ISBN 978-983-2014-74-4
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GARIS PANDUAN TENTANG PENGURUSAN MERKURI DALAM INDUSTRI MINYAK DAN GAS
GUIDELINES ON MERCURY MANAGEMENT IN OIL AND GAS INDUSTRY
2011

Jabatan Keselamatan dan Kesihatan Pekerjaan
Kementerian Sumber Manusia, Malaysia.

Department of Occupational Safety and Health
Ministry of Human Resources, Malaysia.

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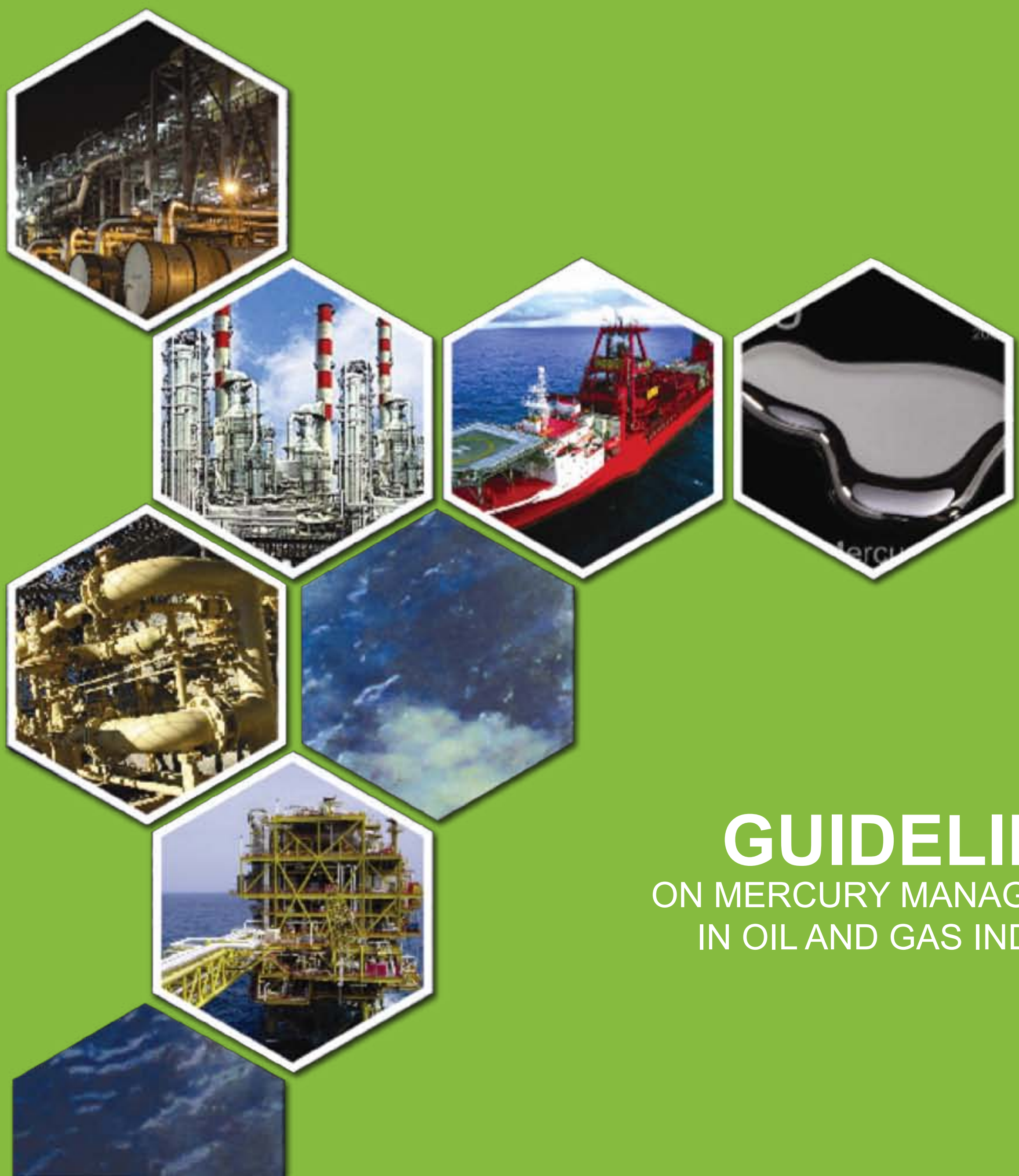


GUIDELINES
ON MERCURY MANAGEMENT
IN OIL AND GAS INDUSTRY

Preface

This Guidelines are cited as the **Guidelines on Mercury Management in Oil & Gas Industry**.

The Guidelines provides information and recommendations on how to manage mercury in the Oil & Gas industry in compliance with the Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000.

Employers are also required to read these guidelines in conjunction with the **Occupational Safety and Health (Use and Standard of Exposure of Chemicals Hazardous to Health) Regulations 2000** so that it will help them in fulfilling the relevant requirements in a comprehensive and integrated approach.

Employers and employees must understand the rationale for and the importance of managing mercury risk in their workplaces, as this will minimize, if not eliminate the associated occupational illnesses due to mercury.

These guidelines will be reviewed from time to time. Oil and gas industry, assessors, hygiene technicians, occupational health doctors, employers, employees and others concerned are invited to give their comments in writing or e-mail to the Department of Occupational Safety and Health, so that these guidelines will be continuously improved thus making the maximum contribution to mercury management in the industry, with increasing organisational productivity and health of the working population.

I would like to thank and acknowledge those who have assisted in the development of the guideline.

Director General
Department of Occupational Safety and Health
Ministry of Human Resources, Malaysia
2011

Acknowledgment

The Department of Occupational Safety and Health, Malaysia wishes to thank and acknowledge the following individuals and their respective organisations for their contributions towards the preparation of this Guidelines:

NO.	NAME	ORGANISATION
1	Ir. Hj. Saiful Azhar bin Mohd Said	Director, Policy and Research Division, Department of Occupational Safety & Health (DOSH)
2	Rashid Muhamad - Chairman	Senior General Manager, Plant Operation Division, PETRONAS Gas Berhad
3	Norhazlina Mydin - Secretary	Industrial Hygienist, Group HSE Division, PETRONAS
4	En. Husdin Bin Che Amat	Director, Industrial Hygiene and Ergonomic Division, Department of Occupational Safety & Health (DOSH)
5	Dr. Jaseema Begum Nazir Khan	Deputy Director, Occupational Health Division, Department of Occupational Safety & Health (DOSH)
6	Ishkandar Bin Md Yusoff	Deputy Director, Industrial Hygiene and Ergonomic Division, Department of Occupational Safety & Health (DOSH)
7	Fairus Iskandar b. Ishak	Assistant Director, Policy and Research Division, Department of Occupational Safety & Health (DOSH)
8	Prof. Dr. Salmaan H. Inayat Hussain	Dean, Faculty of Health Sciences, Universiti Kebangsaan Malaysia (UKM)
9	Dr. Norsayani M. Yaakob	Health Advisor, PETRONAS Carigali Sdn. Bhd.
10	Marina Zainal Farid	Industrial Hygienist, PETRONAS Carigali Sdn. Bhd.
11	Zulfikar bin Said	Industrial Hygienist, PETRONAS Gas Berhad
12	Ariffin b Abd Rahman	Safety & Health Officer, PETRONAS Gas Berhad
13	Rina Adrinas Bt Azizdin	OH/IH Executive, Petroleum Management Unit (PMU), PETRONAS
14	Thirumila Muthukamaru	Industrial Hygienist, BASF PETRONAS Chemicals Sdn. Bhd.
15	Dr. Abu Hassan Samad	Medical Advisor & Country OH Manager, ExxonMobil Subsidiaries in Malaysia/ President, Academy of Occupational and Environmental Medicine Malaysia (AOEMM)
16	Zainal Mubarik Zainuddin	Regional Industrial Hygiene Advisor, ExxonMobil Exploration and Production Malaysia Inc./Malaysian Industrial Hygiene Association (MIHA)
17	Norhamimi Mohd Yusof	Industrial Hygienist, ExxonMobil Exploration and Production Malaysia Inc.
18	Wan Sabrina Wan Mohamad, CIH	Lead Industrial Hygienist, Shell Malaysia Trading Sdn. Bhd.
19	Zulkarnain Mohd Said	Head, Operation HSE, Shell Refining Company
20	Hazizul Azlin Razali	Industrial Hygienist, Shell Sarawak
21	Kama Mohd Lokman Karim	HSE Engineer, Talisman Malaysia Limited
22	Saabi Bin Wahab	HSE Specialist, Lundin Malaysia B V
23	Daryl Low Yong Leong	Division Manager, 3M Occupational Health & Environmental Safety Division/ Malaysian Industrial Hygiene Association

Guidelines on Mercury Management in Oil & Gas Industry 2011

Glossary

Area Monitoring Measurement of release of chemical in a specific work area

Artificial respiration The act of assisting or stimulating respiration, a metabolic process referring to the overall exchange of gases in the body by pulmonary ventilation, external respiration, and internal respiration. Assistance takes many forms, but generally entails providing air for a person who is not breathing or is not making sufficient respiratory effort on their own

Bag-valve-mask device A hand-held device used to provide positive pressure ventilation to a patient who is not breathing or who is breathing inadequately. The device is a normal part of a resuscitation kit for trained professionals, such as ambulance crew. The device is self-filling with air, although additional oxygen (O_2) can be added

Bio-accumulation Progressive increase in the amount of a substance in an organism or part of an organism which occurs because the rate of intake exceeds the organism's ability to remove the substance from the body

Biological Exposure Index (BEI) Guidance values for assessing biological monitoring results. It indicates a concentration below which nearly all workers should not experience adverse health effects from exposure to a particular substance

Biological Monitoring Biological monitoring is the systematic collection and analysis of a biological specimen for the presence of an indicator of exposure or response in the worker

Biomarker Indicator signaling an event or condition in a biological system or sample and giving a measure of exposure, effect, or susceptibility

Emergency An unplanned adverse situation or incident that has an impact on operations, personnel, image, environment and property

Exothermic A process or reaction that releases energy from the system, usually in the form of heat, but also in the form of light (e.g. a spark, flame, or explosion), electricity (e.g. a battery), or sound (e.g. burning hydrogen)

Half-life ($t_{1/2}$) The time it takes for half the original amount of a substance to disappear. In the human body, the half-life is the time it takes for half the original amount of the substance to disappear, either by being changed to another substance or by leaving the body

HazMat Hazardous materials; are solids, liquids, or gases that can harm people, other living organisms, property, or the environment and often subject to chemical regulations. Hazardous materials include materials that are radioactive, flammable, explosive, corrosive, oxidizing, asphyxiating, biohazard, toxic, pathogenic, or allergenic. Also included are physical conditions such as compressed gases and liquids or hot materials, including all goods containing such materials or chemicals, or may have other characteristics that render them hazardous in specific circumstances

Hazardous waste Any gaseous, liquid or solid waste, which because of its quantity, physical, chemical or infectious characteristics can result in

	hazards to human health or the environment
Health surveillance	Any examination and investigations which may be necessary to detect exposure levels and early biological effects and responses, and includes biological monitoring, biological effect monitoring, medical surveillance, enquiries about symptoms of occupational poisoning or occupational disease and review of records and occupational history
LNG	Liquefied natural gas or LNG is natural gas (predominantly methane, CH_4) that has been converted temporarily to liquid form for ease of storage or transport
Medical surveillance	The monitoring of a person for the purpose of identifying changes in health status due to occupational exposure to chemicals hazardous to health
Mercury decontamination	Process of removing or neutralizing mercury contaminants that have accumulated on equipment, tools and personnel
Occupational health doctor	A medical practitioner who is registered with the Director General to conduct medical surveillance programmes of employees
ppb	One part per billion (ppb) denotes one part per 1,000,000,000 parts or one part in 10^9
Permissible exposure limit (PEL)	A legal limit specifying the concentration of a chemical in air which an employee can be exposed to
Personal exposure monitoring	A sample collected in the breathing zone of an employee by means of a sampling device directly attached to the employee and worn continuously during working hour
Personal protective equipment	Any equipment which is intended to be worn or held by a person at work and which protects him against one or more risks to his health or safety and any additional accessory designed to meet that objective
Short-Term Exposure Limit (STEL)	The 15-minute exposure standard. Applies to any 15- minute period in the working day and is designed to protect the worker against adverse effects of irritation, chronic or irreversible tissue change, or narcosis that may increase the likelihood of accidents
Speciation	Analytical activities of identifying and (or) measuring the quantities of one or more individual chemical species in a sample
Stream Sampling	Measurement of potential mercury content in a process stream
Time-Weighted Average (TWA)	Represent a work shift of 8 hours over one day. This means that the value assigned for a TWA should not be exceeded over the period of 8 hours during a working shift
$\mu g/m^3$	Micro gram per meter cubed

Contents

Guidelines on Mercury Management in Oil & Gas Industry 2011

Chapter 1 - Introduction

1.1 Purpose

The Guidelines provide information on how to manage mercury exposure in the Oil & Gas industry in compliance with the Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000 (USECHH).

Regulation 14 (1) in USECHH stipulates the duty of an employer to take actions required to eliminate or reduce the actual or potential exposure of an employee to chemicals hazardous to health. These include the presence of mercury where changes to work processes, practices, procedures, plant or engineering control equipment is necessary to reduce workers' exposure so far as is reasonably practicable.

Hence, the objective of this Guideline is to set recommended standard for good technical practice to be applied by oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities, or any other such facility, where mercury poses risk.

1.2 Applications & Scope

This Guideline applies to all activities including normal operations and shutdown/turnaround conducted in Oil & Gas industry in Malaysia, not limited to:

a. Offshore facilities such as platform, floating storage and offloading (FSO), floating production, storage and offloading (FPSO), and/or drilling rigs etc.
b. Onshore facilities such as oil & gas terminals, gas processing plants, refineries, petrochemicals, transmission and distribution pipelines etc.

This Guideline may also be referred for planning purposes in setting up adequate Mercury Management Program for new installations or projects. The health risk management outlines in this Guideline addresses concerns associated with elemental mercury since most of mercury exposure in Oil & Gas industry in Malaysia relates to elemental mercury. Should facilities deal with other species of mercury, it is recommended for them to review the mercury management approach.

This Guideline:

a. Provides an overview of mercury and its scenario in the Oil & Gas industry in Malaysia – Chapter 2
b. Describes the health effects arising from exposure to mercury – Chapter 2
c. Describes a mechanism to conduct mercury health risk assessment – Chapter 3
d. Outlines the types and methodology of mercury exposure monitoring – Chapter 4
e. Specifies the methodology to establish health surveillance programs – Chapter 5
f. Specifies appropriate control measures in mercury handling – Chapter 6
g. Provides practical guidance in carrying out mercury decontamination – Chapter 7
h. Outlines the approach to manage mercury-contaminated waste – Chapter 8
i. Sets the important considerations to address emergency related to mercury – Chapter 9
j. Recommends the appropriate type of personal protective equipment (PPE) to be used when handling mercury – Chapter 10
k. Summarises relevant records/documents related to mercury required to be kept and their associated retention time – Chapter 11

Chapter 2 - Mercury & Its Effects

2.1 Background

Mercury is a naturally-occurring metal, traces of which occur in rocks of the earth's crust. The uncharged metallic or elemental mercury (Hg^0), readily vaporizes from its liquid state, and is the most common form of mercury in the atmosphere. Limited amounts of elemental mercury may be found in soils and water. In soils and surface waters, it is in mercuric (Hg^{++} - with a double positive electrical charge) and mercurous (Hg^+ - with a single positive charge) states, as ions with varying solubility. Mercuric chloride, a simple salt, is the predominant form in many surface waters.

Inorganic mercury can be methylated by microorganisms native to soils, sediments, fresh water, and salt water, to form organic mercury. Almost all of the mercury found in animal tissues is in the form of methyl mercury[1].

In 1497 Corradinus Gilinus first used mercury in the treatment of syphilis[2]. Mercury in the form of metallic mercury and mercury(I)chloride (Hg_2Cl_2) remained the main form of treatment till the early 20th century when an arsenic containing drug, Salvarsan, was developed. Until the 1970s, methylmercury and ethylmercury compounds were used to protect seed grains from fungal infections and up until 1991, phenylmercuric compounds were used as antifungal agents in both interior and exterior paints[3]. Thimerosal or thiomersal is an organomercury compound $C_9H_9HgNaO_2S$ acting as an antiseptic and antifungal agent that was removed from U.S. childhood vaccines, starting in 1999[4].

Mercury undergoes recycling as per Figure 1.

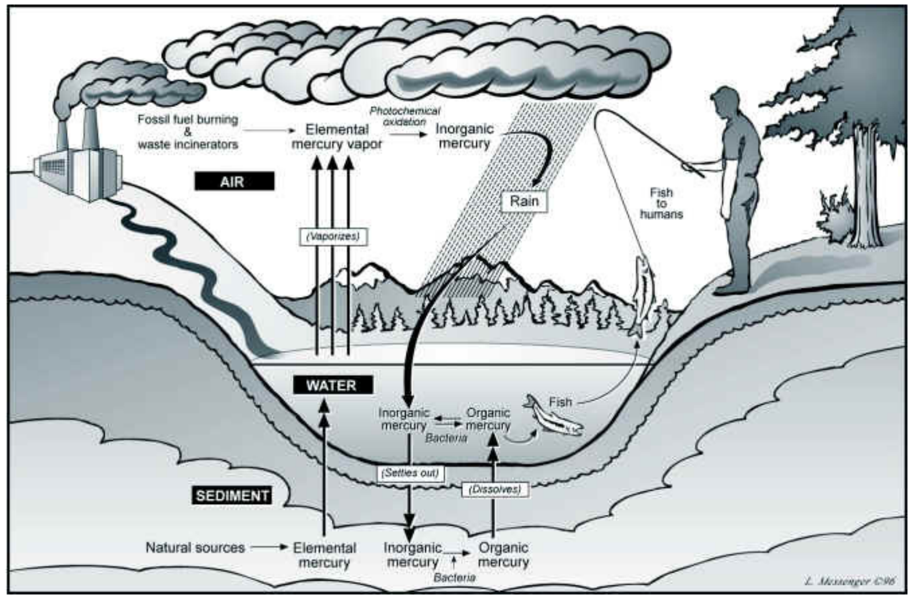


Figure 1 Environmental Mercury Cycle[5]

2.2 Sources of Mercury

Mercury is one of the natural elements that make up our solar system. Sources of mercury are both naturally occurring and manmade, either within the occupational or non-occupational setting as per table below.

Table 1 Sources of Mercury

Natural Occurring	Occupational	Non-Occupational
• Volcanoes • Rocks e.g. granite • Soil & sediment • Seawater / freshwater • Cinnabar - HgS	• Gold mining • Metal Smelting • Cement Making • Petrochemicals • Incineration of batteries and mercury containing paints • Coal Plants	• Seafood • Thermometers • Fluorescent Light Bulbs • Dental Fillings: silver amalgam 50-60%Hg • Skin Care Products (Lightening creams/soaps) • Medicinal Products

2.3 Physical Properties of Mercury

Table 2 and 3 show the physical properties of elemental mercury and solubility and volatilities of various mercury compounds respectively.

Table 2 Physical Properties of Elemental Mercury[6]

Atomic number	80
Atomic weight	200.59 atomic mass units
Boiling point	357 C (675 F)
Boiling point/rise in pressure	0.0746 ^{0}C/torr
Density	13.546 g/cm^3 at 20 C (0.489 lb/in^3 at 68 F)
Diffusivity (in air)	0.112 cm^2/sec
Heat capacity	0.0332 cal/g at 20 C (0.060 Btu/lb at 68 F)
Henry's law constant	0.0114 atm m^2/mol
Interfacial tension (Hg/H_2O)	375 dyne/cm at 20 C (68 F)
Melting point	-38.87 C (-37.97 F)
Saturation vapor pressure	0.16 N/m^3 (pascal) at 20 C (68 F)
Surface tension (in air)	436 dyne/cm at 20 C (68 F)
Vaporization rate (still air)	0.007 mg/cm^{2}hr for 10.5 cm^2 droplet at 20 C

Table 3 Solubility and Volatilities of Mercury Compounds[6]

Formula	State	Volatility	Hg Solubility in H_20; 25 C	Name
Hg^0	Liquid	Boiling Point 357 C Vapor Pressure 25 mg/m^3 (25 C)	50 ppb	Elemental
$HgCl_2$	Solid	Boiling Point 302 C	70 g/L	Mercuric chloride
$HgSO_4$	Solid	decomposes 300 C	0.03 g/L	Mercuric sulfate
HgO	Solid	decomposes 500 C	0.05 g/L	Mercuric oxide
HgS	Solid	Sublimes under vacuum, decomposes 560 C	- log Ksp$^{(1)}$ = 52	Mercuric sulfide
HgSe	Solid	Sublimes under vacuum, decomposes 800 C	- log Ksp ~ 100	Mercuric selenide
$(CH_3)_2Hg$	Liquid	Boiling Point 96 C	< 1 ppm	Dimethylmercury
$(C_2H_5)_2Hg$	Liquid	Boiling Point 170 C	< 1 ppm	Diethylmercury

(1) Ksp = solubility product

2.3.1 Types of Mercury

Mercury is categorized into Elemental, Inorganic and Organic Mercury. The table below illustrates the different mercury compounds for both categories.

Table 4Types of Inorganic and Organic Mercury

Elemental		Inorganic Mercury		Organic Mercury	
Elemental Mercury	Hg^0	Mercury sulphide	HgS	Ethyl Mercury	$C_2H_5Hg^+$
		Mercury sulfate	$HgSO_4$	Methyl Mercury	$(CH_3Hg)^+$
		Mercury Oxide	HgO	Diethyl Mercury	$(C_2H_5)_2Hg$
		Mercury selenide	HgSe	Dimethyl Mercury	$(CH_3)_2Hg$
		Mercury Iodide	HgI_2	Dibutyl Mercury	$(n\text{-}C_4H_9)_2Hg$
		Mercury chloride	$HgCl_2$	Dipropyl Mercury	$(n\text{-}C_3H_7)_2Hg$
		Ionic Mercury	Hg^{+2}, Hg^{+1}	Di-isopropyl Mercury	$(iso\text{-}C_3H_7)_2Hg$

2.3.2 Forms of Mercury in Oil & Gas Industry

The forms and examples of mercury and its associated compounds most commonly found in natural gas, condensate and crude oil are shown in Table 5.

Table 5 Mercury Compound in Oil & Gas Industry[6]

Crude/Condensate		Natural Gas
Form of Mercury	**Example**	**Form of Mercury**
Dissolved elemental mercury	Hg	Elemental Mercury
Dissolved organic mercury	RHgR or RHg-X where R = CH_3, C_2H_5 etc and X=Cl	
inorganic (ionic) mercury salts	$Hg^{2+}X$ or $Hg^{2+}X_2$, where X is an inorganic ion	
Complexed mercury	HgK or HgK_2	
Suspended mercury compounds	mercuric sulfide (HgS) and selenide (HgSe)	
Suspended adsorbed mercury	elemental and organic mercury that is not dissolved but rather adsorbed on inert particles such as sand or wax.	

2.4 Effects of Mercury

2.4.1 Health Effects

The health effects of mercury are dependent on the type of mercury exposed to and the uptake is via specific routes of entry for respective mercury types. The following table describes the percentage uptake via various routes of entry and corresponding exposure limits for the different types of mercury.

Table 6 Routes of entry and uptakes of mercury[7]

Mercury Form	Routes of Entry	PEL (mg/m^3)
Elemental	Inhaled – 80% Skin - ~3% Ingest – poor	0.025 Ceiling: 0.03
Organic (Alkyl)	Inhaled – 90% skin ~ 5% Ingest – 95%	0.01
Inorganic (Aryl)	Inhaled – 15% Skin – limited information Ingest – 20%	0.1

Note: A Ceiling of 0.03 mg/m^3 is recommended for elemental mercury by US Environmental Protection Agency

2.4.1.1 Acute

Short-term exposure to high concentrations of mercury vapour causes harmful effects on the nervous, digestive, respiratory and renal systems. Among the symptoms observed due to high concentration exposures to mercury are fatigue, fever and chills. Exposures to mercury can also adversely affect the respiratory system and cause to develop symptoms such as cough, shortness of breath, tightness and burning pains in the chest and inflammation of the lungs. Occupational exposure ranging from 1 to 44 mg/m^3 of mercury vapour for 4 to 8 hours has been seen to cause chest pain, cough, coughing up blood, impaired lung function and inflammation of the lungs. Deterioration of nerves in the arms and legs (polyneuropathy) has been reported in employees with high exposures. Reduced sensation and strength in the arms and legs, muscle cramps and decreased nerve conduction have also been observed.

2.4.1.2 Chronic

Long term exposures of mercury mainly show its effects on the nervous system. This can be seen through muscle incoordination, alteration in mood, behaviour, memory, feeling and decreased nerve conduction. The nervous system effects of mercury toxicity are sometimes referred to as "Mad Hatter's Disease" since mercurous nitrate was used in making felt hats. Tremor is regarded as an indicator of long term, low level exposures. It is a common sign of mercury toxicity, usually of the fingers, hands or arms and occasionally the eyelids, lips, tongue, and whole body.

A summary of mercury toxicological features for various forms of mercury is provided in Table 7.

Table 7 The major clinical toxicological features of mercury[8]

VARIABLE	MERCURY VAPOR	INORGANIC DIVALENT MERCURY	METHYL MERCURY	ETHYL MERCURY
Route of exposure	Inhalation	Oral	Oral (from fish consumption)	Parenteral (through vaccines)
Target organ	Central nervous system, peripheral nervous system, kidney	Kidney	Central nervous system	Central nervous system, kidney
Local clinical signs				
• **Lungs**	Bronchial irritation, pneumonitis (>1000 µg/m³ of air)			
• **Gastrointestinal tract**	Metallic taste, stomatitis, gingivitis, increased salivation (>1000 µg/m³ of air)	Metallic taste, stomatitis, gastroenteritis		
• **Skin**		Urticaria, vesication		
Systemic clinical signs				
• **Kidney**	Proteinuria (>500 µg/m³ of air)	Proteinuria, tubular necrosis		Tubular necrosis
• **Peripheral nervous system**	Peripheral neuropathy (>500 µg/m³ of air)	Acrodynia		Acrodynia
• **Central nervous system**	Erethism (>500 µg/m³ of air), tremor		Paresthesia, ataxia, visual and hearing loss (>200 µg/liter of blood)	Paresthesia, ataxia, visual and hearing loss
Approximate half life (whole body) (days)	60	40	70	20

2.4.2 Effects to Machinery

Mercury and its compounds have a negative effect on process equipment and efficiency of catalyst. Mercury forms amalgams with a variety of metals, including aluminum, copper, brass, zinc, chromium, iron, and nickel causing liquid metal embrittlement (LME), a rare instantaneous phenomenon. It is a complex metal fracture mechanism that occurs without warning.

When these amalgams form with metal components of processing equipment, corrosion of the equipment results, because either the amalgams are weaker than the mercury-free metal[9,10], or, as is the case with the aluminum amalgam, the amalgam reacts with moisture to form a metal oxide plus free mercury, which then can continue the corrosion process[11]. Specific examples include corrosion of aluminum in cryogenic heat exchangers, gates and stems of wellhead valves.

Such mercury-induced corrosion of aluminum heat exchangers resulted in catastrophic failure of exchangers at the Skikda LNG plant in Algeria[12]. Also, mercury

and its compound can speciate and bond with various anions causing the effect on catalyst efficiency.

Another incident on January 1st 2004 at the Santos Moomba facility in Australia was related to a mercury leak in the Liquids Recovery Plant (LRP). It created a large vapor cloud that ultimately ignited and exploded. It is understood that, the Moomba incident is the first known occurrence of a gas release and fire due to LME causing a 'faulty inlet nozzle' leading to the explosion.

The mercury concentration in crude oil varies from approximately <1 wppb to >500 wppb, with levels above 100 ppb being potentially problematic for refineries[13]. In the case of separation process for gas products, typically cryogenic, provides the opportunity for condensation (precipitation) of elemental mercury, if the concentration is sufficiently high to allow this to occur. Such condensation is reported for gas separation plants having mercury in feeds in excess of approximately 10-20 µg/m^3 [4,5].

Hence, for optimum production and process integrity, it is crucial to determine the content of mercury to ensure its effects are controlled via design.

2.4.3 Effects to Environment[3]

Most of the mercury found in the environment is in the form of metallic mercury and inorganic mercury compounds. Metallic and inorganic mercury enters the air from mining deposits of ores that contain mercury, from the emissions of coal-fired power plants, from burning municipal and medical waste, from cement kilns (where limestone used to make cement containing mercury), and from uncontrolled releases in factories that use mercury.

Metallic mercury is a liquid at room temperature, but some of the metal will evaporate into the air and can be carried long distances. In air, the mercury vapor can be changed into other forms of mercury, and can be further transported to water or soil in rain. Inorganic mercury may also enter water or soil from the weathering of rocks that contain mercury, from factories or water treatment facilities that release water contaminated with mercury, and from incineration of municipal garbage that contains mercury (for example, in thermometers, electrical switches, fluorescent light bulbs, or batteries that have been thrown away). Inorganic or organic compounds of mercury may be released to the water or soil if mercury-containing fungicides are used.

Microorganisms (bacteria, phytoplankton in the ocean, and fungi) convert inorganic mercury to methylmercury. Methylmercury released from microorganisms can enter the water or soil and remain there for a long time, particularly if the methylmercury becomes attached to small particles in the soil or water. Mercury usually stays on the surface of sediments or soil and does not move through the soil to underground water. If mercury enters the water in any form, it is likely to settle to the bottom where it can remain for a long time.

Mercury can enter and accumulate in the food chain. The form of mercury that accumulates in the food chain is methylmercury. Generally, larger fish eat smaller fish or other organisms that contain methylmercury resulting in larger and older fish living in contaminated waters having build-up and the highest amounts of methylmercury in their bodies. Saltwater fish (e.g. short body mackerel, long tail tuna and swordfish) that live a long time and can grow to a very large size tend to have the highest levels of mercury in their bodies. Plants (such as corn, wheat, and peas) have very low levels of mercury, even if grown in soils containing mercury. Mushrooms, however, can accumulate high levels of mercury if grown in contaminated soils.

Guidelines on Mercury Management in Oil & Gas Industry 2011

Chapter 3 - Mercury Health Risk Management

3.1 Introduction

As with any other health risk management protocol, mercury health risk should be managed through four important steps:

- Identify – identification of the presence and use of mercury, workers potentially exposed to mercury, and processes or equipment susceptible to mercury in a facility
- Assess – assessment of mercury health risk
- Control – implementation of control measures to minimize mercury exposure to so far as is reasonably practicable based on the outcome of the assessment
- Recover – implementation of recovery measures should workers be exposed to mercury

3.2 Identification of mercury, critical equipment and potentially exposed workers

As the first step to risk management, an oil and gas facility shall identify the following:

3.2.1 Sources of mercury

<u>Mercury content in crude oil, condensate or natural gas</u>

Typically the mercury in crude oil, condensate or natural gas is the primary source of mercury in a facility. Mercury content provides critical information required to trigger and decide the extent of mercury risk management plan. In order to better assess the risk, data such as total mercury concentration is needed. The typical mercury species in the oil and gas industry is described in Chapter 2.3.2.

Stream sampling is the first step in conducting mercury identification. Mercury concentrations in crude oil can range from <1 wppb to >500 wppb, depending on its origin. Crude within the same region may not have similar mercury contents. Oil fields, which are hundreds of kilometers apart, may have significantly different mercury contents. Thus it is important to determine the potential mercury content by conducting mercury testing of the incoming crude, associated condensates and natural gas.

Stream sampling protocol is described in Chapter 4.1.1.

Since stream sampling and mercury speciation requires extensive resources, various level of speciation is proposed depending on the mercury content in crude oil/natural gas as per Table 8.

Table 8 Recommendation for Mercury Speciation[14]

Total mercury content in crude oil/ natural gas	Extent of speciation proposed
• Less than 5 ppb liquid (<5 µg/m^3 gas)	• Speciation of mercury compounds is not required given the analytical uncertainties
• Between 5 and 100 ppb liquid (5-50 µg /m^3 gas)	• Limited operational speciation of mercury to determine the % of elemental mercury in the measured total concentration
• Greater than 100 ppb liquid (>50 µg /m^3 gas)	• Detailed speciation of mercury compounds are recommended

Other sources of mercury

Other usage of mercury during work (e.g. use of mercury chloride for wastewater analysis, maintenance work dealing with thermometer containing liquid mercury etc.) should also be recorded.

3.2.2 Identification of process equipment

As described in Chapter 2.4.2, it is important to identify process equipment and process conditions such as significant change in temperature and pressure that could potentially cause mercury to amalgamate with equipment leading to liquid metal embrittlement (LME), corrosion and process failure. Examples are processes such as cryogenic aluminium heat exchangers, separation processes, overhead fin-fans, cold boxes, coalescers and compressors where amalgamation and accumulation of mercury is possible.

3.2.3 Identification of similar exposed groups

Workers who will be involved in activities where mercury is potentially present and their associated tasks shall be identified. These include turnaround contractors working during mercury removal unit catalyst changeout, cryogenic technicians, mercury decontamination contractors, laboratory technicians, process operators, mercury waste contractors etc.

3.3 Assessment of mercury health risk

Assessing potential health risk to workers is a reasonably straightforward exercise if relevant data and information is available to make sound judgment. The concept of mercury health risk assessment (HRA) is similar to the Chemical Health Risk Assessment (CHRA)[15], where risk is a function of hazard and exposure.

Mercury hazard is thoroughly described in Chapter 2. Mercury exposure to similar exposure groups is dependent on:

- Frequency and duration of tasks involving mercury

- Nature of work (e.g. routes of entry, distance between source and workers, inhalation rate based on work intensity)
- Existing control measures, based on the hierarchy of controls (i.e. from elimination to PPE)

Qualitatively, the above information shall be obtained through observation, documents review, site visit and personnel interview and recorded as part of the assessment.

Information on mercury concentration in stream and potential mercury exposure would determine the levels of mercury risk to subjected workers. The flowchart showing the mercury health risk management is as follows:

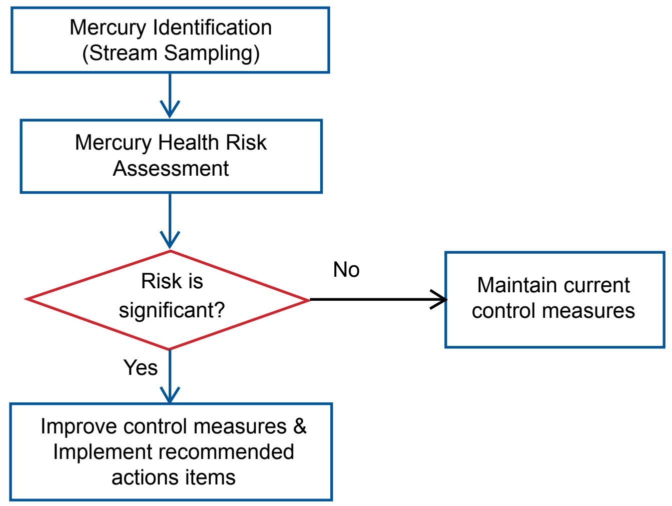


Figure 2 Mercury Health Risk Management

3.4 Controlling mercury health risk

If the mercury health risk assessment concludes that the risk is significant to the workers, new or improvement on the existing control measures is required to further reduce the risk to so far as is reasonably practicable.

Chapter 6 describes the possible control options for mercury risk management based on the hierarchy of controls and Chapter 10 specifically outlines the PPE for mercury.

Besides strengthening the control measures, quantitatively, mercury health risk should be further assessed through workplace exposure monitoring and health surveillance programs, as per the methodology outlined in Chapter 4 and 5 respectively. The requirement for workplace exposure monitoring and health surveillance for routine and non-routine exposures is further explained in Chapter 3.6 and 3.7. The main difference between the two categories is the sequence and requirements for health surveillance.

3.5 Recovery measures for mercury exposure

Should the workers be exposed to mercury, relevant recovery measures should be activated. The recovery measures should be incorporated as part of the mercury management plan to ensure the workers' exposure is controlled to so far as is reasonably practicable. Chapter 7 outlines the scope of mercury decontamination and proposed methodology. Decontamination is the process of removing or neutralizing mercury contaminants that have accumulated on personnel, tools and equipment. Chapter 9 recommends the specific emergency preparedness plan for mercury, and it is to be incorporated in the site existing emergency response plan.

3.6 Mercury risk management for routine exposure

3.6.1 Routine exposure

Routine exposure is defined as the situation where the workers are exposed regularly to mercury. The employer should determine whether their workers are regularly involved in activities that may expose them to significant mercury risk and shall follow the steps provided in Figure 3.

Examples of routine exposure:

- Daily or weekly laboratory sample collection and testing at mercury contaminated process lines
- Regular cleaning of mercury contaminated vessel by contractors (i.e. the same contractors performing tasks at various companies with mercury contaminated areas one after another)
- Perform routine checks
- Perform daily maintenance

Chapter 3

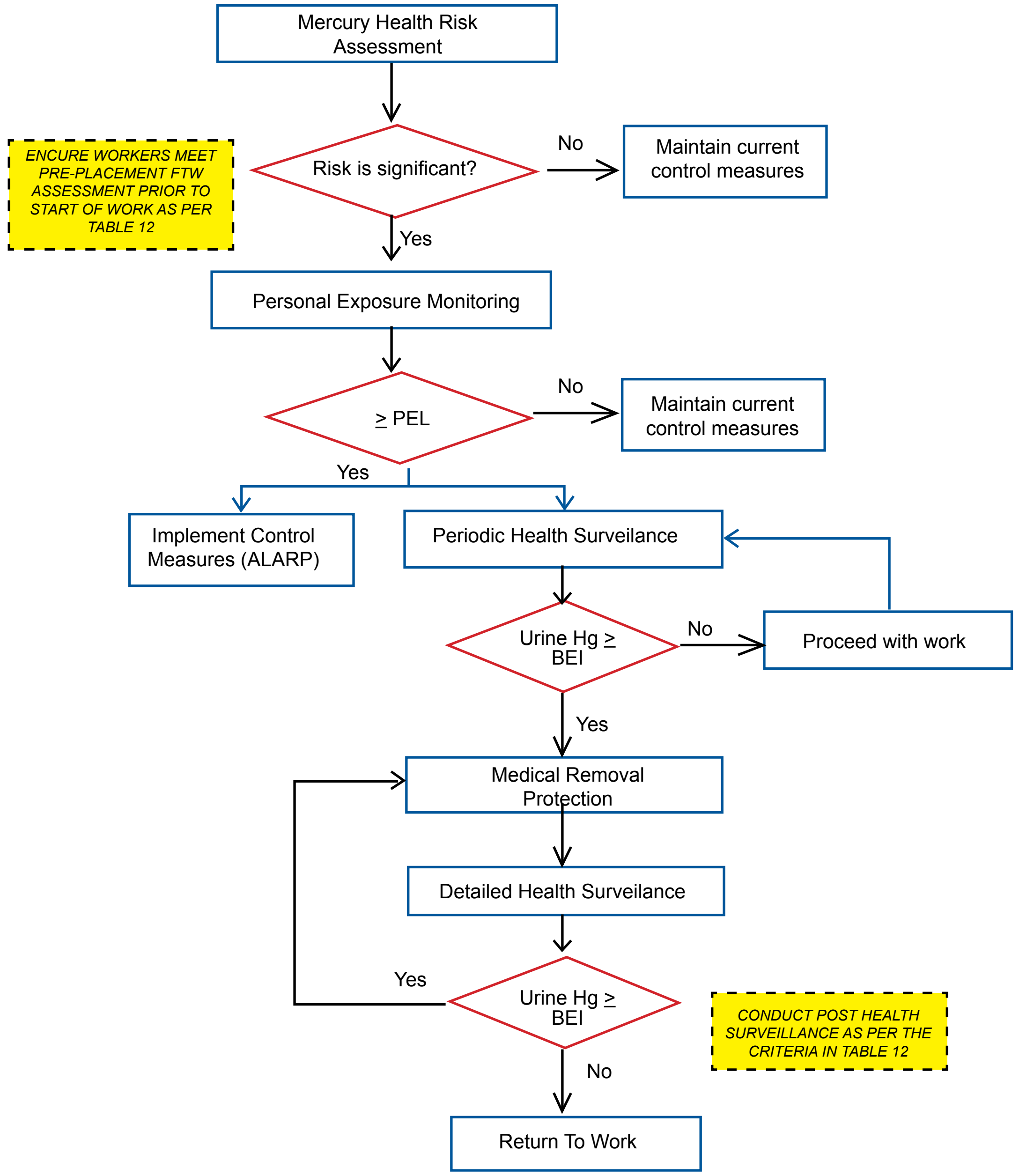


Figure 3 Mercury Risk Management for Routine Exposure

3.6.2 Requirement for fitness assessment

If the mercury risk assessment from Chapter 3.3 concludes that the risk is significant and further risk management steps are required, the workers who will be working in the area shall undergo Fitness to Work (FTW) health assessment.

The Fitness to Work health assessment shall be performed by an Occupational Health Doctor (OHD) who is registered with DOSH. This assessment shall determine if a worker is medically fit to work in an environment that has potential mercury exposure.

Workers that are deemed unfit are to be given restricted duty to avoid areas or tasks that pose potential mercury exposure. Only workers that are deemed medically fit shall be allowed to proceed with work (see Chapter 5 for details).

3.6.3 Requirement for exposure monitoring

Personal exposure monitoring shall be conducted based on the recommendations of CHRA. The results of the personal exposure monitoring will determine the estimated mercury exposure through inhalation during task performance.

If the personal exposure monitoring results indicate mercury concentration at or above the Permissible Exposure Limit (PEL) of 0.025 mg/m^3 (time weighted average (TWA) - 8 hours)[15], additional control measures shall be put in place to reduce exposure levels to below PEL based on so far as is reasonably practicable.

3.6.4 Requirement for health surveillance

If the personal exposure monitoring shows that the mercury level is at or above the PEL, Periodic Health Surveillance shall be performed by an OHD.

Periodic Health Surveillance shall determine mercury levels in urine.

- If the urine mercury levels are at or above the Biological Exposure Index (BEI) of 35 µg/g creatinine[16], the worker shall be placed under the Medical Removal Protection (MRP) programme to ensure that they are not further exposed to mercury. The workers may be temporarily assigned to other tasks without significant mercury risk.

- If the urine mercury levels are below the BEI, the worker shall be allowed to proceed with performing tasks.

Once under the Medical Removal Protection (MRP) programme, the workers shall undergo a detailed health surveillance assessment by an OHD. This assessment shall also include a repeat biological sampling on monthly interval.

- If the urine mercury levels are at or above the BEI, the worker shall continue to be placed under the Medical Removal Protection (MRP) programme.

- If the urine mercury levels are below the BEI, the worker shall be allowed to Return To Work (RTW) at areas with significant mercury risk and they should be placed under periodic health surveillance.

3.7 Mercury risk management for non-routine exposure

3.7.1 Non-routine exposure

Non-routine exposure is defined as the situation where the workers are exposed to intermittent levels of mercury. The employer should determine the nature of their workers exposure in activities that may expose them to significant mercury risk and shall follow the steps provided in Figure 4.

Examples of tasks include plant operator/technicians involving in turnaround/ shutdown activities, handling of a particular crude oil shipped in with high mercury content, spill clean-ups etc.

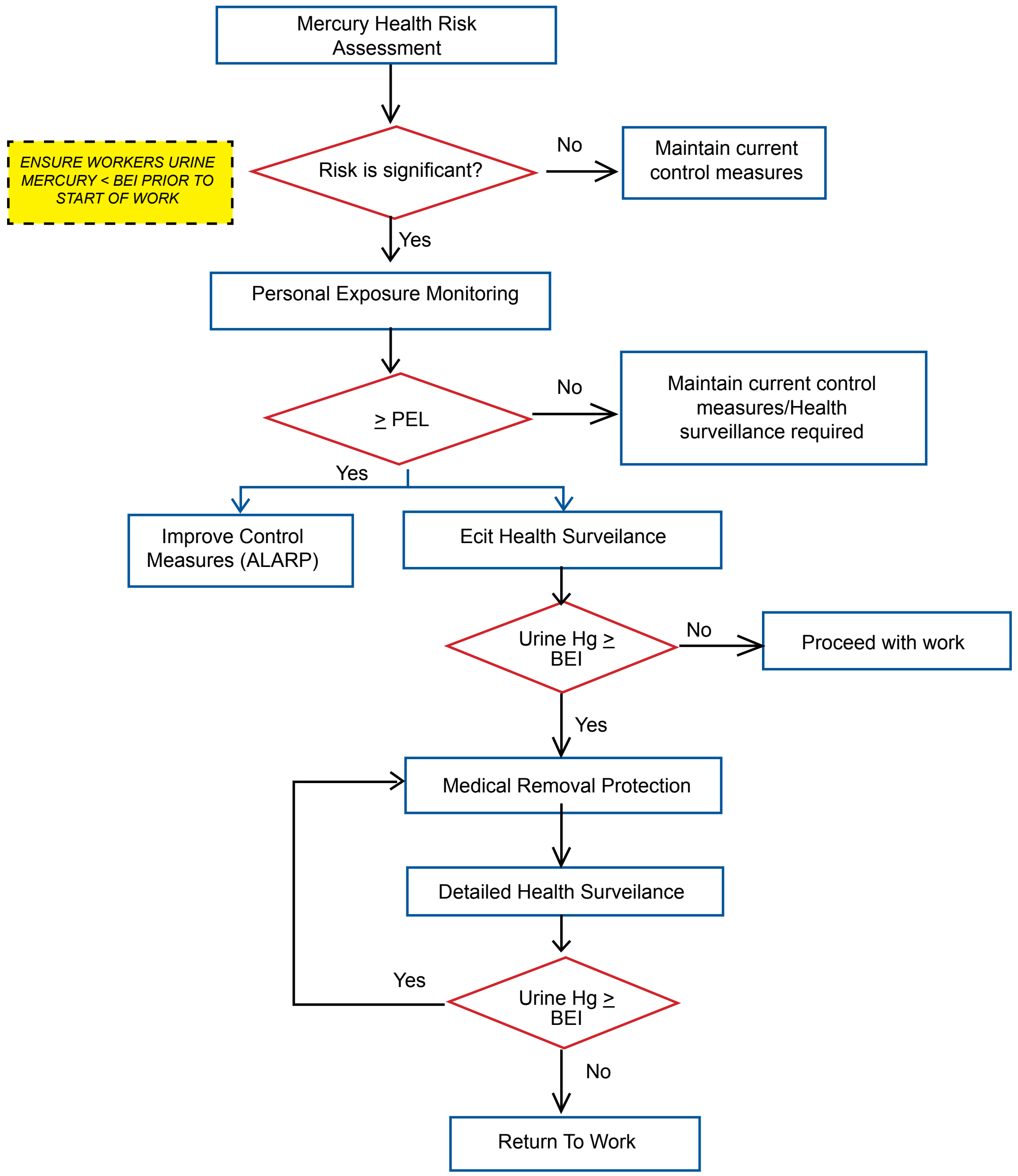


Figure 4 Mercury Risk Management for Non-routine Exposure

3.7.2 Requirement for fitness assessment

If the mercury risk assessment from Chapter 3.3 concludes that the risk is significant and further risk management steps are required, the workers who will be working in the area shall undergo Fitness to Work (FTW) health assessment.

For non-routine jobs, urine mercury monitoring is required. The employees are not allowed to proceed with the work if the urine mercury level is at or above the BEI of 35 µg/g creatinine. The workers will only be allowed to proceed with the works once the urine mercury falls below BEI and certified fit by the OHD.

3.7.3 Requirement for exposure monitoring

Personal exposure monitoring is required should the risk assessment indicates that the risk is significant. The personal exposure monitoring will determine the mercury concentration in the air that may be inhaled by the workers during works.

If the personal exposure monitoring results show that mercury concentration is at or above the PEL of 0.025 mg/m^3 (average exposure of 8 hours), further control measures must be put in place to reduce the level below the PEL.

3.7.4 Requirement for health surveillance

If reducing the level to below PEL is not feasible, the control measures should be in place to reduce the mercury exposure level to so far as is reasonably practicable. Concurrently, the workers have to undergo a post-work urine mercury monitoring to determine if the urine level in the body is significant and whether further controls are required to reduce the workers' risk.

- If the post-work urine mercury level is below the BEI, the workers are allowed to proceed with works that may have mercury risk.
- If the post-work urine mercury levels are at or above the BEI, the workers are required to be placed under the MRP programme.

The workers placed under the MRP shall be monitored for urine mercury on monthly intervals. They may return to work if the urine mercury level falls below the BEI and deemed fit by the OHD.

Chapter 4 - Workplace Exposure Monitoring and Measurement

This chapter will describe the concept of exposure monitoring, sampling method and strategy, instrumentation and related laboratory analysis pertaining to mercury.

4.1 Type of Mercury Monitoring

The potential for occupational exposures to mercury vapor is a critical concern within the oil and gas industry operations that produce or process streams containing mercury. A variety of industrial hygiene sampling methods currently exist for the measurement of personal and area samples. Additionally, a number of direct reading instruments are commercially available for real time measurements of airborne mercury vapor concentrations. However, prior to conducting personal sampling, it is important to determine the presence of mercury in the process/equipment.

4.1.1 Stream Sampling

Stream sampling is done to determine the potential mercury content in the process stream. Prior to deciding if a personal or area sampling is required or not, a stream sampling is highly recommended as an input to mercury health risk assessment (Refer to Chapter 3.2). Samples of product and by-products within the system and process line may be analysed for mercury as an early indication of mercury accumulation within the process.

In the oil and gas industry, such samples can be, but are not limited to:

- Effluent water
- Natural Gas
- Product
- Scale & Sludge

Samples may be taken from hydrocarbon out of a process stream or water out of a waste stream. Examples of process areas to consider include Liquid Petroleum Gas (LPG) Colaeser, Atmospheric Pipestill (APS) bottom, desalter, preheat exchanger, Well Stream, Comingled Stream, etc.

4.1.2 Personal Exposure Monitoring

Personal exposure monitoring is performed to determine the levels of exposure to workers for:

- the 8-hour, 12-hour or full shift exposure for identified worker groups
- the duration of the tasks for identified tasks

These measurements are taken as cumulative levels of mercury in air where its results can be used to determine:

- whether limits of a TWA value have been exceeded
- necessity for health surveillance.
- adequacy of control measures, including the PPE used

4.1.3 Area Monitoring

Area monitoring is done for the purpose of establishing controls, work permitting and for hazard evaluation and screening. It is carried out to determine:

- If a ceiling limit has been exceeded
- Levels of mercury in air for clearance to enter a confined space
- Possible leakage of mercury
- Post-decontamination residual levels of mercury
- Perimeter mercury exposure levels
- Determine protection level of PPE to be provided and worn

Examples of scenarios where area monitoring would be conducted are as follows:

1. When a task or job to be done may potentially expose personnel to mercury vapor exposure such as opening a pipeline flange, opening a choke or opening equipment. Area monitoring would be performed to establish the appropriate respiratory protective equipment depending on the levels of mercury measured in the air.
2. When a task or a job would potentially release mercury vapor in a surrounding area and the area needs to be restricted from those not authorized or not protected – area monitoring would be performed to determine the boundaries where the barricade should be installed beyond which only people with protection or authorized are allowed.
3. For work permitting purpose whereby for any work with known mercury contaminated equipment, area monitoring would be conducted pre-work, during work and post work to establish the appropriate PPE requirements, controls and safe handing over.

Area monitoring is typically conducted using direct reading instruments or detector tubes.

4.2 Sampling Method and Instrumentation

This Section will describe the various methods of mercury sampling with respective objectives and instrumentation.

4.2.1 Stream Sampling

Collection of stream samples may be done as per the following recommendations:

Table 9 Specification for Collection of Stream Samples[17]

Criteria	Description
Container	• Purchase pre-cleansed or acid-cleaned • Recommended: Teflon lined 40 ml volatile organic analysis (VOA) vial sample containers • Alternative: 125 ml Borosilicate glass containers with Teflon lined caps • LPG Samples: collect in 50 and 100 ml pre-cleaned bombs
Collection	• Flush lines • Pre-cleaned containers should be filled once • Do not rinse containers • Keep headspace to a minimum • Place samples under ice after collection and during transportation • Do not use chemical preservatives • LPG: collect in 50 and 100 ml gas bombs • Gas sample: collect in a 20 and 50 L sample
Holding Time	• Analyze all total mercury samples within 48 hours to minimize sample loss • To minimize volatility losses, it is recommended to keep samples refrigerated until ready for analysis
Quality Control	• Prepare sample blank • Minimum 20% replicate analyses on duplicate samples (if possible, collect duplicate samples and analyse both)
Safety	• Handle with care during sampling, sample handling and analysis
Analysis Method	• Standard methods based on mercury gold amalgamation e.g. Cold Vapor Atomic Absorption (CVAA) or Cold Vapor Atomic Fluorescence (CVAF)

Common methods used to conduct stream sampling are listed in Table 10.

Table 10 Analysis Methods for Various Substances Containing Mercury[18, 19, 20]

Method Name	Description
US EPA Method 200.8	Determination of Trace Elements in Waters and Wastes by ICP-MS
US EPA Method 245.7	Mercury in Water by Cold Vapor Atomic Fluorescence Spectrometry
US EPA Method 1631E	Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry, August 2002
US EPA Method 6020A	Inductively Coupled Plasma-Mass Spectrometry
US EPA Method 7470	Mercury in Liquid Waste
US EPA Method 7471	Mercury in Solid or Semisolid Waste
US EPA Method 7473	Mercury in Solids and Solutions by Thermal Decomposition, Amalgamation and Atomic Absorption Spectrophotometry
ISO 6978-2	Natural gas - Determination of mercury - Part 2: Sampling of mercury by amalgamation on gold/platinum alloy
ASTM D3223	Standard Test Method for Total Mercury in Water
ASTM D5954	Standard Test Method for Mercury Sampling and Measurement in Natural Gas by Atomic Absorption Spectroscopy
ASTM D6350	Standard Test Method for Mercury Sampling and Analysis in Natural Gas by Atomic Fluorescence Spectroscopy
APHA 3112B	Cold-Vapor Atomic Absorption Spectrometric Method, Standard Methods for the Examination of Water and Wastewater
UOP 938-00	Total Mercury and Mercury Species in Liquid Hydrocarbons
UOP 516-00	Sampling and Handling of Gasolines, Distillate Fuels and C3-C4 Fractions

4.2.2 Personal Exposure Monitoring

Personal exposure monitoring consists of active and passive sampling methods. The monitoring instrument or sampling train is attached to workers with the sampling head within 30cm radius of the breathing zone.

4.2.2.1 Active Sampling

The most common active sampling method utilises either Hopcalite or Hydrar packed sorbent tubes. Samples are collected until a minimum collection air volume of 3 L (or a maximum collection volume of 96 L) is reached.

Among the methods that can be used for active samplings are:

- NIOSH Manual of Analytical Methods 6009: Elemental Mercury[21]
- OSHA US Method ID-140: Mercury Vapour in Workplace Atmospheres[22]
- HSE MDHS 16/2: Mercury and its Inorganic Divalent Compounds in Air[23]

Active sampling instrumentation is usually performed, but not limited to the following:

- With low-flow sampling pump or high-flow sampling pump with a low-flow adapter.
- Using 200 mg/500 mg hopcalite or carulite sorbent tubes as sampling collection media
- Primary or regularly tested secondary calibrator

4.2.2.2 Passive Sampling

Passive monitors require no sampling pumps and usually are simpler to use than active samplers. Two passive mercury monitors that are commercially available are the SKC Inorganic Mercury Passive Sampler (SKC 520 series) and the Assay Technology X593 Mercury Vapor Badge.

The SKC Inorganic Mercury Passive Sampler (SKC 520 series) samples air by diffusion of mercury vapour through polyethylene mesh discs which are located at the face of the badge. Mercury is collected on a sorbent capsule containing SKC proprietary sorbent, Anasorb C300, which is comparable to Hydrar and Hopcalite. The dosimeter is analyzed per OSHA ID-140 method or MDHS 16/2 at any appointed laboratory.

(a) (b)

Figure 5 Example of mercury passive sampler (a) SKC 520 series and (b) Assay Technology X593

The Assay Technology X593 Mercury Vapor badge, is collected by a thin ultra high-purity layers of gold. It also referenced OSHA ID-140 as the analytical method and can be analyzed at the manufacturer's lab or other accredited lab capable in performing the analysis.

4.2.3 Area Monitoring

Area sampling is normally done using direct reading instruments. Direct reading instrumentation will give an immediate measurement on level of mercury in air with respective errors at different concentration ranges. They can be used for personal and area monitoring to determine control measures to be adopted during work involving mercury exposure. Area monitoring is also conducted regularly during mercury decontamination (Chapter 7) and mercury emergency response (Chapter 9).

Important criteria for the selections of mercury direct reading instrument include the following:

- Accuracy
- Range
- Frequency of Factory Calibration
- Analysis Time (in seconds or minutes)
- Operating Temperature Range
- Instrument Size and its portability
- Weight
- Cost

Final selection depends on company need basis. Examples of commercially available direct readings instruments used are given the Appendix A.

4.3 Sampling Strategy

Exposure monitoring is conducted for two reasons:

a. To monitor the integrity and performance of hazard control systems
b. To access health risk of persons at workplace

The sampling strategy used for airborne exposure monitoring which includes parameters such as number of samples and field blanks shall be as per DOSH Guidelines on Monitoring of Airborne Contaminants for Chemicals Hazardous to Health[24]. Frequency of monitoring will vary depends on exposure monitoring results obtained and the related legislative requirement. The sampling activity should be conducted by competent persons.

4.4 Laboratory Selection

In any industrial hygiene sampling work, lab analysis is one of the important components. It is very crucial that the laboratory appointed to conduct the analysis of the collected samples is reliable and has good track record in handling and analyzing IH samples.

Some criteria that may be considered when selecting a laboratory for industrial hygiene samples, specific for mercury analysis are:

a. Laboratory Accreditation – the laboratory should be accredited by relevant organisation such as National Laboratory Accreditation Scheme/ Skim Akreditasi Makmal Malaysia (SAMM), American Industrial Hygiene Association (AIHA), etc.
b. Participation in Proficiency Analytical Testing for mercury base on the required method (request to see the results if necessary)
c. Person conducting the required analysis is competent
d. Have the ability and the instrument to perform the required analysis with validated analysis method (either standard published method, or in-house method)
e. Instrument calibration – instrument used are calibrated within the specified frequency
f. Limit of Detection (LOD) – able to analyse to the specific LOD required, especially important in samples containing low levels of mercury
g. Provide sampling media to ensure the media used is from the same batch with lab blank.

Chapter 5 – Health Surveillance for Mercury Exposure

5.1 Introduction

Health surveillance for mercury is a process where a worker's exposure to mercury in a workplace is monitored and the data gathered analyzed to detect health related problems arising from mercury exposure. With respect to the mercury health risk management protocol (as per Chapter 3), health surveillance is a part of Control.

Health surveillance is required for the following objectives:

- Timely detection of medical conditions arising from a worker's exposure to mercury at his/her workplace.
- To determine the effectiveness of control measures put in place to protect the worker from unacceptable exposure to mercury at the workplace.

Typical health effects arising from acute and chronic mercury exposure is explained in Chapter 2.4.

5.2 Components of Mercury Health Surveillance Program

Typically, the program should consist of the following:

- Pre-placement fitness to work (FTW) assessment
- Biological monitoring & Biological effect monitoring
- Medical examination
- Medical removal protection
- Illness investigation and reporting

Mercury health surveillance should be performed by an OHD who is registered with DOSH. Related forms as per DOSH Guidelines on Medical Surveillance (Appendix USECHH 1)[25] and additional guidelines for mercury as per Appendix B of this Guidelines should be used. A brief description on above components is explained below, whereas specific health surveillance requirement for routine and non-routine exposures is given in Chapter 5.3 and 5.4 respectively.

5.2.1 Pre-placement FTW assessment

If the mercury risk assessment from Chapter 3.3 concludes that the risk is significant and further risk management steps are required, the workers who will be working in the area shall undergo Fitness to Work (FTW) health assessment.

Pre-placement FTW assessment should be performed prior to the workers' deployment to another/new job and/or job location that will expose them to significant mercury risk. The purpose is to determine the presence of medical conditions, clinically or sub-clinically that may render the employee to be medically unfit to perform his new assignment/job scope.

The type of job and/or job location requiring pre-placement FTW assessment should be determined by the site management based on the Mercury Health Risk Assessment conducted. Refer to Table 12 and 13 for FTW assessment details for routine and non-routine exposures respectively.

5.2.2 Biological monitoring & Biological effect monitoring

Biological monitoring and biological effect monitoring refers to laboratory and/or clinical testing of selected body fluids and/or tissues to evaluate the amount of the hazards present in the workers' bodies or the presence of early damage to target organs due to such exposures.

The specific types of biological monitoring for mercury exposure are as follows:

Table 11 Biological Exposure Determinants for Mercury[16]

Determinant	Biological Exposure Indices (BEI)
Total inorganic mercury in urine	35 µg/g creatinine
Total inorganic mercury in blood	15 µg/L

In this Guideline, total inorganic mercury in urine is mostly referred.

However, total inorganic mercury in blood maybe required when:

- Clinically indicated (based on sign & symptoms)
- Short exposure duration to mercury (i.e. recent exposure within days based on personal exposure monitoring at/above PEL).
- Post-emergency exposure e.g. spill, splash and responding to emergency response

Should other forms of mercury species is present, the Health Surveillance approach should be revisited to include total inorganic mercury in blood.

Note:

i. For blood sample, total inorganic mercury speciation to exclude methylmercury related to seafood.

ii. The half-life of inorganic mercury in the blood is only around 3 days. Therefore, in the case of intermittent mercury exposure, blood is a good biomarker of exposure to inorganic mercury only if the exposure is very recent or is on-going. Urine is definitely *the most appropriate and most reliable indicator of exposure to all forms of inorganic mercury.*

Biological Effect Monitoring shall be conducted when biological monitoring shows results at or above BEI. The types of tests to be done are:

- Urine analysis looking specifically for low molecular protein as an indicator of early kidney involvement
- Other lab tests e.g renal function test (if clinically indicated, as determined by the OHD)

5.2.3 Medical examination

Medical examination is carried out among workers placed under the Health Surveillance Program at pre-determined frequency, to detect early signs and symptoms of adverse effects on health due to exposure to mercury. The requirement of medical examination listed in Appendix B includes:

- History taking (medical, family and occupational history)
- Symptoms survey
- Physical examination

5.2.4 Medical removal protection (MRP)

MRP is the procedure to temporarily or permanently remove affected worker from a workplace aimed at preventing him/her from further exposure to mercury.

Based on the significant risk conclusions, employees should be removed from further mercury exposure if:

- They reveal signs or symptoms of mercury poisoning; OR
- Their biological monitoring levels are at or above the ACGIH BEIs listed in Table 11.

Medical removal protection program applies to:

- Employees with blood/urine mercury at or above BEI
- Those with existing medical conditions that may be exacerbated by mercury exposures
- Those with clinical signs of mercury poisoning
- Pregnant and/or breast feeding workers if CHRA shows significant risk

Guidelines on Mercury Management in Oil & Gas Industry 2011

5.2.5 Return to Work (RTW)

Under RTW program, those employees who are placed under the MRP due to urine mercury at or above BEI shall be monitored for urine mercury on monthly interval. The employee can be returned to work when:

- The urine mercury falls below BEI
- Signs and symptoms of mercury toxicity have resolved
- Pregnancy and/or breastfeeding have ended
- He/she is free from mercury exposure

Certification of fitness to RTW shall be done by the attending OHD.

5.2.6 Illness investigation and reporting

Similar to all other health surveillance, Management should investigate all cases of elevated results from biological monitoring and/or biological effect monitoring and positive results from medical surveillance, to ascertain if exposure to the identified health hazard was contributed by the employee's work and/or workplace.

Potential occupational mercury illness/poisoning shall be investigated by Management when:

- Presence of sign & symptoms of mercury poisoning; AND/OR
- Urine/blood mercury at or above BEI

Steps for investigating the occupational mercury illness/poisoning include the following:

- Personal interview
- Review of employee's medical record
- Worksite inspection
- Review of CHRA/personal exposure monitoring
- Review of effectiveness of existing control measures
- Medical records on other incidences on mercury related problem

Diagnosis of occupational mercury illness/poisoning is established by an OHD when all of the following criteria are met:

a. Presence of sign & symptoms of mercury poisoning; AND

b. Urine/blood mercury at or above BEI; AND

c. Clear occupational relationship

Illness reporting to DOSH is required as per the following requirement:

a. All occupational mercury illness/poisoning diagnosed by OHD is reportable to DOSH using JKKP7 by both the employers and OHD - as per the Notification of Accident, Dangerous Occurrence, Occupational Poisoning and Occupational Disease (NADOPOD) Regulations 2004

b. Medical surveillance for mercury need to be reported to DOSH using applicable USECHH forms by the OHD – as per the Use and Standards of Exposure of Chemicals Hazardous to Health (USECHH) Regulations 2000

5.3 Health surveillance program for routine exposures

As part of the mercury risk management for routine activities (refer Chapter 3.6), the following is the typical types of health surveillance proposed:

a. Pre-placement/pre-deployment health assessment

b. Periodic health surveillance

c. Exit health surveillance

Table 12 summarizes the requirement such as when the assessment should be performed, what is the typical tests/examination to be carried out and criteria of acceptance for the three (3) types of health surveillance.

Table 12 Requirement for various types of health surveillance for routine exposures

	Pre-placement FTW Assessment	Periodic Health Surveillance	Post Health Surveillance
When to perform	Whenever the other/ new job and/or job location has: i. Significant mercury risk identified based on mercury Health Risk Assessment (HRA) (if personal exposure monitoring not done); or ii. Hg personal exposure monitoring at or above PEL	To be conducted annually for the workers whose routine job has significant mercury exposure (confirmed by personal exposure monitoring, level showing at or above PEL)	Performed for workers whom: i. Ceased to work in mercury-related tasks and risks ii. Risk assessment shows no significant mercury exposure (from repeat mercury HRA)
What to perform	i. History taking (medical, family and occupational history) ii. Symptoms survey iii. Physical examination iv. Biological monitoring: Urine mercury v. Biological effect monitoring (if biological monitoring is at or above BEI)	Same as pre-placement/pre-deployment health assessment	Same as pre-placement/pre-deployment health assessment
Criteria of acceptance	Workers are not fit to work and should not be allowed to proceed with the placement if: • presence of signs/symptoms of mercury poisoning; and/or • urine mercury level at or above BEI The placement to the workplace will only be done once the employee is free from mercury exposure and certified fit by the OHD.	Workers should not be allowed to proceed with the work and to be placed under MRP if: • presence of signs/symptoms of mercury poisoning; and/or • urine mercury level at or above BEI Workers will only return to work once he/she is free from mercury exposure and certified fit by the OHD.	Workers to be placed under MRP if: • presence of signs/symptoms of mercury poisoning; and/or • urine mercury level at or above BEI

Pre-placement FTW assessment should be carried out as close as possible to the actual date of commencement of placement and within the half-life of the specific mercury forms, as listed in Table 7.

Post health surveillance should be carried out after the exit date; as close as possible to the actual date of the exit, preferably within 30 days post exit. Allowing longer period before urine sampling for post health surveillance may lead to error in the results due to potential mercury exposure from other sources e.g. other workplaces with significant mercury risk.

5.4 Health surveillance program for non-routine exposure

As part of the mercury risk management for non-routine activities (refer Chapter 3.7), the following is the typical types of health surveillance proposed:

- Pre-placement/pre-deployment health assessment
- Exit health surveillance

Table 13 summarizes the requirement such as when the assessment should be performed, what is the typical tests/examination to be carried out and criteria of acceptance for the two (2) types of health surveillance.

Table 13 Requirement for various types of health surveillance for non-routine tasks

	Pre-placement FTW Assessment	**Post Health Surveillance**
When to perform	Whenever the other/ new job and/or job location has: i. Significant mercury risk identified based on mercury HRA; or ii. Mercury personal exposure monitoring at or above PEL	Performed when; i. The workers have exposure to mercury at or above PEL ii. Risk assessment shows no significant mercury exposure (from repeat mercury HRA)
What to perform	Biological monitoring: Urine mercury	Biological monitoring: Urine mercury
Criteria of acceptance	Workers are not fit to work and should not be allowed to proceed with the placement if: • urine mercury level at or above BEI The placement to the workplace will only be done once the employee is free from mercury exposure and certified fit by the OHD.	Workers to be placed under MRP and monitored if: • urine mercury level at or above BEI

Similar to routine exposures, post health surveillance should be carried out right after the exit from the non-routine job; as close as possible to the actual date of the exit, preferably within 30 days post exit.

Chapter 6 – Controlling Mercury Risks

6.1 Introduction

Similar to any other health hazards, control measures for mercury hazard are the steps taken to prevent or minimize mercury risks to so far as is reasonably practicable.

Specifically, the objectives of control measures are to:

- Prevent or minimize the release of mercury hazard that could potentially expose the workers
- Mitigate the potential effects should the exposure control measures fail, and to prevent potential escalation of health risks.

Control measures are assessed during a mercury risk assessment with the following steps:

- Identify current mercury control measures installed/practiced at site in the removal or reduction of mercury and its exposure
- Evaluate the adequacy of the existing controls based on its suitability, use, effectiveness and maintenance
- Recommend additional control measures (if required) to further reduce the risks to ALARP

If the mercury health risk assessment indicates that the risk is significant, management shall initiate to implement the required control measures within a specific time frame.

6.2 Hierarchy of controls

Control measures should be evaluated in the following hierarchy of controls:

i. Elimination

ii. Substitution

iii. Isolation of the work to control mercury emission

iv. Use of engineering control equipment

v. Administrative controls

vi. Use of personal protective equipment

Table 14 provides additional information on some of the control options described above.

Table 14 Examples of control options for managing mercury risk

	Type of control measures	Description
1	Elimination	• As mercury is naturally occurring contaminant in the natural gas or crude oil, elimination of mercury (not total elimination) from the process stream can be achieved through mercury removal technology.
2	Substitution	• Substitute mercury containing reagent with less hazardous chemicals • Select raw materials (crude oil, condensate, or natural gas) contains less mercury content within operations and safety and health limits
3	Isolation of the work to control mercury emission	• This can be achieved by segregation, either by distance or a physical barrier of mercury-related tasks from others. Warning signage is made available. • Isolation also includes the Medical Removal Protection (MRP) requirement as described in Chapter 5. • Restricted access and barricade
4	Use of engineering control equipment	Application of engineering control equipment such as: • Local exhaust ventilation (LEV) in laboratory for analysis of samples containing mercury. • Hopper to remove activated carbon contaminated with Hg • Closed-system sampling point • Sampling points supplied with cover Maintenance of the engineering controls includes: • Periodic inspection, examination & testing • Immediate repair when there is a breakdown • Re-testing after any repair work
5	Administrative controls	• Mercury health risk assessment – Chapter 3 • Exposure monitoring – Chapter 4 • Health surveillance – Chapter 5 • Mercury decontamination –Chapter 7 • Safe system of work (e.g. Permit to work (PTW), Job Hazard Analysis (JHA)) • Warning signage Good personal hygiene includes: • Do not eat at the mercury- contaminated areas • Remove contaminated working attire prior to leaving the area • Wash hands properly before eating, drinking or smoking;

Chapter 6

6	Information & training –	• Provide relevant information to the workers handling mercury. • Training shall cover at least the following elements and shall be conducted every 2 years: ✓ Identification of Hg exposure in workplaces ✓ Mercury health effects ✓ Various controls measures associated with mercury ✓ Proper use of personal protective equipment (PPE) and its maintenance ✓ Emergency response
7	Personal Protective Equipment (PPE)	• Refer to the Guidelines outline in Chapter 10

Figure 6 Example of warning sign posted at work places

6.3 Overview of Mercury Removal Technologies[26]

Most commonly used technology to scavenge mercury applied in the oil and gas industry is by using adsorbent technology. However, other technologies, such as chemical oxidation and ion exchange may be applied within a water treatment system.

Figure 7 An example of a mercury removal system at an onshore facility

6.3.1 Adsorption Process

Adsorption is a process involving a combination of concurrent reactions including electrochemical bonding, micro-reticular and macro-reticular pore entrainment, and to a lesser extent, ion exchange at the surface of a microporous solid (adsorbent). The combinations of concurrent reactions involved depend very much on the presence and form of a surface-active functional group on the adsorbent. Example of different types of adsorption materials are as follows:

Table 15 Types of adsorption materials for mercury removal

Activated Carbon	Sulphur Impregnated Activated Carbon	Potassium Impregnated Activated Carbon	Metal Sulphide
Simple and straight forward process. Economical for removing low concentration mercury content for dry gas media. Not suitable for dew point gas and hydrocarbon condensate	High purification efficiency and adsorption capacity. Not suitable for hydrocarbon condensate	High purification efficiency and adsorption capacity. Suitable for dry, dew point gas and hydrocarbon condensate.	High purification efficiency and adsorption capacity. Suitable for dry, dew point gas and hydrocarbon condensate.

All the above adsorption process should have pre-treatment equipment for particulate filtration, free water removal, heavy hydrocarbon and other inorganic contaminants.

6.3.2 Chemical Oxidation Treatment

This method is applied to convert elemental mercury and organomercury compounds to a soluble form, such as $HgCl_2$ or HgI_2. These soluble forms can then be separated from the fluid and subsequently treated. Oxidising reagents used include sodium hypochlorite, ozone, hydrogen peroxide, chlorine dioxide and free chlorine plus other proprietary reagents.

Typical characteristics of chemical oxidation treatment are as follow:

- Effective for aqueous waste treatment. Not applicable for hydrocarbon gas and condensate.
- Commonly found in small scale processes.
- May have hazardous side products.
- Need to be used in conjunction with other processes for complete removal and final treatment of mercury.

6.3.3 Ion Exchange Treatment

Ion exchange treatment is capable to remove mercury from aqueous media which has concentrations of 1 to 10 ppb and typically operated as packed bed. After the bed is saturated, the bed needs to be regenerated via backwashing activity. The spent resin is regenerated by designated solution. The rinse step removes excess regeneration solution before the column is brought back online for the next service cycle. Spent ion exchange resin and rinsing effluent are hazardous and need to be disposed in a hazardous waste unit. This process is limited to remove mercury in the form of anionic complexes.

6.3.4 Generic Criteria For Mercury Removal Technology Selection

General basic criteria of technology selection are as follows:

a. Proven and reliable technology - The selection shall be based on the precedent successful of the technology and its proven reliability.
    - Capability to meet total mercury content in the product.
    - Ability to remove all mercury species.

    - Ease of operation / maintenance.
    - Acceptable results of adsorbent performance analysis.
    - No impact on other product specification parameter.

b. Operational constraint - The ability of a technology to be deployed across wide range of conditions such as space especially for offshore facilities, capacity, weather condition and maintenance cost.

c. Time constraint - Fabrication and turnaround time are critical factors for dynamic work strategies.

d. Ability to integrate with existing facilities and platform.

Chapter 7 – Mercury Decontamination

7.1 Introduction

Decontamination of mercury refers to the process of removing or neutralizing mercury contaminants that have accumulated on equipment, tools and personnel. In mercury health risk management, the needs to carry out decontamination should be a risk-based approach. If the risk assessment (as outlines in Chapter 3) concludes the risk is significant, and decontamination has been identified as one of the required control measure, the recommendations in this Chapter may be considered.

Decontamination is required for the following objectives:

- Minimise or possibly eliminate workers' exposure to mercury
- Protects plant or site personnel by minimizing the transfer of harmful materials into clean areas
- Protects end users from mercury that may contaminate and eventually permeate the protective clothing, respiratory equipment, tools, vehicles or vessels, and other equipment used in the vicinity of exposed areas

7.2 Principles of Mercury Decontamination

7.2.1 Scope

Scope of mercury decontamination in this Guideline refers to decontamination of:

- Equipment/Tools
- Personnel

Equipment refers to the process set-up in plant areas such as aluminium heat exchangers, mercury removal units, compressors, flanges, flanges, bolts/nuts etc.

Tool refers to the apparatus brought to the site to support the tasks, e.g. spanner, hammer, bucket, crane etc.

Personnel are the employees and contractors, including the decontamination personnel that are working in mercury-contaminated areas.

7.2.2 Decontamination techniques

Decontamination of mercury from mercury-contaminated surfaces of metals and porous materials deserves special considerations because of the unique properties of elemental mercury, which is supposed to be the main species in the mercury-containing contaminants. Elemental mercury is a liquid and is volatile at room temperature. It may transfer from one area to another very easily and quickly. Raising temperature will increase this relocation process dramatically.

On the other hand, elemental mercury forms amalgams with many metals, such as copper, zinc, nickel, tin, cadmium, and gold. The formation of amalgams, instead of

Guidelines on Mercury Management in Oil & Gas Industry 2011

surface absorption makes the decontamination process more complicated. Elemental mercury has very low solubility in water and in many mineral acids. Procedures involving mobilization of mercury by washing with steam water are not appropriate and efficient techniques. Application of strong mineral acids directly on the surface of metals and porous materials is also a bad choice because of the low efficiency for removing elemental mercury and the potential damage of the surfaces. The properties of mercury are given in Chapter 2.

Considering the unique behaviour of elemental mercury, therefore, the types of decontamination techniques available for mercury are usually classified as mechanical or chemical.

7.2.2.1 Mechanical decontamination

Mechanical decontamination is typically referred to manually applied, physical contaminant removal techniques, like washing, foaming, wet-wiping, steam cleaning, evaporation etc. These techniques are applied to either clean surfaces of contamination or to remove the contaminated surface itself. When contaminants are located on or at near surface levels, surface cleaning is usually effective, depending upon the contaminants involved and the nature of the surface material. Contamination at deeper levels may require surface removal techniques and depending upon the type of surface material may be of limited practicality (e.g., activated metal structures). For mercury, mechanical decontamination may be applied together with the chemical decontamination.

7.2.2.2 Chemical decontamination

In chemical decontamination, chemical reagents are applied to remove mercury from the surfaces of facility structures, fixtures, and equipment or even personnel. This process can be carried out manually or remotely, reaching inaccessible surfaces, with few airborne hazards. Some disadvantages exist, however, including minimal effectiveness on porous surfaces, the generation of moderate volumes of secondary waste that require additional treatment, and corrosion and safety problems if carried out improperly.

For the selection of mercury decontamination chemicals, kindly refer to chemical suppliers/ vendors on the suitability of the chemicals. The general criteria for decontamination chemicals are:

- Non-toxic and non-corrosive
- Inert to product/process streams chemicals
- Non-reactive to equipment
- Effective to suppress mercury vapour and stabilized mercury compounds.

Chapter 7

Evidence or data on the chemical capability to decontaminate mercury, procedures related to the preparation of the chemicals for applications and methods of application shall be made available. Decontamination chemical will suppress mercury from vaporisation usually not more than 3 hours, thus, all activity is advisable to be carried out within that time.

7.3 Decontamination Methodology

7.3.1 Planning

A decontamination plan should be developed and the planning should include the following:

i. Confirm that decontamination is recommended based on the mercury health risk assessment (Refer to Figure 2)
ii. Type of decontamination techniques, including the decontamination chemicals to be used
iii. Decontamination stations should be separated physically to prevent cross contamination and should be arranged in order of decreasing contamination. Separate flow patterns and stations should be provided to isolate workers from different contamination zones containing incompatible wastes.
iv. Entry and exit points - entrance and exits to exposed areas should be conspicuously marked. Dressing stations for entry to the decontamination area should be separate from redressing areas for exit from the decontamination area.
v. Equipment and tools required for decontamination activity - should be sufficient and decontaminated and/or disposed of properly. This includes instruments required to determine the levels of mercury. Refer to Chapter 4.2.3 for mercury measurement using direct reading instrument.
vi. Waste generated from the decontamination activity - all spent solutions and wash water should be collected and disposed of properly. Clothing that is not completely decontaminated should be placed in plastic bags, pending further decontamination and/or disposal. Disposal of waste contaminated with mercury should follow the recommendation in Chapter 8.
vii. Health, safety and environmental (HSE) measures – relevant site HSE requirement, not limited to PTW system and personnel protective equipment (PPE) requirement should be adhered to.

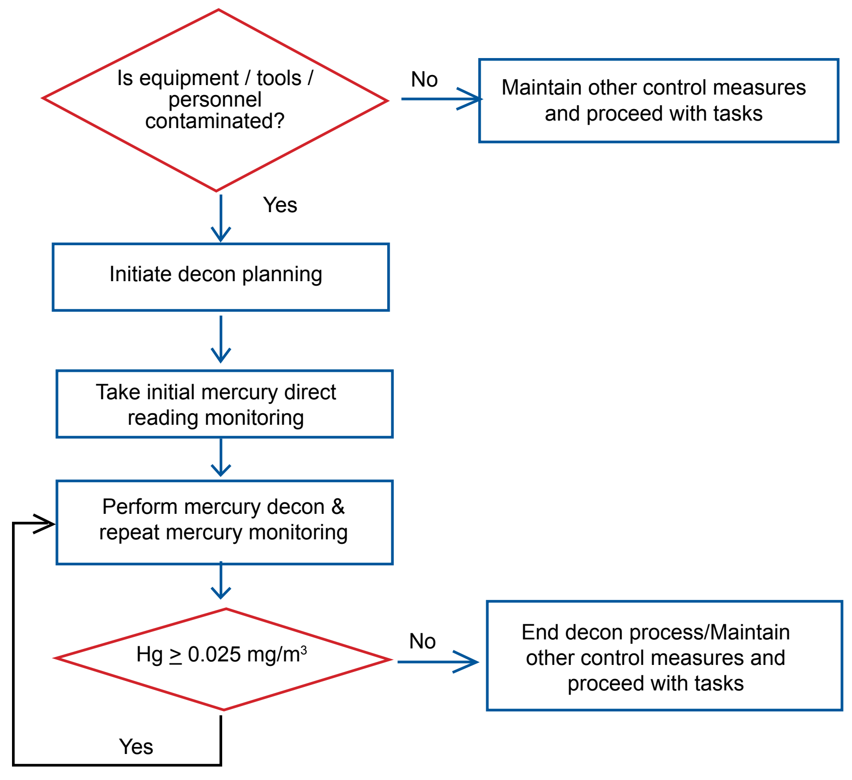


Figure 8 Mercury Decontamination Process

7.3.2 Setting Up a Decontamination Station

The following guides may be referred in setting up decontamination stations and Figure 9 shows typical decontamination station setup:

- Identify the normal traffic flow of personnel and equipment into and out of the contaminated workspace.
- Evaluate the need for multiple decontamination stations based on the proximity of contaminated work sites to each other and the distance workers must walk to reach a decontamination station.
- The selected site for a decontamination station should be upwind from the contaminated work site. Take prevailing wind conditions into consideration.
- Establish the decontamination station as close as practical to a contaminated work site with due regards to emergency access and the potential of cross contaminating safe areas.
- At the edge of the contaminated work site a boot bath should be positioned to allow workers to clean their boots and gloves prior to proceeding to the decontamination station.
- The boot bath area, tool and equipment storage and the main decontamination area should have an impermeable covering laid down to cover the surfaces where personnel will be walking or standing. Suitable coverings include heavy plastic sheets or rubberized tarpaulins (waterproofed canvas).

- Ensure water drainage is to a closed drain system; alternatively contaminated water may be pumped into suitable tanks for transport to a treatment/disposal site.
- Plastic containers or plastic bags should be provided next to the decontamination station for disposal of contaminated protective clothing and other disposable items.

Figure 9 Example of mercury decontamination station

7.3.3 Equipment for Performing Decontamination

All equipment for setting up a decontamination station and performing the actual decontamination process should be made available prior to the start of work:

- Plastic sheeting or rubberized tarpaulins for covering the ground surface or deck.
- Decontamination shower, either purpose built or fabricated from site materials
- Decontamination chemical
- Boot wash baths (e.g., made large plastic washbasins, bucket or tub.
- Portable hand sprayer or backpack sprayer for applying suppressant chemical.
- Dish washing liquid for cleaning of reusable items.
- Stiff handled brushes for cleaning boots (e.g., toilet-cleaning brushes are suitable).
- Hazardous materials waste containers, plastic drums or heavy plastic rubbish bags for solid waste.
- Clean dry rags
- Water proof 'Duct' tape for sealing edges of plastic sheeting
- Barrier Tape for marking off restricted areas or defining walk ways
- Hand basin or bucket for washing of hands and face after decontamination.
- Water supply by pressurized hose or hand bucket

Guidelines on Mercury Management in Oil & Gas Industry 2011

- Method of draining off contaminated water.
- Talc powder for absorbing moisture in boots and glove

7.3.4 Equipment and Tools Decontamination

The basic decontamination process remains similar regardless of the size and shapes of equipment/tools to be decontaminated. All tools and equipment used within the contaminated work site will require decontamination prior to being placed in general work areas and process equipment contaminated with mercury may requires decontamination before workers' access for maintenance activities The following should be considered prior to equipment/tools decontamination activities:

i. Opening of identified equipments, flanges or break-in containment shall be considered as high risk of mercury contamination and shall require work site isolation and full PPE

ii. Tools with porous surfaces such as hammers should have been covered with a strippable coating such as plastic wrap

iii. Protect the work area surfaces with plastic sheeting

iv. Prepare and install mobile drip trays with water blanket to recover any spillage when pipe opening or flange spreading

v. All equipment that is made up of more than one component may require some disassembly to ensure full decontamination (e.g., Chain hoists)

vi. Install air induction if required to ensure mercury vapour concentrations do not exceed the PEL. Vent ducting should be downwind and away from all other work areas. Offshore vent ducting should be long enough to go over the side of the platform and as close to the sea surface as practical

vii. Mercury direct reading monitoring instrument should have been covered with a strippable coating such as plastic wrap

viii. Each tool or equipment component should be lightly sprayed with mercury decontamination chemical and wiped clean with dry rags

ix. Electronic monitoring equipment should have strippable covering removed and wiped with a damp cloth

Chapter 7

Figure 10 Process equipment covered with plastic wrap

7.3.5 Personnel Decontamination

The typical steps to carry out personnel decontamination is outlined below:

i. The decontamination personnel (persons who will decontaminate other workers) is required to wear a chemical suit, chemical gloves and half face respirator with mercury cartridge (as per the PPE recommendations in Chapter 10) while decontaminating other workers.

ii. The worker (persons who performed work in mercury contaminated areas) will first enter the boot decontamination station before proceeding to the decontamination shower. Boots should be washed using mercury decontamination chemical.

iii. The decontamination personnel will then sprays the worker with mercury decontamination chemical using a fine mist to cover all surfaces.

iv. The decontamination personnel rinses off worker before exiting the decontamination shower.

v. Remove the hood of the chemical suit and unzip the suit midway down the chest of the worker as shown in Figure 11.

vi. Remove the goggles and place in the decontamination bath of soapy water, and wash vigorously. Transfer the goggles to the clear rinse water.

vii. Remove the duct tape seal from suit sleeves and pant legs.

viii. Roll back the sleeves of the suit to expose the gloves, ensure the contaminated outer surface of the suit does not come into contact with the workers skin or undergarments.

ix. Remove the gloves by turning inside out as they are pulled off the workers hands. Wash and rinse as above, inspect for tears or punctures, if suitable for reuse, dry and sprinkle talc powder inside the gloves to absorb moisture. If non-reusable, dispose of the gloves in the contaminated waste bin.

Guidelines on Mercury Management in Oil & Gas Industry 2011

x. Fully unzip the disposable chemical suit and peel the suit off the crewman by turning it inside out.

xi. Have crewmember step out of the boots and suit on to clean dry rags.

xii. Remove the suit from the boots.

xiii. Dispose of the suit in the contaminated waste bin provided.

xiv. Remove the respirator from the crewmember and remove the cartridge filters, wash with soapy water and rinse in fresh clean water and then dry.

xv. Cartridge filters should be simply wiped with a clean damp cloth (do not wash in water). Confirm the service indicator on the filters is still showing adequate usage remaining, discard if spent or appears contaminated.

xvi. Wash boots using soapy water with a stiff brush and rinse. Set aside to dry.

xvii. Ensure crewmember washes hands and face with clean soapy water.

xviii. Allow crewmember to don normal work clothing and boots and to leave the area

Figure 11 Personnel decontamination

Chapter 7

Chapter 8 – Mercury Waste Management

8.1 Introduction

This Chapter provides guidance on the handling, storage and transportation of mercury waste from workplaces to disposal facility.

Mercury waste is regulated as scheduled waste by the Department of Environment (DOE) under Environmental Quality (Scheduled Wastes) Regulations[27] 2005, referred as EQ(SW)R-2005 therein. Therefore, it shall be managed and disposed off in a safe and environmentally responsible manner. Mercury waste should be properly labeled, stored in an appropriate waste container and segregated from other waste streams during storage and transportation.

8.2 Definition of Mercury Waste

Mercury contaminated waste is any material or substance that has been in contact with hydrocarbon gases or liquid from a process that is known or suspected to contain mercury. Any material or substance from the above process, not limited to the following conditions shall be considered as mercury contaminated waste:

- Liquid – e.g. liquid mercury, spent mercury decontamination chemicals, waste water streams, contaminated process water etc.
- Sludge – e.g. Any type of hydrocarbon/water separator sludge or other oily sludge, wastewater treatment sludge
- Solid – e.g. spent adsorbent, contaminated PPE, spent filter that were used in any process service, contaminated scaffolding boards or wooden packing, tools etc.

8.3 Mercury Waste Handling

Workplaces handling mercury waste should develop Mercury Waste Management Procedure or integrate mercury waste into their existing Scheduled Waste Management Procedure. It is recommended for the sites to implement the work scopes, not limited to the following:

i. Identify all types of mercury contaminated waste produced and their sources. If uncertainty arises, then the waste shall be sampled and analyzed to identify the waste characteristic and properties.
ii. Characterise the wastes - waste characteristics is also important in deciding the types of treatment to be employed for disposal
iii. Classify the wastes as per the EQ(SW)R-2005 Waste Codes
iv. Segregate mercury waste from non-compatible waste.
v. Packaging - selection of waste container material shall be corrosion & chemical resistant e.g. high density polyethylene (HDPE) or steel containers with plastic lining. The container use for the packaging must be tightly sealed not leaking, bulging, rusting or badly dented.
vi. Labeling of the waste container should comply with the EQ(SW)R-2005.
vii. Implement relevant safety and health requirements - ensure workers handling

mercury wastes is included in the recommendations stated in other Chapters of this Guideline
viii. Ensure contractors appointed to handle, manage or transport mercury waste comply with relevant legal and company requirements and have relevant license to operate

8.4 Storage of mercury waste

Mercury waste storage at worksite is intended to be kept to a minimum and be only short term. All mercury waste must be stored in a designated and cordoned off area and be properly sealed in closed drums or containers. The designated waste storage area shall be located away from any normal work areas or areas normally used for personnel movement and that is designed, constructed and maintained to prevent spillage or leakage of wastes to the environment.

If volumes of mercury contaminated liquid waste is sufficiently large, storage tanks may be used. General recommendations for solid and liquid wastes are:

i. Storage of Solid Type of Waste.
   a. All solid type of waste must be stored in open lid type of Steel/HDPE drum with clamps.
ii. Storage of Liquid Type of Waste.
   a. Any liquid type of waste must be stored in bunghole type of steel or HDPE drums.

Containers should be kept sealed except when adding or removing waste from the container. Storage areas shall be checked regularly to confirm security and containment of the wastes.

Figure 12 Example of HDPE drums for mercury waste storage

8.5 Transportation of Mercury Waste

Shipment of mercury waste should be adequately planned, ensuring all contaminated materials are correctly packaged, labeled and documented for transport. Containers are to be secured in a manner to prevent damage, movement or spill during transportation.

Relevant documentations such as waste consignment note, material transfer form shall be prepared for transportation of mercury waste from sites to approved waste treatment facility, or even shipment from offshore to onshore supply base.

Mercury waste storage on trucks or vessels is intended to be kept to a minimum and is considered to be only temporary storage until waste can be delivered to the shipping destination or disposal facilities.

Guidelines on Mercury Management in Oil & Gas Industry 2011

Chapter 9 - Mercury Emergency Response

This Chapter provides an overview of emergency response related to mercury. The existing site/plant emergency response plan should incorporate the specific recommendations in handling mercury emergency. Should there be any emergency related to mercury, the response plan triggered should follow the existing protocol at the particular sites.

9.1 Introduction

Any activity that breaks containment of a process system that contain/accumulate mercury, has the potential to release vapour or liquids into the local environment where elemental mercury can also be released and spilled onto adjacent surfaces. Therefore, the emergency planning for mercury-related incidents should cover situations such as:

- mercury spillage
- suspected acute mercury poisoning
- equipment/containers containing mercury in fire situation
- effects on down-wind operations and facilities

The recovery measures should include the following:

- evacuation
- notification of all persons who may be affected, including surrounding communities
- co-ordination with local emergency services
- communications system with site and/or external emergency services
- wind speed and direction indication (often a windsock), additional breathing apparatus

9.2 Fire and Explosion Involving Mercury

Mercury is non-flammable and non-combustible under normal conditions. However, it may react upon heating (in a fire) to produce corrosive and/or toxic fumes. A violent heat-producing (exothermic) reaction, possibly an explosion, occurs when mercury comes in contact with chlorine dioxide, lithium, rubidium, halogens, or acetylide.

In the event of a fire involving mercury, use fine water spray and liquid-tight protective clothing in combination with breathing apparatus. Spillages and decontamination run-off should be prevented from entering drains and watercourses. Keep drums, etc., cooled by spraying with water. In case of fire in the surroundings, use appropriate extinguishing media. If access to mercury direct reading instrument is available, perform mercury airborne monitoring as per Chapter 4.2.3.

9.3 Mercury Spills/Leaks

When mercury metal is spilled, it forms droplets that can accumulate in the tiniest of spaces and in small pools and droplets which can emit vapour into the air. Spilled mercury that is not cleaned up properly creates potential mercury exposure for employees and visitors in the area of the spill and possible to further cross-contaminate other areas. Understanding the appropriate methodology is an important part of the clean-up as is having correct equipment and PPE. This guideline addresses spills which are within the scope and ability of on-site personnel to handle.

9.3.1 Spill Prevention

Spill prevention is preferable to spill clean-up. It is important to have established, written work procedures for processes involving the handling of mercury or equipment containing mercury. Where it is known that mercury spills are likely, floors should be sealed so they are free of cracks and crevices and build bunds around the area.

9.3.2 Training

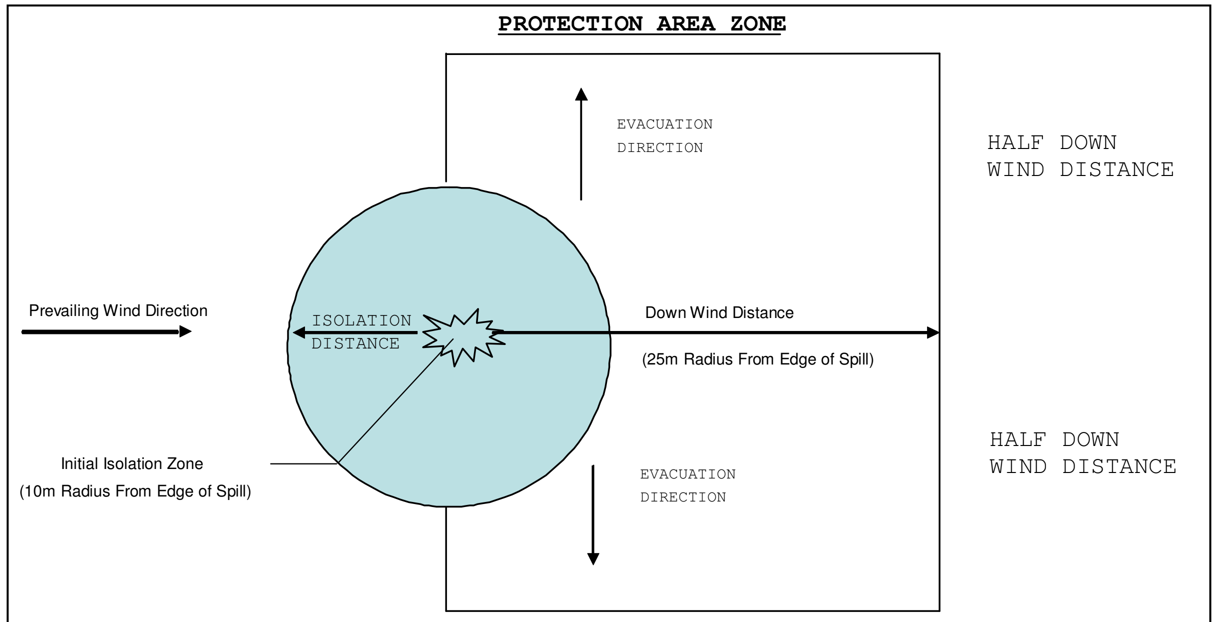
All personnel involved in mercury clean-up must be trained

9.3.3 Response Procedure for Mercury Spill [28, 29]

If a mercury spill occurs, immediately:

1) Notify, isolate and secure the spill area:

a. Evacuate the immediate spill area and notify the emergency response team providing location and extent of spill.
b. Cordon off the area around the spill with barrier tape
c. Once evacuated to a safe distance (preferably upwind of spill) check shoes, clothing, and other articles have not been contaminated with mercury. Any article found or suspected to be mercury contaminated should be removed to limit further spreading of mercury and minimize self exposure. The isolation and protection area zone is shown in Figure 13.
d. Keep away all persons not involved in the clean-up. Close doors to other areas near the spill. Post warning signs and barriers to prevent entry to the spill area by unauthorized persons, as shown in Figure 14.
e. Turn off any ventilating or air conditioning system that circulates air from the spill area to other parts of the workplace



Note:

Isolation distance: 10 m from the edge of spill

Downwind isolation distance: 25 m from the edge of spill

Figure 13 Isolation & protection area zone for mercury spills[30]

BAHAYA!!!
KAWASAN TERCEMAR
MERKURI

DANGER!!!
MERCURY CONTAMINATED
AREA

Figure 14 Example of warning sign

2) Assemble trained spill team members and the spill response kit outside the cordoned area.

3) Open the spill kit and don the appropriate PPE. PPE recommendation is given in Chapter 10.

4) Initiate Mercury measurements

a. Determine mercury levels in and around the spill area using a mercury direct reading instrument.
b. Extend the restriction zone as appropriate depending on mercury levels

found and wind direction and any other conditions that could be hazardous.

c. Advise the site management on safe distance from mercury spill.

9.3.4 Mercury Spill Cleanup

i. Use dikes or other appropriate barriers to prevent the mercury from rolling on sloped surfaces and divert mercury away from floor drains and cracks and crevices. Beads of mercury can be pushed together with a squeegee to form larger droplets. These can be collected in a dust pan and poured into a plastic bag or container.
ii. Use cotton rags to soak up the spill and place contaminated rags inside the spill kit container
iii. Work from the outside of the spill area towards the center. Mercury's high density and smoothness cause it to roll fast.
iv. Repeat steps above until no visible trace of mercury is present.
v. Spray or pour mercury suppressant chemical over the spill area and soak up with rags.
vi. Use a mercury vapour detector or mercury indicator powder to confirm all traces of the mercury spill have been removed. Repeat clean-up if required.
vii. Repack all disposable PPE and rags inside the spill kit container
viii. Seal container with duct tape.
ix. Label the container with appropriate mercury contaminated waste label.

9.3.5 The Don'ts for Mercury Spills

- **Never** use an ordinary shop vacuum cleaner or ordinary vacuum pump to clean up mercury. The vacuum will put mercury vapour into the air and increase exposure. Special mercury vacuum cleaners are commercially available and can safely be used.
- **Never** use a broom to clean up mercury. It will break the mercury into smaller beads and spread them around.
- **Never** pour or allow mercury to go down a drain. Not only is this a violation of environmental regulations, but the mercury may lodge in the plumbing and cause future problems during plumbing repairs.
- **Never** allow people whose shoes or clothing may be contaminated with mercury to walk around. They may spread the mercury contamination.

9.4 First Aid Procedures for Mercury

Mercury poisoning can occur from dermal absorption, inhalation or ingestion. In case of emergency, administer first aid as appropriate and seek medical attention. Personnel contaminated with mercury metal or other mercury compounds should exercise the following precautions:

- **Eye**
  Wash immediately with large amounts of water, lifting upper and lower lids, for at least 15 minutes. Seek medical attention immediately.
- **Skin**
  Quickly remove contaminated clothing. Immediately wash contaminated skin with large amount of soap and water. Seek medical attention immediately.
- **Inhalation**
  Move the person to fresh air at once. Evaluate respiratory function and pulse. Ensure that the victim has an unobstructed airway. If shortness of breath occurs or breathing is difficult, administer oxygen. Assist ventilation as required. Always use a barrier or bag-valve-mask device. If breathing has ceased, provide artificial respiration. Seek medical attention immediately
- **Ingestion**
  Do not induce vomiting. Seek medical attention immediately.

Guidelines on Mercury Management in Oil & Gas Industry 2011

Chapter 9

Chapter 10 – Personal Protective Equipment (PPE)

This chapter describes the various types of PPE that are appropriate for use in various mercury-related activities, and provide recommendations in their selection, limitations, use and maintenance.

10.1 PPE Selection

The approach in selecting PPE must encompass an "ensemble" of clothing and equipment items which are easily integrated to provide both an appropriate level of protection and still allow one to carry out activities involving handling of mercury or mercury contaminated materials.

The following is a checklist of components that may form the mercury handling ensemble:

i. Protective clothing (suit, coveralls, hood, gloves, boots);
ii. Respiratory equipment (self-contained breathing apparatus (SCBA), combination SCBA/ supplied air respirator (SAR), air purifying respirators);
iii. Cooling system (ice vest, air circulation);
iv. Head protection;
v. Eye protection (may be incorporated in respirator e.g. full-face respirator)
vi. Ear protection;
vii. Inner garment;
viii. Communications device (high noise levels, or large confined spaces such as vessel tankage)

When selecting PPE, a variety of factors must be considered. These factors include:

- Level of Protection Required
- PPE Fit
- Specific Job functions
- Potential of Exposure
- Duration of Exposure
- Acceptable Level of Exposure

10.2 Recommended PPE for mercury exposure

The selection of appropriate PPE is based on the hazards anticipated or recognized. When changing or selecting a PPE product, the occupational health specialist / industrial hygienist must carefully assess and verify that the selected PPE is suitable for the intended use. A summary of recommended respiratory, hand, foot and body protection for different mercury levels in workplaces is given in Table 16. This Guideline also provides PPE recommendations for different tasks related to mercury, as presented in Table 17.

Table 16 PPE guide for various levels of mercury exposure

Mercury level (mg/m^3)	Respirator	Hand	Foot	Body
< TWA Limit	Not required	Nitrile rubber gloves	Safety boots	Normal coverall
1 - 10xTWA Limit	Half face respirator with mercury cartridge	Nitrile rubber gloves	Safety boots	Normal coverall
10 - 50xTWA Limit	Full face respirator with mercury cartridge	Nitrile rubber gloves	Safety rubber boats	i. Tested in accordance with EN369 or ASTM F739 ii. Permeation rates reaching 0.1 µg/cm2 /min or 1 mg/m2/min and over iii. Resistance to breakthrough > 480 min iv. Material is a recognized skin absorption hazard (ACGIH or OSHA)
> 50x TWA Limit	SCBA or Air Supplied BA	Nitrile rubber gloves	Safety rubber boots	i. Tested in accordance with EN-374 or ASTM Method F739 standards ii. Permeation rates reaching 0.1 µg/cm2 /min or 1 mg/m2/min and over iii. Resistance to breakthrough > 480 min iv. Material is a recognized skin absorption hazard (ACGIH or OSHA)

Figures 15 and 16 show the hand and body, as well as respiratory protection for mercury respectively.

Figure 15 Hand and Body Protection for Mercury

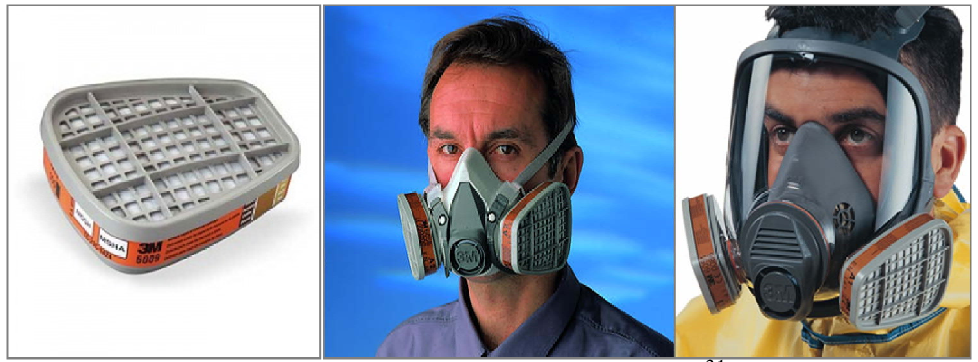


Figure 16 Respiratory Protection for mercury exposure[31]

Table 17 Example of PPE Requirement by Mercury Contaminated Activity

Activity	Required PPE	Discipline
Removing Scaffolding after break of containment	Half Mask respirator with mercury cartridge Chemical Suit - Level C* Chemical resistant boots Chemical resistant gloves -Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Scaffolder
Demolition of process piping	Half Mask respirator with mercury cartridge Chemical Suit - Level C* Chemical resistant boots Chemical resistant gloves -Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Rigger
Opening pipes and breaking flanges	Half Mask respirator with mercury cartridge Chemical Suit - Level C* Chemical resistant boots Chemical resistant gloves -Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Fitter
Handling and Transport of Mercury Contaminated Materials	Half Mask respirator with mercury cartridge Chemical Suit - Level C* Chemical resistant boots Chemical resistant gloves -Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Rigger/ Roustabout
Confined Space inspection & cleaning	Half Mask respirator with mercury cartridge Chemical Suit - Level B or C* Safety rubber boots Chemical resistant gloves -Nitrile Cotton or leather glove over Nitrile glove Mercury Monitoring Badge (ad-hoc monitoring)	Rigger/ Roustabout
Hot Work	Full-Helmet Supplied Air Respirator c/w Welding Guard Chemical Suit - Level B or C* Flame retardant Coveralls over top of Chemical Suit Safety rubber boots Chemical resistant gloves -Nitrile Leather Gloves over Nitrile Gloves Mercury Monitoring Badge (ad-hoc monitoring) • Mercury Monitoring Badge	Welder / Fitter / Maintenance Personnel

Activity	Required PPE	Discipline
Corrective Maintenance	Half Mask respirator with mercury cartridge Chemical resistant gloves -Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Maintenance Personnel
Planned Maintenance	Half Mask respirator with mercury cartridge Chemical resistant gloves -Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Maintenance Personnel
Breaking of Containment	Half Mask respirator with mercury cartridge Chemical Suit - Level C* Chemical resistant boots Chemical resistant gloves -Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Maintenance Personnel
Hydrocarbon (manual) Sampling	Half Mask respirator with mercury cartridge Chemical resistant gloves –Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Production Technician
Manual blow-down or venting	Half Mask respirator with mercury cartridge Chemical Suit - Level C* Chemical resistant boots Chemical resistant gloves -Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Production Technician
Load / Unload Pig	Half Mask respirator with mercury cartridge Chemical Suit - Level C* Chemical resistant boots Chemical resistant gloves -Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Production Technician / Roustabout
Rig -down well services equipment	Half Mask respirator with mercury cartridge Chemical Suit - Level C* Chemical resistant boots Chemical resistant gloves - Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Service Technician
Well Service Activities -Handling / Dressing Tools -Break of Containment	Half Mask respirator with mercury cartridge Chemical Suit - Level C* Chemical resistant boots Chemical resistant gloves -Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Production/ Maintenance Technician
Work on or near flare tips	Half Mask respirator with mercury cartridge Chemical Suit - Level C* Chemical resistant boots Chemical resistant gloves -Nitrile Chemical Safety Goggles Mercury Monitoring Badge (ad-hoc monitoring)	Production/ Maintenance Technician

** Level A, B, C, or D is the levels of protective clothing based on the hazardous materials classification*

10.3 Maintenance and Care of PPE

Every PPE wearer should follow the specific PPE maintenance requirement as specified by the manufacturers namely on cleaning, storage, re-use and disposal.

Specifically on mercury vapour cartridges, it should be discarded when the end of service life indicator changes colour, cartridge is damaged, dirty, 30 days from first use or the expiration date exceeded, which ever occurs first. Mercury cartridges to be re-used must be stored so that they are protected against damage, contamination, dust, sunlight, extreme temperatures, excessive moisture, and damaging chemicals.

10.4 PPE Training

PPE wearer should undergo relevant training on PPE every 2 years[32].

Chapter 11 – Record Keeping

The employer shall ensure that all records that are generated under this guideline are kept in accordance to the requirements in the Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations 2000 or USECHH Regulations.

Table 18 provides the summary of records to be kept and their minimum retention duration according to the USECHH Regulations.

Table 18 Summary of mercury related record keeping

No.	Type of Record	Minimum Retention Period (years)	USECHH Regulations Section
1	Mercury Health Risk Assessment (or CHRA) report	30	13
2	Exposure monitoring (personal) report	30 years	26 (4)(a)
3	Exposure monitoring (other case) report	5 years	26 (4)(b)
4	Health surveillance record	30 years	27 (4)
5	Engineering control equipment record (i.e. design, construction, testing, inspection, examination and maintenance records)	Not specified	19
6	Training record	Not specified	22 (4)
7	Waste Inventory & consignment notes	3 years	EQA (SW) 2005

Guidelines on Mercury Management in Oil & Gas Industry 2011

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Appendix A – Example of Commercially Available Direct Reading Instrument for Mercury Vapor

Detector	Limit of Detection	Analyte Measured	Accuracy	Sampling Time	Interferences	Observations
Jerome 411 Mercury Vapor Analyzer	0.003 mg/m3	Vapor	± 5% at 0.100 mg /m3	10 Seconds	Organic Mercury Compounds*	Temperature Range: 0 -40°C Battery Life: 4 hours Dimensions: 6" x 13" x 4"
Jerome 431 Mercury Vapor Analyzer	0.003 mg/ m3	Vapor	± 5% at 0.100 mg /m3	13 Seconds	Organic Mercury Compounds*	Temperature Range: 0 -40°C Battery Life: 6 hours Dimensions: 6" x 13" x 4"
SafeAir Gas Monitoring Badge	0.42 mg/m3 - 15 Minute STEL 0.013 mg/m3 - 8 hour TWA	Vapor	± 30 %	15 Minutes - 48 Hours		Direct Reading Badge Temperature Range: 0 -40°C Humidity Range: 15 - 87 %RH
ChromAir Gas Monitoring Badge	0.4 mg/m3 15 Minute STEL 0.02 mg/m3 - 8 hour TWA	Vapor	± 30 %	15 Minutes - 48 Hours		Direct Reading Badge Temperature Range: 0 -40°C Humidity Range: 15 - 87 %RH Average Concentration Determined locating the highest cell with color change and dividing the corresponding dose level (mg/m3 x hr) by the sampling time in hours
Nippon Instrument Corporation EMP-2	0.001 mg/m3	Vapor	± 5 %	1 Second	Acetone, Carbon Tetrachloride	Temperature Range: 0 -45°C Battery Life: 5 hours Dimensions: 4.5" x 8.7" x 10.1 "
Sensidyne Colorimetric Detector Tube (Mercury Vapor 142S)	0.01 mg/m3	Vapor	± 30 %	60-300 Seconds	Hydrogen Sulfide, Carbon dioxide, Chlorine, Nitrogen dioxide	Temperature Range: 0 -40°C 1 - 5 Pump Strokes Potential Interferences:
Draeger Colorimetric Detector Tube (Mercury Vapor 0.1/b)	0.05 mg/ m3	Vapor	± 30 %	15 - 600 Seconds	Free Halogens	Temperature Range: 0 -40°C 1 -40 Pump Strokes Potential Interferences:
Gastec Colorimetric Detector Tube (Mercury Vapor 40)	0.05 mg/ m3	Vapor	± 5 (2 - 6 mg/ m3) ± 10 (0.25 - 2 mg/m3)	30 -300 Seconds	Hydrogen Sulfide, Carbon dioxide, Chlorine, Nitrogen dioxide	Temperature Range: 0 -40°C 1 - 5 Pump Strokes Potential Interferences:

Appendix B - Guidance Notes for OHD in Conducting Medical Examination for Employees Exposed to Elemental Mercury at Work

No.	Scope	Detailed Description
1.	**Medical History**	A complete medical history with emphasis on: a. The Nervous system (the target organ for acute and chronic exposure) e.g. loss of coordination, tremor, etc. b. The Kidneys (the target organ for acute and chronic exposure) e.g. proteinuria, oliguria, anuria etc. c. The Oral Cavity (the target organ for chronic exposure) e.g. stomatitis, excessive salivation etc. d. The Lungs (the target organ for acute exposure) e.g. shortness of breath, cough, chest tightness, burning sensation etc. e. The Eyes (affected by the chronic exposure) e.g. redness and burning sensation of the eyes etc. f. The Skin (since mercury is known as the skin sensitizer) e.g. skin redness and itchiness g. Reproductive history e.g. difficulty to conceive among female employees (reduced female fertility rate)
2.	**Physical examination (General)**	a. Personality changes b. Weight loss c. Irritability d. Fatigue e. Nervousness f. Loss of memory g. Indecision h. Intellectual deterioration i. Tremor j. Loss of coordination
3.	**Physical Examination** **(Organ specific)**	To look for signs indicating affect on target organs , based on the medical history obtained and systemic review
4.	**Additional for baseline health surveillance**	Baseline Handwriting sample: indicating effect on central nervous system - small and cramped handwriting due to tremor -difficulty in holding the pencil due to loss of coordination