.g., thermometers, blood pressure sphygmomanometers
  * Paints - antifouling and mildew proofing additives
  * Pesticides - applied to seeds or bulbs to retard fungus growth
  * Hobbies - Photography, taxidermy
  * Gold searching
  * "Alternative medicine" (unregulated "remedies")

3. ABSORPTION, DISTRIBUTION AND EXCRETION OF MERCURY

3.1 Routes of Entry

Elemental mercury and its salts can enter the body through inhalation, skin contact, and ingestion. Inhalation of mercury vapor and/or particles of mercury chloride are the major route of entry from industrial exposures. Approximately 80% of inhaled mercury is absorbed.

There can be significant absorption of mercury through the skin if mercury or mercury vapor is in continuous contact with the skin. Uptake via the skin of metallic mercury vapor, with whole body exposure, is only 2.2% (or 1.76% of contacted material) of uptake via inhalation. Vapor at 0.050 mg/M^3 penetrates at a rate of about $7.2x10^{-8}$ mg/cm^2/hr. (Reference 9.1). An EPA exposure assessment document has estimated that the mean surface area of skin for an adult male is 1.94 m^3 and is 1.69 m^3 for an adult female (Reference 9.2).

Mercury (elemental and inorganic salts of mercury) are poorly absorbed through the gastrointestinal tract (approximately 0.01% for elemental mercury and approximately 7% for inorganic salts of mercury) (Reference 9.1) thus making ingestion a relatively insignificant route of exposure for these forms of mercury. However, organic mercury is extensively absorbed. Organic mercury is not normally associated with the chlor alkali production process.

3.2 Distribution and Metabolism

Once mercury is absorbed into systemic circulation, it is distributed throughout the body (Reference 9.3). Inhaled mercury vapor is rapidly taken up by red blood cells.

Oxidation after absorption of elemental mercury (Hg_0) to divalent mercury (Hg^{++}) is a critical event. Divalent mercury is much less likely to cross cell membranes. The oxidation of elemental mercury to divalent ionic mercury takes place very quickly after absorption, but some elemental mercury remains dissolved in the blood long enough to be carried to and pass through the blood-brain barrier and the placenta. Lung tissue is also capable of oxidizing mercury.

A portion of the elemental mercury not oxidized can bind to specific proteins that allow for the transportation to the central nervous system (CNS) where it is oxidized to the divalent form (References 9.4 and 9.5). Because of the short transit time from the lung to the brain, the majority of the mercury vapor may arrive at the brain before it is oxidized. Mercury that becomes oxidized after passing the blood-brain barrier may become trapped in the CNS, accounting for the very slow clearance of a fraction of the initial burden.

The divalent form of mercury accumulates in tissues (Reference 9.6), with the greatest accumulation occurring in the kidney followed by the brain, particularly the posterior cortex. The liver has also been shown to accumulate mercury.

Although the kidney burden is presumably related to mercury concentrations in other tissues, these relationships are as yet undefined.

A few researchers have postulated that mammalian liver is capable of partial biotransformation of elemental mercury to organic mercury (i.e., methyl mercury). However, no evidence or pathways have been presented indicating that this does occur (Reference 9.7). The major health effects from mercury exposure are related to the specific membrane permeability. In addition, organic mercury readily crosses the placenta in comparison to elemental or ionic forms of mercury.

3.3 Excretion

Mercury in the body that has been absorbed from exposure to elemental mercury and its inorganic salts is excreted in urine, feces, perspiration, and exhaled breath. Some mercury may be incorporated in nails and hair when the source of body burden has been elemental mercury and/or its inorganic salts.

The concentration and form of mercury excreted in urine appears to be related to the rate of exposure and may be indicative of the potential for damage to the nervous system and the kidneys.

Absorbed elemental mercury must be oxidized before it can be detoxified. Inorganic salts of mercury appear to be detoxified by conjugating with glutathione which are then further converted to the mercapturic acid (Reference 9.7) and excreted in the urine. If the rate of absorption of these salts exceeds the rate at which the body can conjugate them, damage to the kidneys may occur. When these conditions do occur, inorganic salts of mercury are excreted unchanged in the urine. However, those salts reaching the blood-brain barrier have little effect as compared to elemental mercury.

Determination of biological half-life of inorganic mercury in various body compartments, including kidneys and brain, is a very complex issue. The best estimate is that after short term exposure to elemental mercury vapor, there is a first rapid phase of elimination of the majority of the burden, with a half-life of the order of days, followed by a slower second phase with an average half-life elimination of one to two months. The half-life turnover in the brain is expected to be even much longer. Inorganic mercury in the brain has been detected years after cessation of exposures in miners and dentists indicating a very long half-life for at least a small fraction of the initial burden (Reference 9.8).

When the rate of absorption of elemental mercury exceeds the rate of oxidation, damage to the CNS may occur. Under these conditions, elemental mercury is excreted unchanged in the urine.

Persons who have accumulated a body burden of mercury may have elevated urinary mercury concentrations with all of the mercury in the bound form. Thus, the determination of urinary mercury concentrations can serve as a measure of the extent of exposure.

The level of mercury in blood is an indicator of recent days' exposure to mercury. Urinary excretion of mercury is reflective of the gradual accumulation of mercury in the kidney over the preceding months.

4. HEALTH EFFECTS

Effects of mercury exposure can be local (confined to one area of the body) or systemic (involving whole organ systems); and can occur as a result of either acute or chronic exposures. (References 9.4, 9.6, 9.9, 9.10, 9.11, 9.12, 9.13)

4.1 Local Effects

4.1.1 Irritation

Mercury salts can cause dermatitis. Mercury vapors are irritating to the respiratory tract.

4.1.2 Allergic Reactions

Allergic contact dermatitis can occur with exposure to mercury and its salts, but is rare. (Reference 9.14)

4.2 Systemic Effects

4.2.1 Acute Exposure

Exposure due to an emergency condition such as a large spill or fire can cause effects to different systems of the body, especially nervous and respiratory systems. NIOSH has established an IDLH for mercury at 10 mg/m^3. The vapor pressure of mercury is such that the concentration of mercury in air (assuming saturation [equilibrium]) exceeds the IDLH concentration at temperatures at approximately (and above) 17^0C (62^0 F). Table 4.1 below shows approximate mercury vapor concentrations at various temperatures. Symptoms can develop within hours, causing chest pains, shortness of breath, bronchiolitis, chemical pneumonia (inflammation of the lungs), and acute pulmonary edema (accumulation of fluid in the lungs). Nervous system symptoms can include hand tremors, irritability, mood swings, and aggressive behavior. Most symptoms completely subside within a few days. (References 9.5 and 9.15)

Table 4.1 - Mercury Vapor Concentrations in Air (assumes saturation)

Temperature, ^{0}C	Concentration of mercury in air (assuming saturation) mg/m^3
0	2.2
5	3.52
10	5.56
15	8.62
20	13.2
25	19.9
30	29.5
35	43.3
40	62.5

4.2.2 Chronic Exposure

Symptoms related to chronic exposure can occur from prolonged, repeated overexposure. During chronic exposure to mercury by inhalation, the critical organ is the central nervous system. Symptoms such as anorexia, weight loss, tremors, and insomnia are well correlated with different degrees of exposure. The kidney becomes the critical organ following ingestion or skin absorption of inorganic mercury salts with possible development of nephrotic syndrome (kidney dysfunction resulting in high levels of protein in the urine).

Tremor is the most evident clinical sign and is a constant observation in all cases of mercury intoxication. It is both static (occurring when the muscle is at rest) and intentional (occurring during purposeful movement), and is greatly enhanced by emotional stimuli. Initially it is imperceptible, but it becomes progressively evident, with complex movements such as writing, buttoning and unbuttoning a shirt and threading a needle. Initially, it is observed at the corners of the mouth. At rest it can be observed involving the eyelids and when the arms and hands are extended. It is aggravated by stress, fatigue, and chronic alcohol consumption. (References 9.16, 9.17, 9.18, 9.19, 9.20)

The most characteristic symptoms of mercury toxicity are the psychological alterations known as “erythrism”, featuring mood changes, a switch from extroversion to neuroticism and shyness, depression, irritability, emotional instability, anxiety, insomnia, and hypochondriac concerns. Memory and concentration deficit will occur only at a later time, should exposure and absorption continue. Numerous studies have been conducted in an attempt to correlate urine mercury levels with neuropsychological effects, but findings have been inconsistent as to the ability to discern individual cases. (References 9.15, 9.19, 9.20)

Mercury exposure can also cause oral symptoms, such as gingivitis, ulceration of lips, and tooth loss, along with a metallic taste in the mouth.

Mercury is not classed as a human carcinogen. (Reference 9.21)

4.3 Reproductive Effects

Elemental mercury is known to pass the placental barrier and is recoverable in maternal milk. It is not known whether mercury vapor can adversely affect fetal development in the absence of obvious signs of mercury intoxication. Only a small fraction (<0.03% to 0.22%) of inhaled mercury by the mother has been reported to cross the placental barrier. (Reference 9.22, 9.23, and 9.24) Very little research has been done on the effects of low exposure to elemental and inorganic mercury during pregnancy and lactation on children.

A study of relatively recent origin (Alcser, 1989) (Reference 9.25) was inconclusive as to whether paternal mercury exposure is or is not a risk factor for miscarriage. Cordier, et al. (1991) (Reference 9.26) examined spontaneous abortions for wives of exposed workers. The frequency of miscarriages increased as exposure increased, but the increase was not statistically significant.

To prevent adverse reproductive and pre-and post-natal development effects, appropriate counseling in accordance with the company's hazard communication program should be provided to the worker concerning mercury health and exposure issues. Elemental mercury is not believed to be a teratogen (Reference 9.27).

Exposure to elemental mercury has been reported to cause menstrual disturbances, infertility, and spontaneous abortions, although study results have varied widely. (Reference 9.28) Exposure to elemental mercury has been shown to affect hormonal and reproductive organ function in rats resulting in a reduction in fertility (Reference 9.29) although the effects have not been shown to be as great as with organic mercury compounds.

5. MEDICAL SURVEILLANCE PROGRAM

A Medical Surveillance Program should be established for employees, including contract employees, who have the potential for exposure to mercury as determined the exposure assessment (See Section 6). The medical surveillance program should be under the overall direction of a qualified physician. Many portions of the program can be implemented by any qualified medical professional. The detailed nature of preplacement and periodic physical examinations is left to the professional judgment of the physician. The physician should be knowledgeable about both the job requirements and the health effects of mercury.

Participation should be based on potential for exposure (e.g. job classification), or an appropriate alternate method. The medical examinations should:

(1) Be performed by a qualified medical professional experienced in addressing occupational medicine and mercury related issues.

(2) Include pre-placement, periodic (e.g., annual), and exit-from-program exams for all participants.

(3) Include employees who may have been exposed to relatively large quantities of mercury during an emergency such as a massive spill or fire.

5.1 Medical Examinations

The medical surveillance program is meant to detect adverse effects of exposure as early as possible, at a stage where they are still reversible, so that exposures can be controlled and serious permanent adverse effects prevented. The physical examination program should be integrated with industrial hygiene and biological monitoring information. Biological monitoring is an integral part of the medical review and surveillance program. See Section 6.3.

The qualified medical professional performing the exam should consider a description of the affected employee's duties; the employee=s representative airborne and biological exposure levels; and, respiratory and other required protective equipment to be used.

The physical examination should include work and personal history updates and verification of pertinent symptomatology and clinical end points. These include, acute (severe respiratory irritation with chest pain and dyspnea) and chronic conditions (stomatitis, excessive salivation and digestive disorders; headaches, insomnia, irritability, mood swings and timidity; tremors of eyelids, lips, tongue, fingers and extremities; fatigue, muscle weakness and weight loss.)

Ancillary tests include routine urinary mercury determination, and /or blood mercury determination in selected circumstances. Quantitative analysis of urinary protein may be desirable in specific cases. (e.g. positive urine dipstick test result). Other general tests such as pulmonary function and routine blood chemistry panels are to be administered as per examining medical professional's judgment. The medical surveillance program is also an opportunity for one to one counseling and health education on pertinent mercury related hygiene matters.

5.1.1 Pre-placement

The pre-placement physical exam is aimed at ascertaining status of organs and systems particularly susceptible to the action of mercury (CNS, oral cavity, kidneys, skin, and respiratory system). Within a basic history and physical examination protocol (including pertinent ancillary tests), particular interest should be paid to the neurologic exam, testing visual-motor coordination and the microscopic examination of urine sediment.

The initial medical and occupational history will then include inquiry for previous exposure to mercury (both occupational and non-occupational), personal habits, and history of present or past oral, gastrointestinal, respiratory, skin, renal, central nervous system and psychiatric disorders. Any current pre-exposure health problems which may be exacerbated by mercury or potentially attributed to mercury exposure once the worker has been employed should be identified.

Workers required to use respirators should be medically certified to use respirators. In the United States, the Occupational Safety & Health Administration (OSHA) has specific regulatory requirements. (Reference 9.30)

5.1.2 Periodic

The frequency of the periodic examinations is left to the discretion of the physician in consultation with the employer. The Chlorine Institute suggests a follow-up exam after six months from hire or placement be considered. Thereafter an annual frequency should be considered. Medical surveillance frequency may be changed at the physician=s discretion in individual cases, or if employees develop signs and symptoms or if warranted by an unusual event.

5.1.3 Post Emergency Situation

In the event of a potential significant exposure due to an emergency condition (e.g. major spill or fire), the potentially exposed person(s) should be examined by a qualified medical professional knowledgeable about the acute effects of exposure to mercury. Selective analysis of mercury in blood to determine whether exposure occurred and the severity of such exposure should be considered. Such analysis should occur as soon as practicable after the exposure occurred.

5.1.4 Exit from Program

Whenever possible, after an employee is removed from work exposure to mercury, an exit physical should be provided to ascertain that no adverse health effects have developed potentially related to mercury. If biological monitoring studies show elevated urine mercury levels, additional urine mercury samples should be considered on a periodic basis until they have fallen within an acceptable range.

5.2 Written Opinion

The physical examination is concluded by a qualified medical professional's written opinion as to:

a) The ability of the affected employee to perform the work with the appropriate personal protective equipment including respiratory protection. Any limitations in the ability of the employee to perform the work or use any necessary personal protective equipment should be discussed.

b) Whether the employee has any medical condition that would place him/her at risk of health impairment from exposure to Hg.

c) If the routine medical surveillance and non-routine medical review (first screening level) reveal objective signs compatible with Hg absorption, referral to an appropriate specialist may be considered for verification (second level). More complex diagnostic procedures or referrals to third level specialists such as a specialist in Occupational Neurology may be required for more complex cases.

5.3 Medical Intervention Assessment

There is an inter-individual and intra-individual variability in urinary Hg excretion which is not a mathematical predictor of appearance of clinical effects. Temporary removal from the job should be considered in the proper context of safety, hygiene and medical considerations. Temporary removal can take place pending medical review. Not all medical reviews necessarily coincide with temporary removal. Urine mercury levels (U-Hg) are a better group assessment tool for chronic exposures than as an individual predictor of exposure. On an individual basis, other determinants must be considered such as individual susceptibility and differential diagnosis of symptoms and signs. Employees who are repeatedly removed and subsequently returned should be assessed for individual susceptibility.

Medical intervention assessments should be conducted by a qualified medical professional familiar with the health effects of mercury.

Medical intervention assessment (see Table 6.1a in Section 6.3.4) is prompted by:

- An employee exhibits health effects/symptoms consistent with overexposure to mercury. (In these instances, the employee must be excluded from tasks involving exposure to mercury until authorized by the physician conducting the medical intervention assessment).

- Employee with urinary mercury level >= 100 g/g-crt.

In addition to Medical Intervention Assessment based on actual individual numeric results, a facility should consider some type of program based on increasing trends in exposure measurement for individuals. Section 6.3.5 and Table 6.1b present one such method for making an assessment based on trends.

After removal from tasks associated with mercury exposure, there are two phases of urinary excretion of mercury: The first phase averages two days and accounts for 20-30% of excretion. The second phase has a half-life of 70 days. Within one year of initial exposure, the urinary mercury values are more indicative of mercury accumulated in the kidney rather than of workplace exposure levels. This explains why persons with intermittent exposures may experience higher than expected Hg-U levels during a period of non exposure.

Mercury urine values cannot be used to assess level of mercury in brain tissue. The half life of mercury in brain tissue is reported to be around 22 years (Reference 9.31).

5.4. Contractors

Contract employees should be subject to the same medical surveillance criteria that are applied to the company=s employees.

6. EXPOSURE ASSESSMENT

6.1 General

In order to quantify the specific cell room work-related activities that may contribute to elevated mercury body burdens, a systematic approach must be used to evaluate individual work tasks. An industrial hygiene exposure assessment that addresses inhalation, dermal and ingestion routes of mercury exposure should be performed for each task where there is potential exposure. This assessment should include background mercury exposure potential that is not specifically associated with a specific task or activity. Examples would include mercury fugitive emissions or contaminated clothing. As exposure for these tasks is defined, steps should be taken to reduce exposure to the lowest feasible level using a combination of engineering and administrative controls. Employees assigned to such work may use personal protective equipment to further reduce the uptake of mercury vapor.

6.2 Exposure Assessment – Air

6.2.1 Exposure Assessment

A person, knowledgeable in industrial hygiene exposure assessment techniques, should determine individuals who may have significant risk of exposure to mercury. The exposure assessment approach can be either individual or exposure group based. Typically, the exposure assessment process begins with a qualitative screening process to prioritize or rank exposures. The assessment process may proceed to more rigorous semi-quantitative or quantitative approaches depending on the original purpose of the exposure assessment and the desired certainty of the outcome. If warranted, based on the results of the exposure assessment, industrial hygiene personnel monitoring measurements should be collected for representative members of an exposure group or for each individual potentially exposed to mercury if an exposure group approach is not used. An exposure assessment strategy typically addresses full shift exposure and specific activities or tasks conducted by cell-room workers or other individuals involved in mercury related activities.

Mercury area-monitoring data should be periodically collected in the cell-room and basement areas to obtain the background mercury concentration level in the areas. Particular attention should be paid to areas with high potential for leaks or spills. In addition, as appropriate, air measurements should be collected with a direct reading instrument to identify proper respiratory protection or to restrict areas where potentially high exposure could exist such as the opening of a cell.

6.2.2 Mercury-in-air Exposure Limits

OSHA has established an eight hour time weighted average (TWA) permissible exposure limit (PEL) of 100 $\mu g/m^3$ (1 mg/10 m^3). The reader should note that, for the past several years, Table Z-2 of 29 CFR 1910.1000 has incorrectly listed the mercury PEL as a ceiling level. OSHA has acknowledged this error in a September 3, 1996 Standards Interpretation letter. Appendix 10B provides a copy of the OSHA. The ACGIH has established an 8-hour time weighted average (TWA) threshold limit value (TLV) of 25 $\mu g/m^3$ for mercury. Based on a thorough review of the scientific literature, the Chlorine Institute has concluded that the establishment of a STEL (short-term exposure limit) is also advisable to protect worker health. Mercury is lipid soluble and is

transported throughout the body by circulation of the blood. (See Section 3.2). High concentrations of mercury vapor may have the potential to overwhelm the oxidative capacity of the blood, allowing elemental mercury to reach the CNS.

The Chlorine Institute recommends facilities establish an 8-hr TWA exposure limit of not greater than 50 μg/m3. Based on this recommended limit and applying the ACGIH's statement that "Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during a workday, and under no circumstances should they exceed 5 times the TLV-TWA, provided the TLV-TWA is not exceeded." (Reference 9.32). The Institute recommends a short-term exposure limit (STEL) of 150 μg/m3, as a 15-minute time weighted average. Potential STEL exposures should be controlled through engineering and administrative controls to the lowest feasible level and augmented with respiratory protection if necessary consistent with requirements specified in the OSHA Respiratory Protections Standard (Reference 9.30).

6.2.3 Exposure Monitoring

6.2.3.1 Personnel Monitoring – Full Shift

Full-shift monitoring consists of one or more samples that are representative of the full shift exposure. Patty's Industrial Hygiene and Toxicity (Chapter 3 Section 3.2) (Reference 9.33) states that full shift sampling should last at least 70% of the shift. In its Occupational Exposure Sampling Strategy Manual (N. Leidel, K Busch and J Lynch, U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, January 1977, DHEW (NIOSH) Publication No. 77-173, page 40), NIOSH states that full shift sampling should be 70 –80% of the shift. Full shift monitoring for mercury should be performed according to the OSHA Inorganic Module Method #:ID-140 (Reference 9.34), equivalent NIOSH Method 6009 (Reference 9.35) or an equivalent validated method. Active or passive sampling is appropriate for full shift monitoring. A NIOSH/AIHA accredited industrial hygiene laboratory or OSHA can provide guidance regarding media type, flow rates and minimum and maximum sample size. All samples should be analyzed by a laboratory accredited by NIOSH/AIHA. (Reference 9.36).

As appropriate, a sampling strategy that addresses full shift exposures should be established for each exposure group or individual. Selection of exposure groups to be monitored should consider the likely intensity of exposure. Exposure groups with exposure intensity above 50 percent of the exposure limit should be monitored. A portion of the remaining exposure groups should be monitored to validate the exposure assessment process. Sample collection should be as random as practical. The American Industrial Hygiene Association in its 1998 document titled "A Strategy for Assessing and Managing Occupational Exposures" (Reference 9.37) recommends that 6 to 10 samples should be collected to assess each exposure group. The preferred metric used to determine acceptability of exposure is the 95^{th} Percentile although other metrics may be appropriate under various circumstances. The above publication provides rationale for this approach and includes software that can be used to perform the required calculations.

6.2.3.2 Personnel Monitoring – Short Term Task

A **short term** task is a work activity which can be performed in approximately one hour or less. Efforts should be made to break work activities which take longer than one hour to perform into shorter duration tasks. For example, a work activity such as cell clean-out can be broken into the following tasks:

1) Raking mercury butter from cell bottom
2) Cell wash down
3) Acid wash of cell bottom, etc.

All tasks less that 60 minutes in duration should be monitored utilizing NIOSH Method 6009, active sampling. In general, passive sampling may not be suitable for short term sampling. Sampling times and rates should be controlled so that the lower limit of quantification of the method is no higher than 25% of the STEL and preferably less than 10% of the STEL. Tasks that are too short to utilize personnel sampling (e.g., tasks that take less than 5 minutes to perform) can be sampled with the area survey meter described in the section below with probe positioned in the breathing zone of the worker sampled.

The site's STEL sampling strategy should assure that tasks with potential for mercury exposure above allowable limits are characterized. As with full shift sampling, the typical metric used for comparison to the exposure limit is the 95^{th} percentile although other metrics and compliance strategies may be appropriate.

6.2.3.3 Area Surveys

In contrast to personal monitoring samples that measure worker exposure, area surveys are used to obtain measures of concentration at various points in the workplace. Uses of area surveys data include: establishing background concentrations in process areas; concentrations in control rooms or break rooms to assure that process and administrative controls are effective; investigating potential points of emissions related to equipment that may not be performing adequately; establishing boundaries for regulated areas and the need for respiratory protection equipment and type; and used to estimate exposure associated with non-routine tasks such as maintenance tasks.

1. Survey Instrumentation

All field survey instruments utilized in the mercury vapor surveys described below (i.e. scheduled cell-room surveys, scheduled maintenance task surveys, and investigative surveys) should:

- be used only by properly trained personnel
- be zeroed in an uncontaminated area or by utilizing a mercury vapor filter attachment, prior to each use. Where multiple samples are collected, such as in the daily survey, the survey instrument should be zeroed, as a minimum, every fifth sample or when it is suspected that the sensor has

become saturated from a high sample. It may be necessary to readjust the zero point after the instrument has returned to room temperature.

- be calibrated according to the manufacturer's recommendations, utilizing a known concentration of mercury vapor (note: usually after the sensor regeneration stage).

Written documentation of field calibrations and instrument performance should be maintained in accordance with the facility's record retention program. Documentation should include at least the following:

- instrument serial number
- date of field calibration
- reading before/after calibration
- notes of any adjustments made during field calibrations
- notes of any manufacturer's repairs or calibrations.

2. Scheduled Cell-Room Surveys

A mercury vapor survey should be conducted on a regular basis in accordance with the facility's industrial hygiene exposure assessment program. The purpose of the scheduled survey is to evaluate the effectiveness of process and/or administrative (i.e. hygiene/housekeeping) controls. The results of the survey should trigger actions such as emission source investigation, maintenance, removal of all non-essential personnel, establishment of a regulated area, respiratory protection, etc. The appropriate actions are dependent on the concentration levels observed. The scheduled survey does not replace the need to perform surveys whenever it is suspected that mercury contamination has occurred (See "Investigative Surveys", below). High exposure maintenance activities may increase ambient concentrations of mercury during the time it takes to complete the maintenance activities and may make it difficult to determine the variability in air concentrations which are a result of process fugitive emissions or poor housekeeping. Therefore, scheduled surveys should be conducted when high exposure maintenance tasks are not being performed. Additional scheduled surveys should be performed for each maintenance task which may create a potential exposure situation as noted in "Maintenance Task Surveys", below.

The scheduled survey should consist of a pre-defined number of samples for each work area to be surveyed. Samples should be collected in approximately the same location in order to reduce any variability when charting performance over time. Results of the surveys should be documented by pre-defined location numbers.

The purpose of the data analysis is to determine the effectiveness of the overall exposure control strategy over time. The data points need to be classified into groups of data which would facilitate problem identification and resolution. Examples of groups would include:

- cell room
- break room
- control rooms
- change rooms

In order to determine the effectiveness of the exposure control strategy over time, it is recommended that consideration should be given to charting survey data. If the survey data are charted, group data should be pooled on a periodic basis and percentages calculated as the total of all survey points collected for the period. Statistical process control (SPC) charts are useful for presenting survey results and determining trends in exposure control strategies. Reference 9.38 provides more information on the use of control charts.) Any modifications in process or work practices resulting in a shift, above or below the mean line or confidence levels, should be documented and distributed with the control charts.

3. Scheduled Maintenance Task Surveys

Certain maintenance activities have the potential to expose individuals above the Institute's recommended exposure limits (8 hr. TWA 50 μg/m3 or 15 min. STEL of 150 μg/m3), therefore it is necessary to determine exposure levels when performing any maintenance task where the potential exists for exposure to mercury vapors. For routine maintenance tasks, where it can be established that exposure levels are similar each time the task is performed, documented standard operating procedures (SOPs) may be utilized to establish required controls (i.e. work practices and appropriate level of respiratory protection/PPE, if required). Where PPE requirements have not been established, it will be necessary to perform scheduled maintenance task surveys. Results of the scheduled maintenance task survey should be utilized to establish regulated areas and to determine the appropriate level of respiratory protection/PPE.

4. Investigative Surveys

An investigative survey should be conducted whenever it is suspected that mercury contamination has occurred (i.e. spills, leaks, or as a result of maintenance tasks conducted without regard to good work practices which may have contributed to contamination of other areas, equipment or PPE). In addition, the Institute recommends investigative surveys be conducted where scheduled surveys indicate mercury levels in excess of 0.05 mg/m3.

The purpose of the investigative survey is to:

- identify the sources of mercury emissions for abatement evaluation;
- aid in decontamination of the work area, equipment or PPE;
- establish boundaries of regulated areas.

6.3 Exposure Assessment – Biological Monitoring

6.3.1 Role of Biological Monitoring

Mercury in urine levels have been used for some time at mercury chlor-alkali facilities of Chlorine Institute members to characterize mercury exposures and to complement administrative and engineering control strategies for mercury exposures. Although both mercury in urine and mercury in blood measures can provide useful information related to workers exposures to mercury, this section will limit its discussion to mercury in urine monitoring. Mercury in urine levels represent the average exposure a worker encountered over the last 2 to 3 months as compared to a mercury in air measure that represents the exposure encountered during the sample period monitored (day or task). Mercury in urine may also reflect exposure from the dermal and ingestion routes of exposure, while mercury in air is limited to inhalation. Both types of measures are useful to effectively manage occupational exposure to mercury. To properly interpret mercury in urine data, several limitations of the biological monitoring should be recognized.

- Individuals excrete mercury at different rates. Therefore it is often difficult to utilize BEIs to determine whether one individual is experiencing higher exposures relative to another individual.

- Mercury in urine levels represent a surrogate of the body burden on the kidney only. The kidney is the body system least likely to be affected by exposure to mercury. The central nervous system is the body system at greatest risk from exposure to mercury in air. The body burden on the CNS is not represented by mercury in urine levels because the biological half-life of mercury in the CNS is extremely long and adds insignificantly to the total mercury excreted in urine.

- Mercury in urine levels do not correlate well to mercury in air levels. Shifting emphasis away from controlling mercury in urine to controlling mercury in air will provide increased protection to the adverse effects mercury has on the CNS.

- An individual's excretion of mercury in urine is highly variable between days even when the exposure is relatively constant between days.

- If the units used in reporting mercury in urine is in micrograms per gram creatinine, it should be noted that individuals performing heavy work will produce and eliminate more creatinine per day than will individuals who perform only light work. In addition, if an individual's kidney function deteriorates, the quantity of creatinine in urine will increase. In both cases, the mercury in urine value would appear to be reduced even though the amount of mercury eliminated is the same.

Whereas mercury in air data can be directly compared to occupational exposure limits, mercury in urine data requires a strategy that results in recommendations that have varying triggering levels. This is not a short coming but rather must be recognized in effective utilization of the data.

6.3.2 Specific Gravity Correction or Creatinine Adjustment

Previously, the Chlorine Institute had recommended that a specific gravity correction should be applied to urinary mercury testing results. This recommendation was based on abnormally diluted urine resulting from high fluid intake or abnormally concentrated urine from high fluid loss which may not yield results easily related to exposure. There is some disagreement whether mercury levels in urine should be corrected for specific gravity or whether mercury levels should be measured in terms of creatinine. However, most experts believe that one of these two methods should be used. The Institute believes that creatinine adjustment should be used. Specific gravity adjustment may be done for additional information or when creatinine determination is not available.

If the mercury concentration is based on the creatinine adjustment method, World Health Organization recommends resampling if the creatinine value is not greater than 0.3 or less than 3.0 grams/liter. (Reference 9.32, page 85).

Measurement of mercury in urine using the specific gravity correction is performed as follows:

$$\text{Corrected Value} = (\text{Uncorrected Value}) \times ((1.020 - 1)/(\text{Specific Gravity} - 1))$$

This is based on a standard specific gravity of 1.020. The World Health Organization recommends re-sampling if the specific gravity is not greater than 1.010 or less than 1.030 (Reference 9.32, page 85).

“Specimens falling outside of either of these ranges should be discarded and another specimen should be obtained. Workers who provide consistently unacceptable urine specimens should be referred for medical evaluation” (Reference 9.32, page 85).

6.3.3 Sample Collection

Routine periodic urine samples are best collected prior to the employee starting the work shift. Variations in mercury levels have been observed due to variations in the time of day sampled. Accordingly, it is preferred to collect all periodic samples from an individual at about the same time of the day. To avoid contamination from hands or clothing, care should be taken. In consultation with medical, industrial hygiene, and any other appropriate personnel, each facility should establish a program providing for the frequency and consistency of collection. Tables 6.3.2 A and B provide a suggested frequency for monitoring of new employees potentially exposed to mercury.

6.3.4 Evaluation of Individual Results

Biological monitoring is used to assess the effectiveness of engineering, personal protection, and hygiene measures to control exposure. When values exceed the levels listed in Table 6.1a, the margin of safety may not be adequate. The measures recommended are to assist in reducing exposures while at the same time assuring that health is not being impaired.

6.3.5 Evaluation of Trends in Exposure Measurement for Individuals

As discussed in Section 5.3, Medical Intervention Assessment based on increasing trends in exposure measurement for individuals should be considered. If a facility chooses to assess trends, there are numerous ways to implement such trend assessments. Table 6.1b provides one possible approach that a facility might consider.

Table 6.1a
Individual Measurements

Recommended Action Steps for Employees (Including Contractors) Potentially Exposed To Mercury Based on Biological Monitoring for Mercury

Individual's Result (after Confirmation, if appropriate) µg Hg/g Creatinine	Monitoring Frequency	Action Steps (See Table 6.2)
<35	Quarterly	None
>=35 and <75	Monthly	Review
>=75 and <100	Weekly	Investigation
>=100	Determined by Medical	Medical Intervention

Notes:

(1) The exposure assessment should determine which employees will be routine monitored. See Section 6.2.

(2) Medical removal is typically immediate at confirmation of 100 µg Hg/g creatinine or greater and continues until the medical intervention has determined the needed action steps and they have been implemented.

(3) Urine analysis results for mercury of newly exposed employees are considered unreliable for the first six months. Because the body has not yet reached equilibrium, mercury may be absorbed faster than it is excreted. As a result the test result may be low.

(4) Results should be verified before action is initiated. Any abnormal result (unexplicitedly high or low), when compared with past data, should be verified.

(5) Facilities, in consultation with their plant physician, may choose to modify these recommendations as their individual circumstances dictate.

Table 6.1.b

Possible Approach for Assessing Trends in Exposure Measurements of Employees (Including Contractors) Potentially Exposed to Mercury Based on Biological Monitoring for Mercury

Trends in an Individual's Result as Compared to the Individual's Average (IA) µg Hg/g Creatinine	Monitoring Frequency	Action Steps (See Table 6.2)
IA < 25	Quarterly	None
25 <= IA < 35 and four consecutive measurements above IA	Monthly	Review
35 <= IA < 75 and four consecutive measurements above IA	Weekly	Investigation
IA = > 75 and four consecutive measurements above the IA	Determined by Medical	Medical Intervention

Notes:

(1) The exposure assessment should determine which employees will be routine monitored. See Section 6.2.

(2) Medical removal is typically immediate at confirmation of 100 µg Hg/g creatinine or greater and continues until the medical intervention has determined the needed action steps and they have been implemented.

(3) Urine analysis results for mercury of newly exposed employees are considered unreliable for the first six months. Because the body has not yet reached equilibrium, mercury may be absorbed faster than it is excreted. As a result the test result may be low.

(4) Results should be verified before action is initiated. Any abnormal result (unexplicitedly high or low), when compared with past data, should be verified.

(5) The approach used to establish the individual's average (IA) is at the prerogative of the company. Examples of valid approaches to calculate an IA include the statistical process control mean or the running average of the six prior measurements.

Table 6.2

Explanation of Action Steps

Review Level

Proper work procedures, personal hygiene practices and protective equipment practices/requirements should be reviewed with employee. Emphasis should be placed on identifying and correcting potentially problematic work habits. Reviews should be conducted periodically with any employees whose levels remain at or above 35 ug/g creatinine.

Investigation Level

A detailed investigation of the potential sources of mercury exposure and possible corrective actions should be completed. Medical consultation may be necessary to determine if any non-occupational mercury sources are contributing to the exposure and to determine if the employee has any observable signs of mercury related illness. Consideration should be given to urine mercury levels of other employees in similar jobs/exposure to identify any possible trends in individuals or groups. Investigations and reviews should be conducted periodically with any employees whose levels remain at or above 75 ug/g creatinine.

Medical Intervention

After confirmation that the urinary mercury level is at/or above 100 ug/g creatinine, temporary removal from exposure should be considered until seen by a physician. The other steps undertaken at the Investigation level should also be undertaken/repeated. The treating physician should perform a work fitness determination and communicate the results to appropriate operations personnel. Operations will assign the employee to job tasks in agreement with fitness determination. The employee may return to normal assignments when authorized by the treating physician.

7. EXPOSURE CONTROL STRATEGY

7.1 Engineering Controls

7.1.1. Process Design

when exposure is above accepted levels, the feasibility of the following design issues should be established and documented:

- ventilation system on end boxes (where present)
- vapor outlet with a connection to the end box ventilation system on submerged pumps used for recycling mercury from decomposers to the inlet of the cell
- enclosed collection system for drips from hydrogen seal pots and compressor seals
- enclosed collection system for solids and liquids collected from back flushing the caustic filters
- enclosed collection system for impure amalgam removed from cells and mercury recovered from process systems

Note: In general, an enclosed collection system refers to a hard piped process system. A hard piped process system should be considered in lieu of collection under a water seal in an open container where feasible.

The reader should note that OSHA has specific regulations pertaining to exposure limits to chemicals (Reference 9.39), to process safety management of highly hazardous chemicals (Reference 9.40), respiratory equipment (Reference 9.30), and other regulations that may be applicable to the process design. In addition, EPA is expected to have promulgated the emission limits as well as housekeeping requirements for mercury cell chlor-alkali plants in its Mercury Maximum Achievable Control Technology (MACT) regulation in December 2003 (Reference 9.41). These requirements must be implemented not later than three years after promulgation.

7.1.2. Ventilation Systems

7.1.2.1 Ventilation Design

Non-Process Areas

Ventilation systems for clean work areas such as control rooms, break rooms and change rooms should be designed:

- with fresh air make-up
- consideration of the effects of possible contamination from the adjacent area.
- to maintain the lowest feasible contaminant levels

Process Areas

General and local exhaust ventilation can add significantly to exposure control in process areas by removing or diluting fugitive emissions. In addition, general ventilation systems can significantly decrease temperatures in process areas which in turn can reduce exposure levels. The vapor pressure of mercury is reduced by approximately half for every 20^0F decrease in ambient temperature. (See Table 4.1 in Section 4.2.1.) Therefore, when considering ventilation as an exposure control strategy, it is recommended that an individual with extensive expertise in ventilation be secured in the design phase to ensure maximum benefits are obtained from this type of engineering control.

7.1.2.2 Preventive Maintenance

A preventive maintenance program for the ventilation systems should be implemented and the findings documented (i.e. tags or critical items checklist). The following items should be addressed:

- Periodic performance check of mechanical fans in process areas (i.e. belts, fan speed, etc).
- Periodic surveys of the air return filters on all air conditioner/heating systems with the mercury survey meter. Filters should be replaced when needed.
- Where systems are designed to maintain a positive pressure, periodic verification should be conducted.

7.1.2.3 Controlled Areas

The Institute recommends controlled areas be established whenever area surveys indicate levels in excess of 0.05 mg/m3. Controlled areas should be demarcated in such a way that persons entering the area are informed of the need to wear respiratory protection. Access to controlled areas should be limited to authorized persons, wearing the appropriate level of respiratory protection.

7.1.3. Critical Items Checklist

A critical items checklist should be considered to monitor critical areas. Such check lists can assist in reducing the potential for personnel exposure to mercury. Such a check list may assist facilities to conform to the current mercury NESHAP and the new Mercury MACT promulgated (Reference 9.41). As part of the current NESHAP for mercury cell chlor-alkali plants, the US EPA has developed "Good Housekeeping Practices for

Mercury Cell Chlor-Alkali Plants" (Reference 9.41) In addition, the Chlorine Institute has developed a guidance document, Guidelines for Mercury Cell Chlor-Alkali Plants Emission Control: Practices and Techniques that provides useful information. (Reference 9.42). Critical items may include the following:

- Inspection of pumps for leaks;
- Inspection of cell, decomposer, and end box covers for leaks;
- Inspection of floors for cracking and contamination;
- Inspection of water level in end boxes (note: physical boiling of water indicates insufficient level of water); and
- Inspection of gaskets on decomposers and hydrogen piping to detect hydrogen leaks (note: the thermal conductivity mode of a combination LEL/O_2 instrument can be used to measure % hydrogen).

The facility needs to establish a documentation procedure for the critical items check. An example of an option for documentation includes incorporation into the documentation of existing routine shift activities.

7.2 Personal Protective Equipment

7.2.1 Respiratory Protection

Based on the results of the exposure assessment program, tasks or activities where workers can be expected to encounter a high concentration of mercury vapor (in excess of 50 µg/m^3 TWA or 150 µg/m^3 STEL) workers must wear a NIOSH approved respirator for mercury vapor. In those cases where objective exposure data are not available and there is reason to believe that significant mercury vapors could be present, appropriate respirators should be worn until an assessment can be completed.

Proper selection of respirators should be determined by a qualified occupational health or safety specialist, in accordance with applicable standards and the limitations of the specific respirator. If the respirator is also used to protect the worker from other contaminants (e.g. chlorine), a cartridge change out schedule must be established for all contaminants. . A complete Respirator Protection Program meeting all of the requirements of 29 CFR 1910.134 should be established (Reference 9.30).

7.2.2 Protective Clothing

A comprehensive PPE programs should be developed consistent with the requirements of OSHA Standards (e.g., Body Protection – 29 CFR 1910.132, Hand Protection – 29 CFR 1910.138, etc.) (Reference 9.43). Typical components of a comprehensive PPE program include the following:

- PPE Hazard Assessment - Assessing the need for personnel protective equipment by reviewing the nature of the hazards of the process or job.

- Determine the protection level and performance required of the PPE.
- Selection of PPE by job and task.
- Decontamination procedures
- Training programs
- Inspection, maintenance and repair
- Audit

7.3 Hygiene Facilities and Practices

The following special provisions apply in connection with occupational exposure to mercury.

- Employees should change from street clothes to separate work clothes before starting jobs where there is the potential for exposure to mercury. Street clothes should be kept in separate lockers so that they will not become contaminated with mercury by contacting contaminated clothes or by absorbing mercury vapor.
- Clothing worn on jobs involving potential exposure to mercury should be dedicated and worn only on the job. To the extent possible, clothing should be made to minimize cuffs, pockets, and belts, or other places where mercury can lodge.
- Protective clothing should be turned in after each shift of work unless the procedures, as indicated below, are followed. Any protective clothing or footwear provided for a longer period of use should be stored separately from personal street clothing, street footwear, food, tobacco products, and other personal effects.
- All work clothing should be removed in change rooms and deposited in marked laundry containers. If clothing is not laundered at the plant, the laundry that will be cleaning the clothes should be informed that the clothes may be contaminated with mercury. Contaminated clothing or footwear should not leave the plant except in packages for laundry, decontamination or disposal.
- Lockers for work clothing should be monitored periodically for mercury contamination and cleaned as appropriate.
- Shower facilities should be provided and workers required to shower at the end of the workday prior to changing in street clothes and encouraged to shower after completing tasks during the workday where significant exposure could have occurred.

- Eating, drinking, smoking, using smokeless tobacco, chewing gum, or applying cosmetics should be avoided where mercury may be present.

8. EMPLOYEE TRAINING

Employee protection against exposure to mercury is enhanced by effective training and supervision. Training should be provided so that all employees are familiar with, and understand, hazards and precautionary measures that they must follow in order to protect themselves, their coworkers, and their families.

All employees with the potential for exposure to mercury should receive appropriate training prior to any potential exposure to mercury. Refresher training should be provided periodically for all employees who may be potentially exposed to mercury. All training should be documented and maintained in accordance with the facility's record retention policy.

OSHA provides training recommendations in its directive CPL 2-2.6: Inorganic Mercury and its Compounds (Reference 9.44). OSHA also provides guidance in its Hazard Communications Standard (Reference 9.45).

Recommendations Include:

- Advise affected employees of the signs and symptoms of over-exposure to mercury
- Inform employees where written procedures and hazard information are available on the premises
- Inform employees as to where in the facility mercury is used and stored
- Emphasize the possibility of ingesting mercury by hand-to-mouth contact when good personal hygiene is not practiced and stress the importance of wearing prescribed PPE
- Instruct employees to advise the employer of the development of the signs and symptoms of overexposure to mercury
- Inform employees of the specific nature of operations which could result in exposure to mercury above the permissible exposure limit
- Describe safe work practices for the handling, use, release, storage, or disposal of the mercury or its compounds
- Instruct employees as to the purpose, proper use, and limitations of respirators
- Instruct employees in proper housekeeping practices, decontamination procedures in the event of a mercury or mercury compound spill, and fire emergency procedures
- Emergency procedures to be followed in case of spills or leaks, and personal protective equipment necessary in emergencies
- Written procedures and means for removal of mercury or its compounds from body surfaces and working surfaces, machinery, or tools to be used later for other work activities

- Provide employees with a description of, and explain the purposes for, the medical surveillance program

Companies should develop training programs appropriate for their facilities and operations.

9. REFERENCES

9.1 American Conference of Governmental and Industrial Hygienists, Mercury, Elemental and Inorganic, Recommended BEI (BEI Documentation), 2001, Cincinnati, Ohio.

9.2 U.S. Environmental Protection Agency: Development of Statistical Distributions or Ranges of Standard Factors Used in Exposure Assessments (EPA 600/8-85/010), USEPA, Office of Health and Environmental Assessments, Exposure Assessment Group, 1985. Washington DC.

9.3 Albers, J. W., *et al*. the Mercury Workers Study Group. 1988. Neurological abnormalities associated with remote occupational elemental mercury exposure. 1992. Kinetics of mercury in blood and urine after brief Ann Neurol 24 (5): 651-659.

9.4 M. Bleecker Ed. Occupational Neurology and Clinical Neurotoxicology. Williams & Wilkins, Baltimore, 1994.

9.5 R. Blum *et al.* Elemental Mercury Vapor Toxicity, Treatment and Prognosis after acute, Intensive Exposure in Chloralkali Plant Workers. Part I: History, Neuropsychological Findings and Chelator effects. Human and Experimental Toxicology (1992). 11.201-210

9.6 Berufsgenossenschaftliche Grundsatze fur Arbeitsmedizinische Vorsorgeuntersuchungen (Federal republic of Germany: Employers` Liability Insurance Association Rules For Industrial Medicine Preventive surveillance. Second Edition May 1991, Gentner Verlag 9 Publishers), Stuttgart.

9.7 The Liver Biology and Pathobiology, Arias, Popper, Schachter, and Schafritz, Raven Press, 1982.

9.8 Goering, P. L., et al. 1992. Toxicity Assessment of Mercury Vapor from Dental Amalgams. Fundam Appl Toxicol 19: 319-329 Hernberg, S., and E. Hasanen, 1971; Relationship of Inorganic Mercury in Blood and Urine. Work Environ Health 8: 39-41.

9.9 Information Notices on Diagnosis of Occupational Diseases; European Commission ISSN 1018-5593. Health and Safety Report EUR 14768 EN 1994.

9.10 Occupational Diseases. A Guide to Their Recognition. CDC/NIOSH U.S. Government Printing Office, Washington, 1977.

9.11 Regulation Respecting Mercury-Under the Occupational Health and Safety Act Ontario Ministry of Labour 141/82, 1982.

9.12 Respiratory Protection Guidelines for Chlor-Alkali Operation, Pamphlet #75, April 1993, The Chlorine Institute, Washington, DC.

9.13 Senn E.P., MD, CIH, Controlling Metallic Mercury Exposure in the Workplace: A Guide to Employers. New Jersey Department of Health, Occupational Health Service CN 360 1996.

9.14 Kanerva, L., *et al.* 1993. Occupational allergic contact dermatitis from mercury. *Contact Dermatitis* 28/1: 26-28.

9.15 Adams, C. R., *et al.* 1983. Mercury intoxication simulating amytrophic lateral sclerosis. *Journal of the American Medical Association* 250: 642-643.

9.16 Hawkins K. A. Occupational Neurotoxicology; Some Neuropsychological Issues and Challenges. Journal of clinical and experimental neuropsychology 1990; 12:664-80.

9.17 Langworth, S., O., *et al..* 1992. Effects of occupational exposure to mercury vapor on the central nervous system. *Br J Ind Med* 49: 394-401.

9.18 Roels, H., *et al.* 1989. Detection of hand tremor in workers exposed to mercury vapor: A comparative study of three methods. *Environ Res* 49: 152-165.

9.19 Smith, R.G., *et al.* 1970. Effects of exposure to mercury in manufacture of chlorine. *Industrial Hygiene Association Journal*; 31:687.

9.20 Stallsten, G., *et al*. 1990. Mercury in the Swedish chloralkali industry: An evaluation of the exposure and preventive measures over 40 years. *Ann Occup Hyg* 34 (2): 205-214.

9.21 Mercury and mercury compounds (1993): IARC Monographs on the Evaluation of Carcinogenic Risks to Humans; 58: 239-345.

9.22 Clarkson, T. W., *et al*. 1985. Reproductive and developmental toxicity of metals. *Scand J Work Environ Health*. 11: 145-154.

9.23 Clarkson, T.W. (1989) Mercury. Journal of the American College of Toxicology 8(7):1291-5.

9.24 Schweinsberg, F. and L. VonKarsa (1990). Heavy metal concentrations in humans. Comparative Biochemistry and Physiology [C] 95(2):117-23.

9.25 Alscer, K. H., K. A. Brix, L. J. Fine, L. R. Kallenbach, and R. A. Wolfe, Occupational Mercury Exposure and Male Reproductive Health, Am J Ind Med 15: 517-529, 1989.

9.26 Cordier, S., F. Deplan, L. Mandereau, and D. Hemon, Paternal Exposure to Mercury and Spontaneous Abortions, Br J Ind Med 48 (6); 375 - 381, 1991.

9.27 Euro Chlor Publication Code of Practice, Control of Worker Exposure to Mercury in the Chlor-Alkali Industry, 4th Ed, 1997.

9.28 Rowland, A. S., *et al.* 1994. The effect of occupational exposure to mercury vapor on the fertility of female dental assistants. *Occupational and Environmental Medicine*. 51/1: 28-34.

9.29 Barlow, .M. and Sullivan, F.M. (1982). Reproductive Hazards of Industrial Chemicals: An Evaluation of Animal and Human Data. Academic Press, New York.

9.30 Code of Federal Regulations, Title 29, Part 1910.134, Respiratory Protection.

9.31 Sugita, M., 1978, The Biological Half-Life of Heavy Metals, Int Arch Occup Environ Health 41: 25-40.

9.32 American Conference of Governmental and Industrial Hygienists, 2003 TLVs and BEIs, Documentation of Threshold Limit Value for Chemical Substances and Biological Agents and Biological Exposure Indices, Cincinnati, Ohio.

9.33 Patty's Industrial Hygiene and Toxicity, Robert L. Harris, 5th edition, John Wiley & Sons, 2000, Hoboken, NJ.

9.34 OSHA Inorganic Module Method #:ID-140 can be found at the following web address: http://www.osha.gov/dts/sltc/methods/inorganic/id140/id140.html

9.35 NIOSH Method 6009 can be found at the following web address: http://www.cdc.gov/niosh/nmam/pdfs/6009.pdf

9.36 The AIHA website provides a listing of such accredited laboratories. The link to the website is as follows: *http://www.aiha.org/*

9.37 The American Industrial Hygiene Association, 1998, A Strategy for Assessing and Managing Occupational Exposures, Fairfax, VA.

9.38 www.sytsma.com/tqmtools/charts.html

9.39 Code of Federal Regulations, Title 29, Part 1910.1000, Air contaminants.

9.40 Code of Federal Regulations, Title 29, Part 1910.119, Process Safety Management of Highly Hazardous Chemicals.

9.41 Code of Federal Regulations, Title 40, Part 63, National Emission Standards for Hazardous Air Pollutants: Mercury Emissions from Mercury Cell Chlor-Alkali Plants.

9.42 Guidelines for Mercury Cell Chlor-Alkali Plants Emission Control: Practices and Techniques, The Chlorine Institute, Inc., Arlington, VA, 2001.

9.43 Code of Federal Regulations, Title 29, Part 1910.132 to .139, Personal Protective Equipment.

9.44 OSHA Directive CPL 2-2.6 [CPL 02-02-006] - Inorganic Mercury and its Compounds, 1978. The link to the website is as follows: http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=DIRECTIVES&p_id=1573

9.45 Code of Federal Regulations, Title 29, Part 1910.1200, Hazard Communication.

9.46 Bernard, A., and R. Lauwerys. 1989. Epidemiological application of early markers of nephrotoxicity. *Toxicol Lett* 46: 293-306.

9.47 Kazantzis, G., *et al.* 1962. Albuminuria and the nephrotic syndrome following exposure to mercury and its compounds; *Q J. Med* 31: 403-418.

9.48 Forzi, M., Cassitti, M.G., Bulgheroni, C., & Foa, V. (1976) Psychological Measures in Workers Occupationally Exposed to Mercury Vapours; a validation study; In: Adverse Effects of Environmental Chemicals an Psysocotoxic Drugs, Amsterdam, Oxford, New York, Elsevier Science Publishers, Vol. 2, pp. 165-172.

9.49 IPCS International Program on Chemical Safety Environmental Health Criteria 118. Inorganic mercury. WHO, Geneva 1991.

9.50 American Conference of Governmental and Industrial Hygienists, Mercury, All Forms Except Alkyl (TLV Documentation), 2001, Cincinnati, Ohio.

9.51 Foa, V., *et al*. 1976. Patterns of some lysosomal enzymes in the plasma and of proteins in urine of workers exposed to inorganic mercury. *Int Arch Occup Environ Health* 37: 115l-124.

10. APPENDICES

A. ADDITIONAL HEALTH EFFECTS GUIDELINES FOR PHYSICIANS AND OTHER QUALIFIED MEDICAL PROFESSIONALS

10.1 BIOCHEMICAL INDICATORS OF EFFECT

No test is available that allows monitoring of the exposed individual in relation to early biochemical reversible alterations. Some early biochemical effects observed are of doubtful clinical significance and are appreciated only when entire groups of people are considered. Although of experimental interest, these molecular epidemiology markers are not apt to monitor individual effects (e.g., lysosomal acid hydrolyses = N-Acetyl aminoglucominidase, NAG). (References 9.46 and 9.51)

10.2 CLINICAL EFFECTS (References 9.4, 9.6, 9.10, 9.11, 9.12, 9.13 and 9.51)

Overexposure to mercury vapor gives rise to neurological effects with initially a fine high frequency intention tremor and neurobehavioral impairment. In occupational settings where chlorine is in contact with mercury, a part of the mercury vapor can be transformed in the atmosphere to mercury chloride and absorbed in this form. In most of today's chlor-alkali facilities, chlorine is well controlled and absorption in this form is usually not a problem. Proteinuria may be an effect of mercuric mercury absorption and be produced through the formation of mercuric-mercury-induced autoimmune glomerulonephritis in some susceptible, overexposed workers. (Reference 9.47)

Exposure to atmospheric mercury vapor in excess of 100 µg/m^3 (8-hour TWA) and urinary mercury levels in excess of 150 µg/g creatinine are associated with increasing risk of developing the classical neurologic signs of mercury intoxication and proteinuria. Repeated incidents and episodes of peak over-exposure may determine chronic long term neurological effects. Subtle effects may be observed for intermediate level of exposure. **(**References 9.1, 9.3, 9.48, 9.49 and 9.50).

Pertinent effects of mercury exposure can be local or systemic, consequent to acute or chronic exposures.

10.2.1 Local Effects

10.2.1.1 *Irritant*

- Mercury salts can cause dermatitis.
- Mercury vapors are irritating to the respiratory tract.
- Massive exposure due to an emergency condition such as a large spill or fire may lead within hours to bronchiolitis, chemical pneumonia, acute pulmonary edema and even renal tubular necrosis. Irreversible pulmonary sequelae are possible after acute manifestations.

10.2.1.2 *Allergic*

- Allergic contact dermatitis can ensue with exposure to mercury and its salts.

10.2.2 Systemic Effects

10.2.2.1 *Acute*

- Metal fume fever

10.2.2.2 *Subacute*

- Encephalopathy
- Renal tubular impairment

10.2.2.3 *Chronic*

- Encephalopathy
- Cerebellar Syndrome
  - Intentional tremor
  - Ataxia, dysarthria
- Tremor
- Peripheral neuropathy
  - Sensory-motor nerve disturbances
  - Guillan Barré syndrome
- Oral cavity
  - Gingivitis, stomatitis, sialorrhea, gingival pain
  - Ulceration of lips and oral mucosa
  - Mercurial line along the gingival margins
  - Metallic taste, tooth loss
- Nephropathy
  - Nephrotic symptoms
  - Autoimmune glomerulonephritis

During chronic exposure to elemental and inorganic Hg by inhalation, the critical organ is the central nervous system. Symptoms such as anorexia, weight loss, tremors, and insomnia are well correlated with different degrees of exposure. The kidney becomes the critical organ following ingestion or skin absorption of inorganic mercury salts with possible development of proteinuria and an autoimmune nephrotic syndrome.

10.2.3 Tremor

Tremor is the most evident clinical sign and is a constant observation in all cases of mercury intoxication. It is both static and intentional, and is greatly enhanced by emotional stimuli. Initially it is imperceptible, but it becomes progressively evident, with complex movements such as writing, buttoning and unbuttoning a shirt and threading a needle. Initially, it is observed at the corners of the mouth. At rest it can be observed involving the eyelids and when the arms/hands are extended. It is aggravated by stress, fatigue, and chronic alcohol consumption (ethilism). Should exposure and absorption continue, tremor will become coarse, with tonic-clonic spasms, at times so violent as to drive the patient off the bed during sleep. (References 9.16, 9.17, 9.18, 9.19, and 9.20)

Asynergies, diadochokinesis, and nystagmus (cerebellar symptoms) will then appear. In most protracted and severe cases of intoxication, neurological symptoms may mimic Parkinson's-like rigidity and involuntary myoclonic and choreic movements.

Measures of neuropsychological function that assess cognitive, visual and motor skills such as the "Grooved pegboard test" have been reported to be informative in experimental settings. Grooved pegboard is a visuomotor task that also requires manual dexterity. Although this is not a direct measure of tremor, the score to completion of the task is slowed by the presence of a tremor.

10.2.4 Psychological Changes (References 9.16, 9.19, 9.20)

The most characteristic symptoms of mercury toxicity are the psychological alterations known as "erethism", featuring mood changes, a switch from extroversion to neuroticism and shyness, depression, irritability, emotional instability, anxiety, insomnia, and hypochondriac concerns. "Erethism" is described more as an idiosyncratic reaction to mercury exposure rather than a dose related symptom complex. Memory and concentration deficit will ensue only at a later time, should exposure and absorption continue. Numerous studies have been conducted in an attempt to correlate urine mercury levels with neuropsychological effects and findings have been inconsistent as to the ability to discern individual discrete cases.

10.3 REPRODUCTIVE EFFECTS

See Section 4.3.

B. OSHA PEL for Mercury –OSHA's September 3, 1996 memo on the proper PEL for mercury.

U.S. Department of Labor
Occupational Safety & Health Administration

Standard Interpretations
09/03/1996 - PEL for inorganic mercury is a time weighted average, not a ceiling.

OSHA requirements are set by statute, standards and regulations. Our interpretation letters explain these requirements and how they apply to particular circumstances, but they cannot create additional employer obligations. This letter constitutes OSHA's interpretation of the requirements discussed. Note that our enforcement guidance may be affected by changes to OSHA rules. Also, from time to time we update our guidance in response to new information. To keep apprised of such developments, you can consult OSHA's website at http://www.osha.gov.

September 3, 1996

MEMORANDUM FOR:	REGIONAL ADMINISTRATORS STATE DESIGNEES
FROM:	JOHN B MILES, JR., DIRECTOR DIRECTORATE OF COMPLIANCE PROGRAMS
SUBJECT:	PEL for Inorganic Mercury

The purpose of this memorandum is to address the permissible exposure limit (PEL) for mercury. As you may know, Table Z-2 of 29 CFR 1910.1000 incorrectly lists the inorganic mercury PEL as a ceiling value of 1 mg/10m^3 (0.1 mg/m^3). It has come to our attention that compliance officers may be citing workplace mercury exposure as a ceiling PEL rather than as an 8-hour time weighted average (TWA).

While this error has not been corrected in Table Z-2 of 29 CFR 1910.1000, OSHA originally issued a correction notice in the old Field Operations Manual. Enclosed for your use and information is a letter of interpretation and a copy of the October 30th, 1978 mercury directive CPL 2.2.6 (formerly OSHA Program Directive #300-2) which provides documentation for the 8-hour TWA mercury PEL as opposed to a ceiling value.

Please assure that all field personnel receive a copy of this memorandum and when a mercury overexposure is cited, it is cited as an 8-hour TWA PEL. If you have any questions please contact the Office of Health Compliance Assistance at (202) 219-8036.

C. CHECKLIST

This check list is designed to emphasize major topics for someone who has already read and understood the pamphlet. Taking recommendations from this list without understanding related topics can lead to inappropriate conclusions.

Place a check mark (**T**) in the appropriate box below:

Yes	No	N/A	
__	__	__	1. Does the facility have a medical surveillance program for employees who have the potential for exposure to mercury ? {Section 5}
__	__	__	2. In concert with a physician, does the facility conduct a medical intervention assessment for employees with symptoms of exposure to mercury or elevated BEIs? {Section 5.3}
__	__	__	3. Does the facility's medical surveillance program and medical intervention assessment cover contract employees using the same criteria as for company employees? {Section 5.4}
__	__	__	4. Does the facility have a program in place (including appropriate monitoring) to assess which individuals may have a significant risk of exposure to mercury {Section 6.2}
__	__	__	5. Does the facility utilize a biological monitoring program to characterize individual exposures to mercury {Section 6.3}
__	__	__	6. Does the facility have appropriate engineering and maintenance controls to minimize exposure to mercury? {Section 7.1}
__	__	__	7. Does the facility have appropriate programs in place to insure that the employees are wearing the appropriate PPE when performing tasks that have the potential for exposure to mercury? {Section 7.2}
__	__	__	8. Does the facility have appropriate programs in place to insure that the employees are wearing the appropriate PPE when performing tasks that have the potential for exposure to mercury? {Section 7.2}
__	__	__	9. Does the facility have appropriate hygiene facilities and practices in place to minimize exposure to mercury? {Section 7.3}
__	__	__	10. Does the facility have appropriate programs in place to train employee to understand the hazards of mercury and the precautionary measures that they must follow to protect themselves, their coworkers, and their families {Section 8}

THE CHLORINE INSTITUTE, INC. ◗ *since 1924* ◗ A LEGACY OF SAFETY STEWARDSHIP

THE CHLORINE INSTITUTE, INC.

A RESPONSIBLE CARE® PARTNER ASSOCIATION

1300 Wilson Boulevard ◗ Arlington, VA 22209 ◗ Telephone: (703) 741-5760 ◗
Fax: (703) 741-6068 ◗ Email: pubs@CL2.com ◗ Website: www.CL2.com