



# **A GUIDE TO REPORTING AND ESTIMATING EMISSIONS FOR THE INTEGRATED**



## **POLLUTANT AND WASTE INFORMATION SYSTEM (IPWIS)**

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## **AN INTRODUCTION TO THIS DOCUMENT: A Guide to Reporting and Estimating Emissions for the Integrated Pollutant and Waste Information System (IPWIS).**

This document is created by the Department of Environmental Affairs and Development Planning, to assist facilities in making effective use of data already available or readily attainable in order to estimate releases and transfers of priority pollutants, for the purpose of reporting to the IPWIS. This is not a complete guide; some specific industrial processes are not discussed, nor are the methods definitively recommended for specific applications. The guide is divided into 5 Parts, i.e. Part A to Part E.

**Part A** focuses on a background to the IPWIS, the Pollutant Release and Transfer Register (PRTR) and the 20 priority pollutants identified by the Department. It also looks at current monitoring of pollutants in the Western Cape. Emissions of these identified pollutants will be required to report to the Department's IPWIS.

**Part B** addresses the identification and reporting of the emissions. This section explains who needs to report, the information required for using estimation techniques, how to identify pollutants released and transferred and how the actual reporting should be done.

**Part C** provides a guideline to estimate emissions of the priority pollutants. This section demonstrates how this guide should be used and the purpose and benefits thereof. It also explains the Emission Estimation Techniques in detail with a few given examples to demonstrate how to use the techniques. A step by step guide from data collection to the final estimation of emission is provided.

**Part D** is the PRTR Reporting form. This is the form that will be used by all facilities for the reporting of emissions. Reporting will also be done online by some facilities. A hard copy of the reporting form is provided.

**Part E** provides a detailed guide on how to complete the Reporting form. Definitions, clarifications, examples of cleaner production/source reduction technologies, etc. are listed.

**PART A: BACKGROUND ON  
THE IPWIS AND THE  
POLLUTANT RELEASE AND  
TRANSFER REGISTER (PRTR)**

## **1. BACKGROUND**

Globally, and historically, pollution and waste management was not regarded as a priority issue. In South Africa and the rest of the world pollution and waste management focused mainly on waste disposal and end of pipe treatment, as a result this approach to pollution and waste management has had serious negative impacts on the environment. It was not until the late 20<sup>th</sup> century that new focus was given to the environmental consequences of uncontrolled pollution and waste disposal. This consideration has created an awareness of the “bigger picture” and has cultivated a more integrated approach to pollution and waste management. With this approach came the need for control over the pollutant and waste cycle, which in turn highlighted an even greater need of information related to the pollutant and waste cycle.

### **1.1 Waste Information System (WIS)**

Many developed countries e.g. United States of America, Australia, Sweden etc. have to date, established comprehensive WIS's, to satisfy their growing information needs with respect to waste management. However in South Africa and especially the Western Cape, consistent and accurate information related to the waste cycle is limited due to a plethora of inadequacies that include amongst others, legislation. The information sets or databases that do exist are inconsistent, not regularly updated, incomplete and not representative which limits their use and application. This situation is characteristic of all the provinces throughout South Africa.

The absence of a functional WIS in South Africa is identified as a critical area of concern, which is why the need for its development has been highlighted in several white papers and policies; which includes the; National Environmental Management Act and the White Paper on Integrated Pollution and Waste Management. The National Waste Management Strategy and Action Plan for the WIS outlined key objectives and deliverables with stipulated delivery time frames. Due to these requirements not being satisfied i.e. deliverables not being achieved within the allocated time frame and the growing need for a WIS in the Western Cape, it was agreed that the Western Cape Province embark on a separate project to establish a fully functional WIS which will be able to satisfy the information needs of all stakeholders. In addition to this the WIS will

have the benefit of being used as a monitoring and planning tool to assess the status of all NWMS initiatives in the Western Cape.

### **1.2 Pollutant Release and Transfer Register (PRTR)**

The PRTR is a catalogue or register of potentially harmful chemical pollutants including information on the nature and quantity of such releases and transfers to the environment (i.e. air, water and land) from a variety of sources. The PRTR will allow for the tracking of trends over time, the use of common identifiers for chemicals, facilities and locations to facilitate comparison of data and the dissemination of information to stakeholders and other interested parties. The PRTR will also allow for reporting on individual pollutants/chemicals by individual industrial facilities periodically with consistently structured data.

A PRTR system may include point source data reported from individual facilities, as well as information on releases and transfers from non-point sources such as agricultural operations and transportation activities. This document focuses on the estimation of point source PRTR data by individual facilities.

One potential application of PRTR information includes the mapping of data using Geographical Information System (GIS) in order to determine the proximity of pollution sources to population centres or ecologically sensitive areas, thereby highlighting potential health or environmental impacts of those pollutants and effectively targeting the management thereof. The PRTR is therefore a tool for promoting efficient and effective policies for environmental protection and sustainable development.

### **1.3 Integrated Pollutant and Waste Information System (IPWIS)**

The Integrated Pollutant and Waste Information System (IPWIS) integrates the functions of both a PRTR and a WIS. The Department of Environmental Affairs and Development Planning (DEADP): Pollution and Waste Management Directorate, is in the process of developing an Integrated IPWIS for the Western Cape. The aim of this project is to develop an IPWIS that would help authorities regulate the pollutants and waste cycle as well as to provide accessible information to interested and affected parties. In so doing, the IPWIS would support effective integrated pollution and waste management. It is envisaged that this system would allow for the successful collection, analysis, storage

and dissemination of data related to the pollutant and the waste cycle i.e. the generation, storage, collection, handling, transport/transfer, treatment and disposal of all waste types and pollutants and would thus provide the mechanism which integrates the functions of both a PRTR and WIS.

#### **1.4 Priority Pollutants**

The Priority Pollutants refers to the list of pollutants identified, on which industries will have to report on. The list of Priority Pollutants is included on Table 4. The list was compiled using different criteria and sources. Some of the criteria and sources are discussed below.

##### ***1.4.1 Pollution and chemical monitoring in the Western Cape***

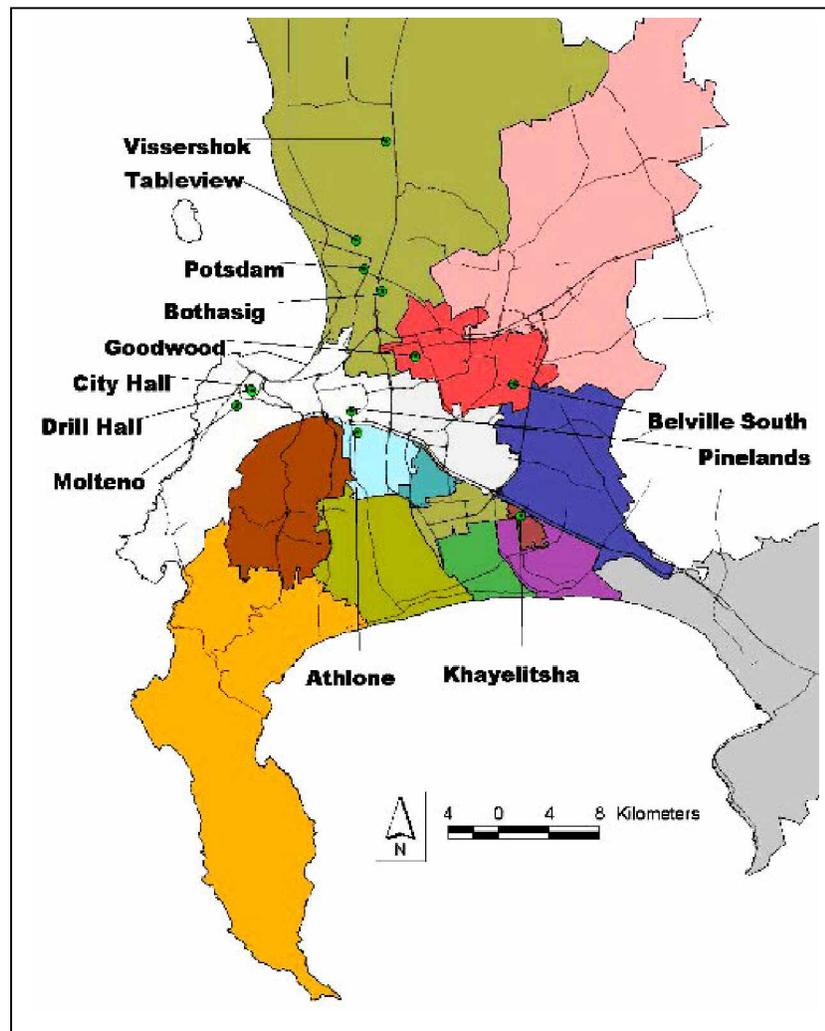
The pollutants/chemicals that are monitored for by the air pollution and water authorities in the province are included in the priority list. A list of chemicals that constitute the pollutants/chemicals that are monitored for in the effluent of industries in the province was requested and provided by the Department of Water Affairs and Forestry (DWAF). Chemicals monitored for in drinking /municipal water were requested from the City of Cape Town's water quality division and municipalities within the province. The list of atmospheric pollutants monitored in the province (Cape Town only) was provided by the City of Cape Town's air quality division.

##### **1.4.1.1 City of Cape Town: Air Quality division**

The Scientific Investigation Services monitors the City's atmospheric pollutants under the auspices of the City of Cape Town's Air Quality Division. The pollutants that are currently being monitored by the City of Cape Town appear in Table1 below. These pollutants are recorded at various monitoring sites as illustrated in Figure 1.

**Table 1: The Atmospheric pollutants as monitored by the City of Cape Town**

1. Particulate Matter less than 10 $\mu\text{g}/\text{m}^3$ ( $\text{PM}_{10}$ )
2. Particulate Matter less than 2.5 $\mu\text{g}/\text{m}^3$ ( $\text{PM}_{2.5}$ )
3. Sulphur Dioxide ( $\text{SO}_2$ )
4. Nitrogen oxides ( $\text{NO}_x$ )
5. Ozone ( $\text{O}_3$ )
6. Carbon Monoxide ( $\text{CO}$ )
7. Hydrogen Sulphide ( $\text{H}_2\text{S}$ )



**Figure 1: Locations of the atmospheric pollution monitoring stations in the City of Cape Town**

#### 1.4.1.2 City of Cape Town: Water Quality division

Water for drinking purposes is the jurisdiction of the municipality within each district in the province. The chemicals that are monitored appear in Table 2.

**Table 2: Chemicals monitored in water by municipalities**

1. Aluminium
2. Ammonia
3. Calcium
4. Chloride
5. Copper
6. Fluoride
7. Iron
8. Lead
9. Magnesium
10. Manganese
11. Mercury
12. Nickel
13. Nitrogen
14. Phosphorus
15. Potassium
16. Sulphide
17. Sulphur

#### 1.4.1.3 Department of Water Affairs and Forestry (DWAF)

DWAF does not specially monitor for chemical pollutants in the water unless there is a request for or complaint of that substance. However, it is mandatory for certain industries in the Western Cape to monitor for certain residual/pollutants in their wastewater. These Industries/applicants of a wastewater license (from DWAF) specify what they should be monitoring for in their wastewater that is not normal to other wastewater, such as heavy metals and pesticides. A comprehensive list of the measurable pollutants/chemicals in the water (either wastewater or river water) was obtained from DWAF.

**Table 3: Chemical pollutants as monitored by DWAF**

1. Ammonia
2. Chromium
3. Copper
4. Cyanide
5. H <sub>2</sub> S
6. Iron
7. Lead
8. Mercury
9. Nickel
10. Phenol
11. Sulphide
12. Vanadium
13. Zinc

#### **1.4.1.4 Department of Environmental Affairs and Tourism (DEAT)**

DEAT does not perform quantitative monitoring or own any pollution monitoring stations in the province. However, the province does have a Chief Air Pollution Control Officer (CAPCO) who deals with the issuing of licenses and permits of scheduled processes as stipulated in the Atmospheric Pollution Prevention Act of 1969; air pollution related matters as well as compliance monitoring.

#### **1.4.2 Pollutants prevalent in the Western Cape**

A Provincial Chemicals Profile was compiled by the Department. This profile assisted in identifying the size and distribution of chemical sectors within the province. Thereafter, desktop and interactive investigations and interviews were conducted with the various municipalities and departmental representatives in the province who deal with chemical management according to the sectors identified in the profile (such as manufacturing, transportation, agricultural, etc.). Comprehensive information on air pollution complaints, hot spots, frequency of complaints, location of industries and number of facilities emitting pollutants were provided by the local municipalities/authorities and the DEAT.

In September 2004, the department hosted an interactive stakeholders/authorities workshop in order to identify the pollutants prevalent in the Western Cape Province. An initial list of 20 pollutants (*Table 4*) were identified according to various criteria, such as its prevalence, toxicity, media (air water, soil), practicality of monitoring/measuring, whether it is currently being monitored and if we have statutory obligations towards the pollutant. This list of 20 pollutants was expanded to a list of individual chemical species (or groups, as appropriate), uniquely identified by their Chemical Abstracts Service Registry (CASR) numbers, presented in Table 4. The information on these pollutants will populate the PRTR and will thus give effect to the IPWIS. Hence the facilities/industries that emit these pollutants would have to provide accurate information on the emissions of these pollutants. This document will assist companies to estimate their emissions using one of the methods in this Guide, and to report their emissions in a standard format. Emissions of all pollutants, from all sources, will be collated and published in the form of an annual report.

**Table 4: The DEADP's priority pollutants of the PRTR which require emission quantification and reporting (in no particular order of priority)**

	<b>Pollutant Group</b>	<b>Pollutant</b>	<b>CAS</b>
1	<b>VOC's</b>	Benzene	71-43-2
2		Toluene	108-88-3
3		Ethylbenzene	100-41-4
4		Xylene	1330-20-7
5		Carbon tetrachloride/ tetrachloroethylene (CCl <sub>4</sub> )	56-23-5
6	<b>Heavy Metals</b>	Iron (Fe) Compounds	1309-37-1
7		Lead (Pb) compounds	7439-06-4
8		Mercury (Hg) compounds	7439-97-6
9		Chromium (Cr) III and VI compounds	7440-47-3
10		Cyanide (Cn) compounds	1445-995-1
11	<b>Particulate Matter</b>	Particulate Matter <10 ug/m <sup>3</sup> (PM <sub>10</sub> )	EDF-077
12		Particulate Matter < 2.5 ug/m <sup>3</sup> (PM <sub>2.5</sub> )	EDF-213
13	<b>Polychlorinated Biphenyls (PCB)</b>	Any applicable PCB	1336-36-3
14	<b>Polycyclic Aromatic hydrocarbons (PAH)</b>	Any applicable PAH	65996-93-2
15	<b>Dioxins &amp; Furans</b>	Any applicable dioxin and furan	100-00-9
16	<b>Others</b>	Ammonia (NH <sub>3</sub> )	7664-41-7
17		Carbon dioxide (CO <sub>2</sub> )	124-38-9
18		Carbon monoxide (CO)	630-08-0
19		Nitrogen oxides (NO <sub>x</sub> ), i.e. Nitrogen dioxide (NO <sub>2</sub> ), Nitric Oxide (NO)	10102-44-0
20		Ozone (O <sub>3</sub> )	10028-15-6
21		Phenol	108-95-2
22		Sulphur dioxide (SO <sub>2</sub> )	7446-09-5

### 1.5 Estimating Emissions for reporting purposes

The first step for the company manager is to determine if the facility has to report to the IPWIS. This entails reviewing the reporting criteria and deciding if they apply to the facility. This will depend on the processes and the emissions of the priority pollutants). It is always worth investigating whether the facility needs to report based on the list of identified priority pollutants. Managers can utilize the available expertise and resources

within the facility to calculate their emissions. There are several estimation techniques that may be adopted. This document provides some of these techniques and examples of estimating the emissions of pollutants and hopes to assist facilities/industries with estimating their emissions if they do not do so presently. This guide also envisages assisting and encouraging continual reporting of emissions.

*Figure 1* illustrates the supplementary documents for reporting and estimation purposes, i.e.:

- The Emission Reporting form for the PRTR (Parts B and D of this document)
- The Emission Estimation Techniques (EET) Guideline Document (Part C) and
- The Reporting form Guideline Document for the PRTR (Part E)

This is a first generation of the document as it will be revised on a continual basis. Reporting to IPWIS should be considered long term for important reasons. Like most tasks, reporting will get easier with each year and it will be good experience for facilities. Another important reason to report to the IPWIS is that facilities can use the data within the facility, both as a means of identifying and implanting reduction opportunities, and for assessing how the changes in activities at the facility have led to changes in pollutant release and transfer levels from year to year. It is also important that the facility keeps records of all reported data for their own use.

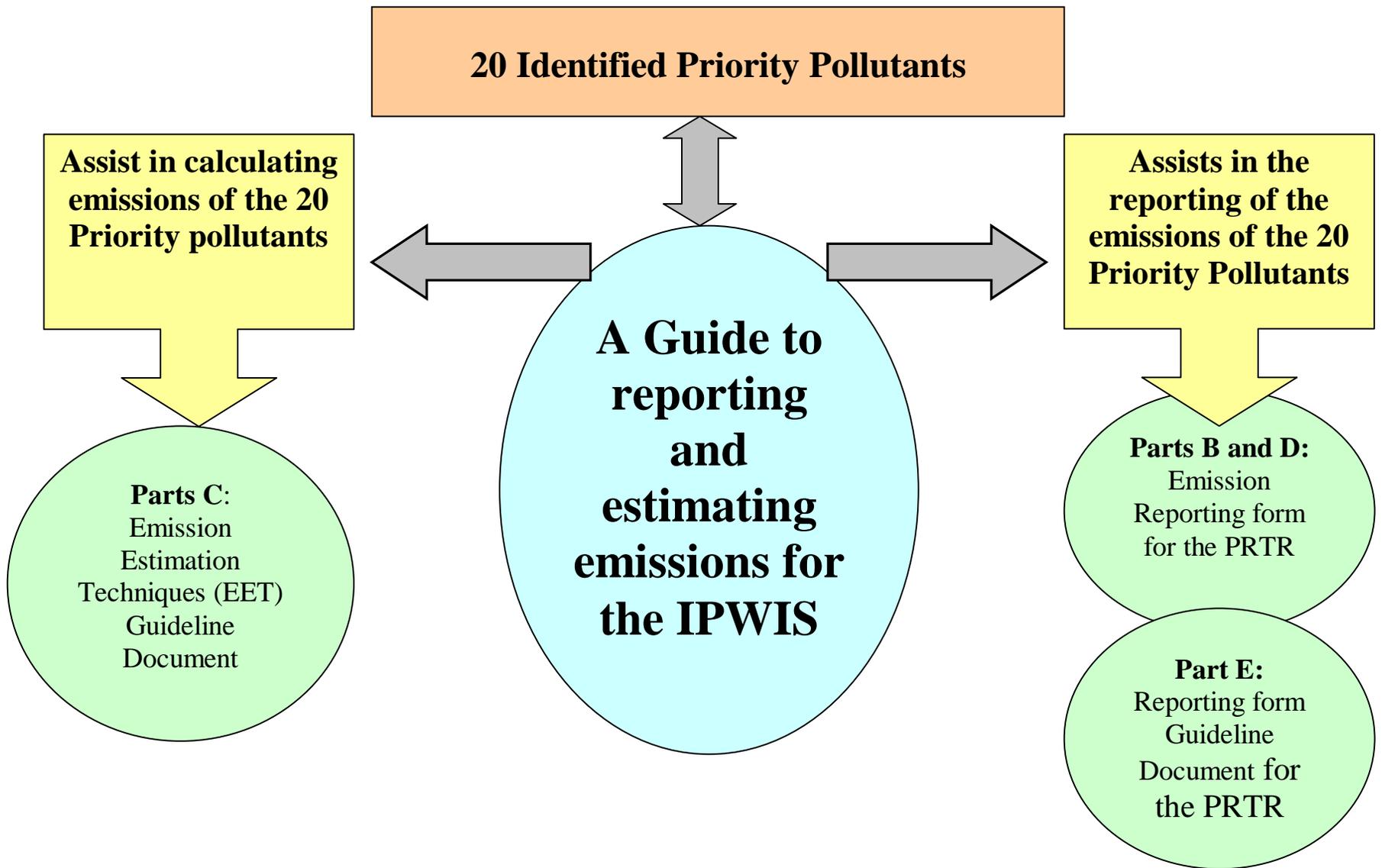


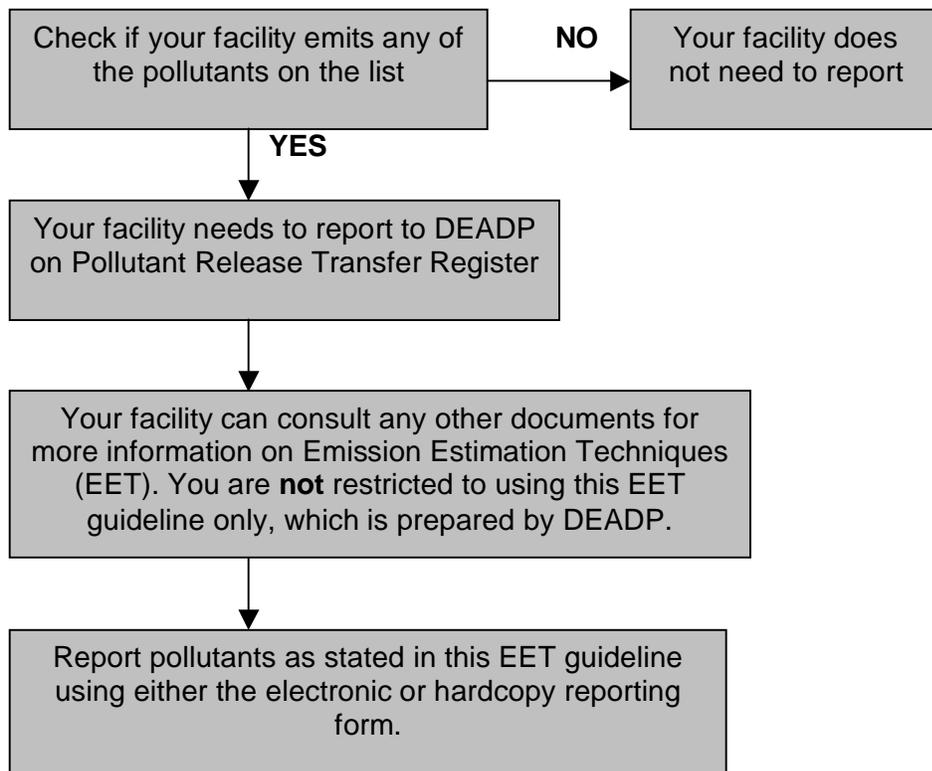
Figure 2: Guideline documents required in order to report on the emissions of the Priority Pollutants

# **PART B: IDENTIFYING AND REPORTING EMISSIONS**

## 1. WHO IS REQUIRED TO REPORT?

Any facility emitting any of the pollutants identified in this document as priority pollutants must report. Reporting must be done regardless of the amount emitted. Only emissions from a stationary point source need to be reported i.e. stacks, vents, etc.

### *To Report or Not To Report Pollutants*



## 2. INFORMATION REQUIRED FOR ESTIMATING AND REPORTING POLLUTANT EMISSIONS (RELEASES) AND TRANSFERS

One will be required to fill in the reporting form. There are four sections to the forms, each section requiring different type of data. The form is divided into:

**Form A:** Facility Identification Data

**Form B and C:** Pollutant Release Inventory Form

**Form D:** Emission Reduction Activities...

Prior to using this guide to calculate emissions, the facility manager should consider the following prerequisites:

### 2.1 Prerequisites for the guide

Each facility should assign a PRTR reporting co-ordinator. A single co-ordinator will provide a clear link within the facility as well as to The Department for reporting purposes. The person or people designated to coordinate PRTR reporting should be familiar with the facility, its processes and the products produced. Facilities usually find that the environmental managers or plant engineers are the people with this type of knowledge. What is more important to the success of the IPWIS is commitment from senior management to allocate the time, resources, and assistance necessary. For every facility it is important for the coordinator to:

i) Identify and describe the process

The process of the facility should be known to be able to identify different emission sources.

ii) Identify type of equipment

This is important for selecting emission factors for certain set of pollutants.

iii) Identify the emission sources

This should be identified prior to doing calculations, so that all possible emissions are accounted for in the results.

iv) Know the process activity, i.e. the quantity of fuel burned.

This provides the quantity of input material to the process equipment and will be used by mass balance and emission factor methodologies as described later. Fuel consumption can be obtained from utility bills or from acquisition records.

v) Know the fuel analysis – for mass balance.

These are physical characteristics and fuel composition and can be obtained from the fuel supplier or performed by analytical laboratories. Fuel analysis gives information of the contaminant contained in the fuel and potential emissions. Mass balance can be used to calculate the emissions of certain metal contaminants.

vi) Know the Controlling Contaminant(s) and Control Efficiency(ies)

These are normally installed devices/techniques and can be obtained from the device manufacturer or from on-site test results

vii) Know exhaust Stack/Vent ID & Description

These can also be obtained from the device manufacturer or on-site test results

viii) Know solvent properties

If a solvent is used within a facility, the information can be obtained from the Material Safety Data Sheet (MSDS) that comes with the solvent. The MSDS lists the concentration of hazardous contaminants in various solutions and can be used to calculate the emissions of the contaminant.

ix) Know the units of measurements

It is crucial that appropriate units of measurement are used in the applicable equations otherwise calculated results will be miscalculated resulting in incorrect values being reported. It is important that when doing calculation, the final answer should be converted to the units given in the reporting form to ensure uniformity.

## **2.2 Select Estimation Method(s)**

Prior to collecting applicable data it is important to select the method(s) to be used to estimate emissions for a particular process.

## **2.2 Data Collection**

Having selected estimation method(s) one can go about collecting data to be used for calculations. This is more likely to come from various sources depending on process and selected method(s) i.e. materials accounting data, process data, general engineering data, material and product specification data, etc. Other departments/personnel within a facility may need to provide a duplicate set of data to be stored with the PRTR coordinator. If the facility already collects data, it may have to be redesigned in order to include new data elements that are needed for the PRTR reporting.

#### Materials accounting data

Specifically the amounts of substances brought on site, amounts of substances produced on site, consumed on site, and shipped in product, as well as inventory data for reportable and non-reportable substances. These data can be used to calculate total use, as well as to estimate releases and transfers.

#### Process data

This data includes inputs and outputs for each production process, and specific sources of releases and off-site transfers. This also includes an equipment inventory, since some fugitive air emissions can be estimated by the number of compressors, valves, and fittings in the processes.

#### General engineering data

Engineering data includes equipment specifications, general reference data for specific processes, and physical and chemical property data for reportable substances. These data are used to estimate loss quantities and efficiencies, especially in the absence of monitoring data.

#### Material and product specification data

This data includes Material Safety Data Sheets (MSDSs). This information can be useful in identifying the composition of the chemical materials and products used at the facility.

Not all of these types of data will be collected by those responsible for environmental compliance. Environmental personnel are most likely to have data compiled for other environmental reporting requirements, as well as data from any monitoring conducted at the facility. However, additional types of information needed for PRTR data estimation will be found in other departments or with other personnel. For example, data on materials brought on site are usually available from the purchasing department, and information on products shipped would be available from shipping or accounting. Routine operating data are available from process or product managers, as is information on possible sources of releases.

### **3. IDENTIFYING POLLUTANT RELEASES AND TRANSFERS FOR PRTR REPORTING**

#### **3.1 Pollutant release and transfers**

Any amount of a substance that is brought or produced on site and does not end up as a product, is not consumed in processing, and is not stored in inventory is waste. Waste can be managed on site, released to the environment, or transferred off site for recycling, energy recovery, treatment, or disposal. A PRTR tracks the amounts and types of environmental releases and transfers of substance-specific wastes from individual facilities (UNITAR and IOMC, 1998).

##### **3.1.1 Environmental releases**

These are direct discharges to air, water or land, whether intentional or not. These releases include fugitive air emissions, point source air emissions, surface water discharges, direct discharges to land, and disposal in on-site landfills. Under a PRTR system, facilities report the quantity of each reportable substance released to each environmental medium.

##### **3.1.2 Air Emissions**

These emissions are divided into point source air emissions and fugitive air emissions. The difference between the two is based on intent. Point source air emissions come from equipment vents, ducts, or pipes that are designed to be air discharge points. Fugitive air emissions are usually unintentional and occur because of equipment leaks or uncontained transfer or storage procedures. Discharges from building ventilation systems are also fugitive emissions.

##### **3.1.3 Surface water discharges**

These are releases into bodies of water such as streams (natural or man made), oceans, and rivers. These include direct discharge of process waste streams as well as waste streams resulting from on-site waste management, such as wastewater treatment. Discharges to holding ponds are not surface water discharges, but are on-site land disposal as long as the holding pond is the final destination. Discharges to municipal treatment works are generally reported as off-site transfers rather than as releases.

### **3.1.4 Releases to land**

Releases to land include discharges of slurries, solids, sludge, and some non-aqueous liquids. These discharges may result from on-site waste treatment or direct discharges from production processes. Releases to land also include discharges to on-site landfills, surface impoundments, and land farms.

### **3.1.5 Off-site transfers**

*These are wastes which facilities send off site for recycling, energy recovery, treatment, and disposal.* In general, waste handlers require facilities to tell them how much of specific chemicals are present in waste shipped off site, so amounts of chemicals in off-site transfers are usually monitored and listed on waste shipping manifests.

## **3.2 Identifying transfers and releases for reporting purposes**

When identifying the transfers and releases for reporting purposes, the following questions must be asked.

- i) What products are produced?
- ii) Do these products contain any of the 20 priority pollutants as identified by the department as formulation components?
- iii) Do these products contain any of the 20 priority pollutants as impurities, such as unremoved byproducts, solvents, or catalysts?
- iv) Are any substances present as inert ingredients?
- v) Are any substances present in packaging materials?
- vi) Is there any required documentation that will list the substances contained in the products, such as MSDSs or customer-required quality control measurements?
- vii) Are any in-house measurements available for these products that will help determine if they contain reportable substances, such as process control or quality control monitoring?
- viii) What production processes are used to produce each product?
- ix) Do any non-production processes, such as storage or wastewater treatment, use reportable substances?
- x) Are any priority pollutants added to the process that gets completely consumed?
- xi) Are any priority pollutants produced in the process?

- xii) Are any priority pollutants produced as intermediates (produced and consumed in the process)?
- xiii) Are any priority pollutants used as solvents, as catalysts, or in other ways that do not end up in the final product?
- xiv) Have possible sources of emissions been identified?
- xv) Have all possible sources of data on specific substances been gathered? Are batch production sheets available?
- xvi) Have all operating data been gathered, including down-times in production and other data such as spills and worker exposure?

The best way to determine if substances are used or produced in a process is to take a walk-through of the plant and looking at each piece of equipment and flow stream. It will also be beneficial to consult with the plant personnel who operate the equipment and processes.

#### **4. REPORTING TO THE PRTR**

##### **4.1 Reporting Thresholds**

Some PRTR's require facilities to report on any substance present on site, no matter how small the amount or what the substance is used for. Typically, however, PRTR reporting is based on the amount of the substance used in the reporting year. That is, there is usually a use threshold for reporting a particular substance. If the facility's use of a substance meets that threshold, all releases and transfers must be reported, even if they are zero. Thus far the department's PRTR System (IPWIS) has not established any thresholds although there are plans to define them in future.

##### **4.2 Reporting to the PRTR System**

The Department's reporting forms will be completed for each facility either electronically via the internet (web-based when IPWIS is up and running) or manually (faxed or posted) and submitted to the department regularly on a predetermined frequency. The reporting will be addressed in more detail in Parts D and E. A reporting period has not been determined as yet.

# **PART C: GUIDE TO ESTIMATING EMISSIONS**

## **1. HOW TO USE THIS GUIDE TO ESTIMATE EMISSIONS**

Four methods of estimating the emissions have been suggested in this guide. These are not the only method of estimating emissions and must be used with caution, as some techniques may be applicable to certain scenarios or pollutants. Depending on the availability of data and type of processes, an appropriate method may be chosen and followed. At least one example per method has been provided in the guide. If the process allows the use of more than one method, it is suggested that all methods be attempted for comparison and verification purpose.

A list of pollutants to be reported on is provided in Section 2.0 of this guide. At this stage only 20 pollutants should be reported on, with more being added onto this list at a later stage.

## **2. PURPOSE AND BENEFITS OF THIS GUIDE**

The DEADP has identified a list of 20 pollutants within the province. These pollutants appear in Section 2 of this guide. The facilities/industries that emit these pollutants (the number of these pollutants will increase each year so as to include other important pollutants within the province) will be required to report on the emission of these priority pollutants on a frequent basis (frequency to be determined). The Department of Trade and Industry SIC Codes for grouping facilities/industries is adapted in this guide. More information on this can be found on [www.dti.gov.za/](http://www.dti.gov.za/).

This guide provides various techniques and examples of estimating the emissions of pollutants and hopes to assist facilities/industries with estimating their emissions if they are not doing so presently. The guide also envisages assisting and encouraging continual reporting of emissions.

This guide will serve to assist particularly those facilities/industries that have not monitoring their release of pollutants to the environment. Applicable examples and equations provided in this guide will assist these facilities/industries to calculate their emissions.

The guide presents estimation techniques that are easy to understand and use for the calculations. It also provides further insight into data monitoring and calculations. The guide envisages encouraging industry to begin reliable monitoring or to expand their monitoring systems. Finally, some components of this guide provide useful and informative background information on the various pollutants and the various estimation techniques.

### **3. EMISSION ESTIMATION TECHNIQUES**

There are many examples of types of emission estimation techniques, they are:

- Sampling and direct measurement / Continuous Emission Monitoring System (CEMS)
- Predictive Emission Monitoring (PEM)
- Source Testing
- Mass Balance
- Emission Factors
- Emission Estimation Model
- Engineering Calculations

Four methods have been chosen, as they are more common and are easy to use. The selection of estimation methods depends largely on the type and quality of data already collected by the facility or which are easily available. Facilities routinely collect many different types of data for everyday operations. The facility must select techniques that are applicable to the facility's emission processes. In most cases, a combination of techniques will be required by the facility. The four estimation techniques illustrated in this guide are:

- 3.1 Sampling or direct measurement
- 3.2 Mass balance
- 3.3 Engineering Calculations
- 3.4 Emission factor

### **3.1 Continuous sampling and direct measurement (continuous emission monitoring system)**

This method provides a continuous record of emissions over an extended and uninterrupted period of time and is also known as Continuous Emission Monitoring System (CEMS). Various principles are employed to measure the concentration of contaminants in the gas stream; they are usually based on photometric measurements. Once the containment concentration and the flow rate are known, emission rates can be obtained by multiplying the contaminant concentration by the volumetric stack gas flow rate. The emission can then be calculated from this data.

### **3.2 Mass balance technique**

Mass balance technique involves the quantification of material flows going into and out of a process, where one could use the information of the inputs and outputs to estimate the discharge to the environment. This method can be applied to an individual process unit or to the overall process, and the process and information available about the process streams will determine that. All streams and information about the inputs and outputs must be accounted for. For cases where the assumption made above is relaxed, particularly when there is a chemical reaction, the reactions taking place have to be incorporated accordingly in the equation, since a substance could either be produced or consumed in the system.

In some cases a material accumulates within the system over a certain period and that depends on the process being looked at. When doing the mass balance, all of the information mentioned above must be considered and when assumptions are made they should be appropriate or justifiable.

It is important to recognize that the estimates derived by using mass balances are only as good as the values used in the calculations. For example, small errors in data or calculation parameters (e.g. pressure, temperature, stream concentration, flow, control efficiencies, etc) can result in large errors in the final emission estimates. Additionally, failure to use representative samples when sampling input or output materials will also contribute to the uncertainty of the result.

### **3.3 Engineering calculations**

Engineering Calculations are used to estimate releases to all media and can be used when direct measurement is not possible. These are the kind of calculations Chemical and Mechanical Engineers are trained to perform. Engineering calculation tools are available from different sources; these include textbooks, engineering handbooks, and equipment manufactures. They are an inexpensive and accurate way to estimate releases, especially small amounts of releases. The wide range of engineering tools for many applications includes estimation of material remaining in empty containers, evaporation losses (of organics) from water treatment plants.

#### **3.3.1 Estimating Point Source Air Emission by Engineering Calculation**

Facilities may use engineering calculation to estimate point source air emissions. Efficiency specifications from pollution control equipment such as scrubbers, absorbers, adsorbers, cyclones, baghouses and filters, may be used as basis of estimating air discharges when loading rates are known. If equipment specifications are not available, unit operation textbooks may be used, e.g. Perry's *Chemical Engineering Handbook* and many other standard engineering references are valuable resources.

#### **3.3.2 Estimating Surface Water Discharges by Engineering Calculations**

Facilities can discharge huge amounts of wastewater, especially when rainfall runoff is treated on site; however facilities may discharge small amounts of reportable substances to surface water

#### **3.3.3 Estimating Releases to Land by Engineering Calculation**

Releases to land usually occur as a result of specific unit operations, engineering calculation is an important estimation method, particularly for sludge and slurries. To estimate the amount of various substances removed from liquid streams, equipment specifications for filters and centrifuges can be used. These specifications can be obtained either from the manufacturer, published values or by measurements.

To apply an engineering assessment method, there are four basic principles that should be followed:

- Review all data pertaining to the specific emission source and to the industrial sector in general
- Use data to provide gross approximations and refine these using sound engineering principles as data becomes available to provide more accurate estimation
- Whenever possible, alternate methods of calculation should be conducted to cross-check each level of approximation; and
- Employ good record keeping which involves documenting all related information for further emission refinement when more accurate data becomes available.

### **3.4 Emission factors:**

Emission factors are dependent on several factors, including process conditions and the presence or absence of emission control equipment. Care should be exercised to use emission factors applicable to the facility under consideration. Available emission factor data for air releases, range from valves and fittings leak rates to emission factors for entire processes or plants.

Emission factors are factors that are multiplied by flow rate, quantity of production, or other measures to yield releases, usually air emissions. A facility can calculate emission factors of its own use based on measurement or rely on published emission factor data. Emission factors can be flow-rate or chemical dependent and should be carefully selected to fit the situation. Emissions factors are used mostly for air emissions, although the World Health Organization (WHO) has published emission factors for surface water discharge and land disposal for certain processes in *Rapid Inventory Techniques in Environmental Pollution*.

#### **4. A STEP BY STEP GUIDE TO CALCULATING EMISSIONS**

There is a step-by-step procedure that needs to be applied to calculate /estimate emissions. Example on how each of the Estimation Techniques may be applied is included in a form of calculation examples. The steps are as follows:

- 4.1 Identify emission sources within the facility
- 4.2 Check the list of estimation methods
- 4.3 List data/ information needed for each method
- 4.4 List available information
- 4.5 Select emission estimation Technology/Technique, this must not only be based on the information you have, but also on the applicability to the process, and measuring instruments that can be acquired to get necessary data
- 4.6 Gather supporting information for calculating emissions; and
- 4.7 Calculate emissions

##### **4.1 Identify the emission source/s within the facility/industry**

The first and very important step of the process is to identify any process within the facility that may release pollutants. Process flow diagrams could be good indicators of emission generators or process units likely to cause emissions. The other useful information with this regard can be obtained from the process staff, since they have a better idea of what is happening out in the plant. Although processes differ from industry to industry, the main sources of emissions can generally be grouped into 5 categories namely:

- 4.1.1 Combustion (e.g. Boiler, furnace, heater, etc)
- 4.1.2 Manufacturing / Processing (e.g. blast furnace, chrome plating)
- 4.1.3 Solvent evaporation (e.g. degreasing, cleaning, printing, painting, etc)
- 4.1.4 Storage (e.g. Silos, tanks, etc.); and
- 4.1.5 Fugitive (e.g., exposed storage piles, road dust, equipment leakage, etc)

#### **4.2 Check list of estimation methods**

The types of estimation methods have been listed below:

- Sampling or direct measurement
- Mass balance
- Engineering Calculations
- Emission factors

#### **4.3 List data/information needed for each estimation method**

South Africa has not yet produced a comprehensive set of EET guides for all processes. Therefore for uniformity of methods, the Australian National Pollutant Inventory will be used as a reference source. Another EET guide may only be used if the Australian guide is not available or is not appropriate to local process flow sheet. This kind of information is process specific i.e. applicable to your process. The examples provided in the guide will give an idea of how the calculations can be done although these examples are just a fraction of different processes existing.

#### **4.4 List available information**

Once all information or data required by each estimation technique is available, choose the most appropriate (preferably with most data) method for the different processes.

#### **4.5 Select the emission estimation technique or method**

Once emission sources within a facility are identified an emission estimation methodology must be chosen. There are several methodologies available for calculating air emissions from the processes at the facility. The choice of methodology depends entirely on the available data. It is more useful if the data available (e.g. emission factors) is specific to the operations of the plant and not industry average data.

#### **4.6 Gather the supporting information for the emissions calculations**

At this stage the information/data available has been identified, and the emission estimation methodologies have been chosen for the emission sources, the next step is to gather the necessary information required by that specific methodology in order to do calculations.

## **4.7 Calculate emissions**

When all emissions processes are identified, emission methodologies are selected and related information are obtained, the next step is to calculate the emissions. Examples of few emission estimation techniques will be shown below.

### **4.7.1 Calculation of Annual Emissions Using Direct Measurement /CEMS**

This method is usually used for point source air emissions, surface water discharges and releases to land. Benefits of using this method include:

- Facilities may already measure waste streams, releases, and process streams for reason other than PRTR reporting.
- When monitoring data is good, Direct Measurement is probably the most accurate estimate of release.
- Direct Measurement is the method that is most likely to give unexpected results, which not only gives a more accurate estimate of releases but also alerts plant personnel to changes in operating conditions.
- Direct Measurement of releases may satisfy government monitoring requirements, such as permits and compliance.

An Example of estimation emissions using Direct Measurement follows below:

#### **Example of Direct Measurement**

Firstly; it is important that the correct raw data is available before any estimation is done. The kind of data needed for Direct Measurement Technique is indicated by the equations below. **Equation 4.7.1** is used to calculate hourly emissions of the pollutant required.

**Equation 4.7(a)**

$$E_i = \frac{(C * MW * Q * 3600)}{22.4 * \left\{ \frac{(T + 273)}{273} \right\} * 10^6}$$

Where:	E <sub>i</sub>	=	emissions of pollutant i, kg/hr
	C	=	pollutant concentration, ppmv,d
	MW	=	molecular weight of the pollutant, kg/kg-mole
	Q	=	stack gas volumetric flow rate, m <sup>3</sup> /s
	3 600	=	conversion factor, s/hr
	22.4	=	volume occupied by one mole of gas at standard temperature and pressure (0°C and 101.3 kPa), m <sup>3</sup> /kg-mole
	T	=	temperature of gas sample, °C

The kind of data required to calculate the emission rate of the pollutant is shown above. The table below, **Table 4.7.1** is an example of the kind of data used for Direct Measurement and the results obtained using related equations.

**Table 4.7.1: Raw data of O<sub>2</sub> % by volume, gas flow rate, combustion rate as well as the SO<sub>2</sub>, NO<sub>x</sub>, CO and VOC concentrations.**

Time	O <sub>2</sub> (% O <sub>2</sub> by volume)	Concentration (C) (ppm <sub>vd</sub> )				Gas Flow Rate (Q) (m <sup>3</sup> /s)	Combustion Rate (A) (tonnes / hour)
		SO <sub>2</sub>	NO <sub>x</sub>	CO	VOC		
1	10.3	150.9	142.9	42.9	554.2	8.52	290
2	10.1	144.0	145.7	41.8	582.9	8.48	293
3	11.8	123.0	112.7	128.4	515.1	8.85	270

Source: Queensland Department of Environment and Heritage, 1998.

\*ppmvd = parts per million volume dry

Actual **annual emissions** can be calculated by multiplying the emission rate in kg/hr by the number of actual operating hours per year (OpHrs) as shown in **Equation 4.7(b)** for each typical time period and summing the results.

**Equation 4.7(b)**

$$E_{kpt,i} = \sum (E_i * OpHrs)$$

**where:**

<b>Ekpy, i</b>	=	annual emissions of pollutant i, kg/yr
<b>Ei</b>	=	emissions of pollutant i, kg/hr (from Equation 4.7(a))
<b>OpHrs</b>	=	operating hours, hr/yr

Emissions in kilograms of pollutant per tonne of oil consumed can be calculated by dividing the emission rate in kg per hour, by the oil consumption rate (tonnes per hour) during the same period (**Equation 4.7(c)**) as shown below. It should be noted that the emission factor calculated below assumes that the selected time period (i.e. hourly) is representative of annual operating conditions and longer time periods should be used for reporting where they are available.

**Equation 4.7(c)**

$$E_{kpt,i} = \frac{E_i}{A}$$

**where:**

<b>Ekpt,i</b>	=	emissions of pollutant i per tonne of oil consumed, kg/t
<b>Ei</b>	=	hourly emissions of pollutant i, kg/hr
<b>A</b>	=	oil consumption rate, t/hr

**Example 1: Estimating SO<sub>2</sub> emissions using Direct Measurement.**

**Problem:** Calculate the annual SO<sub>2</sub> emission from the fuel consumption using Direct Measurement.

Use data given in Table 4.7.1: Raw data of O<sub>2</sub> % by volume, gas flow rate, combustion rate as well as the SO<sub>2</sub>, NO<sub>x</sub>, CO and VOC concentrations.

**Solution:**

Using data given in Table 4.7.1 and applying Equation 4.7(a), SO<sub>2</sub> emissions for the given time periods were calculated in the following manner:

**At Time Period 1: [Pressure assumption of std. atm]**

$$\begin{aligned} E_{SO_2,1} &= (C * MW * Q * 3600) / [(22.4 * (T+273/273) * 10^6)] \\ &= (150.9 * 64 * 8.52 * 3600) / [22.4 * (423/273) * 10^6] \\ &= 296217907 / 34707692 \end{aligned}$$

$$E_{SO_2,1} = 8.53 \text{ kg/hr}$$

**The same step was repeated for Time Period 2 & 3:**

**For Time Period 2, also at 150°C**

$$E_{SO_2,2} = 8.11 \text{ kg/hr}$$

**For Time Period 3, also at 150°C**

$$E_{SO_2,3} = 7.23 \text{ kg/hr}$$

**Say representative operating conditions for the year are:**

Period 1 = 1500 hr

Period 2 = 2000 hr

Period 3 = 1800 hr

**Then the total emissions for the year can be calculated by adding the results of the three Time Periods (P) using Equation 4.7(b) as follows:**

$$\begin{aligned} E_{kpy, SO_2} &= E_{SO_2, P1} * OpHrs + E_{SO_2, P2} * OpHrs + E_{SO_2, P3} * OpHrs \\ &= (8.53 * 1500) + (8.11 * 2000) + (7.23 * 1800) \text{ kg} \\ E_{kpy, SO_2} &= 42021 \text{ kg/yr} \end{aligned}$$

Fuel consumed in each period is given in Table 4.7(a) above.

**Emissions, in terms of kg/tonne of oil consumed when operating in the same mode as Time Period 1, can be calculated using *Equation 4.7(c)***

$$\begin{aligned} \text{Ekpt, SO}_2 &= \text{ESO}_2 / A \\ &= 8.53 / 290 \\ &= 2.94 * 10^{-2} \text{ kg SO}_2 \text{ emitted per tonne of oil consumed.} \end{aligned}$$

#### 4.7.2 Mass Balance

Mass balance is used in most plants. Any releases can be estimated with this technique, either from individual pieces of equipment or for the entire facility. Benefits of using this method include:

- In theory, it's possible to estimate nearly the entire release inventory for the plant by mass balance.
- Since mass balances are mathematical exercises, capital costs are low.
- In addition to process monitoring data, many of the inputs and outputs in mass balances are already available from operating and finance data.
- Amounts of chemicals brought on site during the year are available from receiving invoices and material safety data sheets.
- Batch sheets and production logs provide inputs and outputs for equipment and process mass balances.

#### **Example 2: Estimating Emission using the MASS BALANCE method**

##### **Problem:**

*Company D applies 15 000 litres of 'ECOAT' (a surface coating compound) in a given year. Estimate Annual Emissions Using Mass Balance Method i.e. What should the company report? Calculate the following:*

- *Calculate uncontrolled VOC emissions from the coating material using the given MSDS (Table 4.7.2)*
- *Calculate manufactured, processed or otherwise used (MPO) quantities for the individual compound (specified in the MSDS)*

##### **Solution:**

In general, coatings consist of resins (binders), pigments, additives, solvents, diluents, and thinners. Resins, pigments, and additives are the solid (non-evaporative or non-volatile) portion of the coating. Conversely, the volatile portion of the coating can consist of water, solvents, diluents, and thinners. These compounds evaporate during the mixing, application, and curing of the coating. Most solvents, diluents, and thinners contain VOCs.

Equation 4.7 (d) below, demonstrates that to obtain the mass of the compound emitted, it is important to know the mass of the compound in the input stream, in the finished product, mass accumulated in the system and the mass captured for recovery or disposal.

**Mass Balance: Equation 4.7(d)**

$$M_e = M_i - M_p - M_a - M_c$$

Where  $M_e$  = Mass of compound A emitted, kg

$M_i$  = Mass of compound A in the input stream, kg

$M_p$  = Mass of compound A in the finishing product, kg

$M_a$  = Mass of compound A accumulated in the system, kg

$M_c$  = Mass of compound A captured for recovery or disposal, kg

For this coating process operation, it'll be assumed that there is no loss of coating compound to the coating equipment and no loss to the system's liquid/solid waste streams. All the volatiles, including VOCs that are in a particular coating, are emitted into the atmosphere.

In order to apply the mass balance approach, the VOC content in the coating compound needs to be established or obtained from Material Data Safety Sheet (MSDS) for that compound. The annual consumption of the compound could be obtained from the facility's log or sales slips.

**Table 4.7.2: Material Safety Data Sheet for ECOAT**

<b>Material Safety Data Sheet</b>			
<b>SECTION 1- CHEMICAL PRODUCT AND COMPANY IDENTIFICATION</b>			
<b>PRODUCT NAME:</b>	ECOAT		
<b>SUPPLIER:</b>	ABCDE CORP		
<b>SECTION 2 – COMPOSITION / INFORMATION ON INGREDIENTS</b>			
<b>Chemical Name</b>		<b>CAS #</b>	<b>Percent by weight</b>
Methyl Ethyl Ketone		78-93-3	25%
Xylene	1	3330-20-7	25%
Ethyl Benzene		100-41-4	15%
N-Butyl Alcohol		123-86-4	10%
Carbon Black		133-86-4	<2%
Other		Balance	
<b>SECTION 3 – PHYSICAL AND CHEMICAL PROPERTIES</b>			
<b>Specific Gravity:</b>	1.35	<b>Percent volatiles:</b>	75% by weight

Note: In some cases, the % of volatiles value reported in the MSDS contains water and other non-VOC components. The quantities of these components, if they can be identified, should be excluded from the % volatiles during VOC emission calculations.

1. To calculate uncontrolled VOC emissions from the coating material using the above MSDS – Equation 4.7 (e) was applied

**Equation 4.7(e)**

	$E_{VOC}$	=	$Q * \rho * d / 100$
Where	$E_{VOC}$	=	Total uncontrolled VOC emission, kg
	$Q$	=	Total annual consumption of coating material, litres
	$\rho$	=	Density of coating material, kg/L
	$d$	=	VOC content by weight in coating material, %

The density of the coating material is unknown, therefore the MSDS was used

Density of coating material	=	$1.35 * 1 \text{ kg/litre} = 1.35 \text{ kg/litre}$ (from MSDS)
$d$	=	75% (from MSDS)
<b>Uncontrolled VOC emission</b>	=	$15\ 000 * 1.35 * 75 / 100$
	=	<b>15 188 kg / year</b>

2. To calculate the manufactured, processed or otherwise used (MPO) quantities of an individual compound, Equation 4.7 (f) was applied

**Equation 4.7(f)**

	$M_Y$	=	$Q * \rho * w_Y / 100$
Where	$M_Y$	=	Quantity of compound y in the coating material, kg
	$Q$	=	Total annual consumption of coating material, litres
	$\rho$	=	Density of coating material, kg/L
	$w_Y$	=	Percent by weight of compound y in the coating material, %

Equation 4.7 (f) is used below to calculate the MPO quantities of the individual compounds. The density ( $\rho$ ) and weight by percentage ( $w_y$ ) of coating material are obtained from the MSDS.

***Methyl Ethyl Ketone***

$$M_{\text{Methyl Ethyl Ketone}} = 15\,000 \text{ litres} * 1.35 \text{ kg/litres} * 25/100 = \mathbf{5\,063 \text{ kg}}$$

***Xylene***

$$M_{\text{Xylene}} = 15\,000 \text{ litres} * 1.35 \text{ kg/litres} * 25/100 = \mathbf{5\,063 \text{ kg}}$$

***Ethyl Benzene***

$$M_{\text{Ethyl Benzene}} = 15\,000 \text{ litres} * 1.35 \text{ kg/litres} * 15/100 = \mathbf{3\,085 \text{ kg}}$$

***N-Butyl Alcohol***

$$M_{\text{N-Butyl Alcohol}} = 15\,000 \text{ litres} * 1.35 \text{ kg/litres} * 10/100 = \mathbf{2\,025 \text{ kg}}$$

A second example to demonstrate the MASS BALANCE method follows below:

**Example 3: Estimate emissions released using Mass Balance**

**Problem:**

60 kg/hr of coal is fed to the boiler; 3kg/hr of ash is an output of the same boiler. Estimate SO<sub>2</sub> released through the stack using the Mass Balance by first calculating the amount of Sulphur in SO<sub>2</sub> released through the stack in kg/day. Additional information of Sulphur has been provided.

**Solution:**

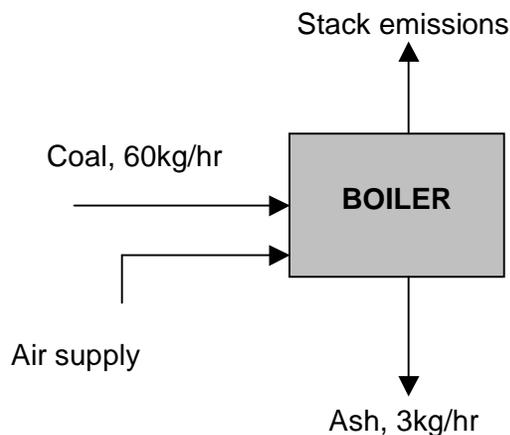
The simplified mass balance equation can be written as:

**Equation 4.7(g)**

$$\text{Accumulation} = \text{Input} - \text{Output}$$

Since the additional information given below is in terms of sulphur (S) content, let us first calculate the amount of S in SO<sub>2</sub> before converting to SO<sub>2</sub> released through the stack.

**Calculating the amount of Sulphur in SO<sub>2</sub> released through the stack in kg/day.**



**Additional Information Given:**

- 1% of coal is sulphur (From the supplier's specification sheet)
- 2% of ash is sulphur (Laboratory results)
- Molar mass of sulphur (S) = 32 kg/kmol
- Molar mass of oxygen (O) = 16 kg/kmol
- Molecular mass of sulphur dioxide (SO<sub>2</sub>) = 32+16X2 = 64 kg/kmol

**Using Equation 4.7(g):**

$$\text{Accumulation} = 0 = \text{Input} - \text{Output}$$

**Then,**

$$\text{Input} - \text{Output} = 0$$

$$\frac{1\% * 60\text{kg} / \text{hr}}{100} - \frac{2\% * 3\text{kg} / \text{hr}}{100} - \text{Sulphur}(in \setminus SO_2)_{Stack} = 0$$

$$\text{Sulphur}(in \setminus SO_2)_{Stack} = 0.01 * 60\text{kg} / \text{hr} - 0.02 * 3\text{kg} / \text{hr}$$

$$\text{Sulphur}(in \setminus SO_2)_{Stack} = 0.54\text{kg} / \text{hr}$$

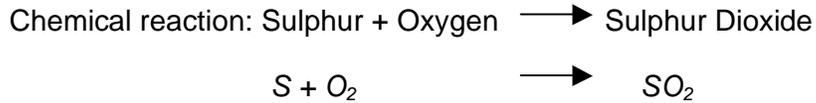
$$1 \text{ day} \equiv 24\text{hours}$$

**Therefore,**

$$\text{Sulphur (in SO}_2\text{)}_{Stack} = 0.54\text{kg/hr} * 24\text{hr/day}$$

$$= \mathbf{12.96 \text{ kg/day}}$$

**Calculating the amount of SO<sub>2</sub> released through the stack in kg/day**



From the reaction above, 1 kmole of sulphur generates 1 kmole of sulphur dioxide

But it is already known that **0.54 kg/hr** of sulphur is in sulphur dioxide leaving through the stack.

**To convert kg/hr of Sulphur to kmol/hr**

$0.54 \text{ kg/hr} \equiv (0.54 \text{ kg/hr}) / (32 \text{ kg/kmol}) = 0.01689 \text{ kmol/hr} \dots\dots\dots \text{Sulphur}$

But: 1 kmol of sulphur generates 1 kmol of SO<sub>2</sub>

So: 0.01689 kmol of sulphur generate 0.01689 kmol of SO<sub>2</sub>

Then: 0.01689 kmol/hr of sulphur dioxide will leave through the stack

**To convert kmol/hr of sulphur dioxide to kg/hr**

$0.01689 \text{ kmol/hr} \equiv (0.01689 \text{ kmol/hr}) * (64 \text{ kg/kmol}) = 1.08 \text{ kg/hr} \dots\dots \text{SO}_2$

**To calculate the amount of sulphur dioxide released per day**

1 day  $\equiv$  24 hours

**Therefore,**

$1.08 \text{ kg/hr} \equiv (1.08 \text{ kg/hr}) \times (24 \text{ hr/day}) = 25.92 \text{ kg/day} \dots\dots \text{SO}_2$

### 4.7.3 Engineering Calculations:

Engineering calculations are used to estimate releases to all media, particularly when direct measurement is not possible. There are many commonly used correlations for release, as well as typical mass transfer calculations to estimate amounts of chemicals in various process and waste streams. Benefits of using this method include:

- Engineering calculation tools are available from a wide variety of sources, including equipment manufacturers, textbooks, and engineering handbooks.
- They are an inexpensive way of estimating releases and can be quite sophisticated and accurate depending on the application, but especially for small amounts of releases
- Engineering calculation correlations for losses from storage tanks are commonly used and are the best way for estimating storage losses.
- These are the kind of calculations chemical and mechanical engineers are trained to perform.

#### **Example 4: Estimating emission releases using Engineering Calculation**

##### **Problem:**

Plant A uses coal for its combustion process. Estimate the annual emissions of Sulphur dioxide (SO<sub>2</sub>) i.e. Fuel Analysis. Assume complete conversion of sulphur (S) to SO<sub>2</sub>.

##### **Data given:**

<i>Fuel Flowrate (Q<sub>f</sub>)</i>	=	20 000 kg/hr
<i>Concentration of Sulphur in fuel (C<sub>S</sub>)</i>	=	1.5 %
<i>Molecular Weight of SO<sub>2</sub> emitted (MW<sub>SO2</sub>)</i>	=	64
<i>Molecular Weight of sulphur in fuel (MW<sub>S</sub>)</i>	=	32
<i>Overall emission control Efficiency CE<sub>SO2</sub></i>	=	90%

##### **Solution:**

Fuel analysis can be used to predict emissions based on the application of conservation laws. The presence of certain elements in fuels may be used to predict their presence in emission streams. This includes toxic elements such as metals found in coal as well as other elements such as sulphur that may be converted to other compounds during the combustion process.

Firstly, the fuel analysis has to be done. *Equation 4.7 (i)* is used for fuel analysis emission estimation. SO<sub>2</sub> emissions from coal combustion can be calculated based on the concentration of sulphur in the coal. The approach assumes complete conversion of sulphur to SO<sub>2</sub>. Therefore, for every kg of Sulphur (MW = 32g) burned, 2 kg of SO<sub>2</sub> (MW = 64 kg) are emitted. The application of this emission estimation is shown as follows:

**Equation 4.7(i)**

$$Er_{Xe} = Q_f * C_x * \frac{(MW_{Xe})}{(MW_x)} * \frac{(100 - CE_{Xe})}{100}$$

Where:

<b>Er<sub>Xe</sub></b>	=	Emission rate of contaminant Xe (kg/hr)
<b>Q<sub>f</sub></b>	=	Fuel Flow rate, (kg/hr)
<b>C<sub>x</sub></b>	=	Concentration of contaminant x in fuel, (g/g-fuel)
<b>MW<sub>Xe</sub></b>	=	Molecular Weight of contaminant Xe (g/g-mole)
<b>MW<sub>x</sub></b>	=	Molecular Weight of contaminant x in fuel (g/g-mole)
<b>CE<sub>Xe</sub></b>	=	Overall emission control efficiency of contaminant xe, %

**Apply equation 4.7(i):**

$$Er_{SO_2} = Q_f * C_x * \frac{(MW_{SO_2})}{(MW_S)} * \frac{(100 - CE_{SO_2})}{100}$$

$$Er_{SO_2} = 20,000 * \frac{1.5}{100} * \frac{64}{32} * \frac{(100 - 90)}{100}$$

**= 60 kg/hr**

**Therefore the hourly emission of SO<sub>2</sub> is 60 Kg/hr**

**If (for example) the boiler runs for 8 000 hours per year, then**

**Annual Emissions of SO<sub>2</sub>** = hourly emission rate \* number of operating hours  
 = 60 kg/hr \* 8 000 hr  
**= 480 000 kg**

### Example 5: Estimate Emissions using the Engineering Calculation Method

#### **Problem:**

Estimate emission from a small industrial boiler that uses 1000 kl/ year of HFO (Heavy Fuel Oil). No emission control equipment is fitted in the plant. The HFO is equivalent to a No. 6 Fuel Oil (i.e. used for oil burning power plants), and has a sulphur content of 3.5% (m/m).

#### **Solution:**

Equations applicable:

$$E_{kpy, i} = Q_f * (\text{pollutant concentration in fuel}/100) * (MW_p/EW_i) * OpHrs \quad \dots 4.7(j)$$

Where:

$E_{kpy, i}$  = annual emissions of pollutant i, kg/yr

$Q_f$  = fuel use, kg/hr

$OpHrs$  = operating hours, hr/yr

$MW_p$  = molecular weight of pollutant emitted, kg/kg-mole

$EW_i$  = elemental weight of pollutant in fuel, kg/kg-mole

Concentration of pollutant i in fuel expressed as weight percent, %

As before, if the activity is given as total fuel processed per year, t of fuel/year:

$$E_{spy, i} = [t \text{ fuel/yr}] * (\text{pollutant concentration in fuel}/100) * (MW_p/EW_i) \quad \dots 4.7(k)$$

The activity rate in terms of [t fuel/ year] (1000kl) has to be converted to t/ year, using the density of the fuel of 0.9kg/l or 0.9t/kl.

**Therefore, activity rate = 1000 \* 0.9 = 900 t/year.**

The sulphur in the fuel is converted to sulphur dioxide; for sulphur,  $EW_i = 32$ ; for sulphur dioxide,  $MW_p = 64$ . If we assume that 100% of the sulphur is converted to  $SO_2$  in the combustion process (a good approximation), the *Equation 4.7(k)* becomes:

$E_{kpy, i} = 900*(3.5/100)(64/32) = 63 \text{ t /year}$  or 63 000kg/ year. This result may be compared with the estimate of 65800 using the emission factor method. Please refer to the emission factor example below for comparison.

#### 4.7.4 Emission factors

Emission factors are often used for estimating air emissions, especially fugitive air emissions such as leaks from valves, fittings, pumps, and compressors. Benefits of using the Emission Factor method include:

- The most commonly used emission factors require only two pieces of information: the number of valves, fittings, pumps, and compressors, all the chemicals flowing through them.
- Emission factors may be extremely useful for estimating small amounts of emission that might be missed by mass balance.

Emission factors can also be used to calculate annual emissions from activity data such as fuel consumption, production, or consumption statistics. Careful consideration of emission factors should be practiced, as there are different published sources of emission factors for the same application and each gives a different result. The use of emission factors often requires a detailed knowledge of a process and it is important to consider the relevance of an emissions factor before applying it.

Three examples of how to apply the Emission Factor method will be demonstrated below.

#### **Example 6: Estimate Emissions using the Emission Factor method**

**Example:** Estimate emission from a small industrial boiler that uses 1000 kl/ year of HFO (Heavy Fuel Oil). No emission control equipment is fitted to the plant. The HFO is equivalent to a No. 6 Fuel Oil (i.e. used for oil burning power plants), and has a sulphur content of 3.5% (m/m).

A: Use of the emission factor method to estimate the emissions of CO, NO<sub>x</sub>, VOCs, SO<sub>2</sub>, SO<sub>3</sub> and PM<sub>10</sub>.

(SO<sub>2</sub> emissions may be calculated using the emission factor method, *provided that the emission factor is adjusted for the actual sulphur content of the fuel*, relative to the sulphur content of the fuel used to derive the emission factor.)

**Equation 4.7(l)**

$$E_{kpy,i} = [A * OpHrs] * EFi * [(1 - (CEi/100))] \dots\dots\dots 4.7(la)$$

where :

- E<sub>kpy,i</sub>** = emission rate of pollutant i, kg/yr
- A** = activity rate, t/hr
- OpHrs** = operating hours, hr/yr
- EFi** = uncontrolled emission factor of pollutant i, kg/t
- CEi** = overall control efficiency for pollutant i, %.

Alternative forms:

If the activity is given as total fuel processed per year, t/year:

$$E_{kpy,i} = [t/year \text{ fuel}] * EFi * [(1 - (CEi/100))]. \dots\dots\dots 4.7(lb)$$

If no emission control equipment is fitted, CEi = 0, and the equation becomes:

$$E_{kpy,i} = [t/year \text{ fuel}] * EFi . \dots\dots\dots 4.7(lc)$$

In the example, fuel use is given in kl (kilolitre, 1000litres) per year. This value could be converted to t/year, using the density of the fuel. But in this case, emission factors are given in kg/kl, so no conversion is necessary.

*The activity rate is therefore: 1000kl/year.*

The next step is to look up the appropriate emission factors:

**Table 4.7.3: Emission factors for uncontrolled combustion of No 6 oil, normal firing, standard burner (not 'low-NOx')**

Pollutant	CO	NOx	VOCs	SO <sub>2</sub>	SO <sub>3</sub>	PM10
No 6 FO E <sub>F</sub> [kg/kl]	0.6	6.6	0.03	18.8*3.5	0.24*3.5	0.86*(0.13*3.5+0.05)

Note that the above figures apply to boilers < 100GJ/hr capacity; for SO<sub>2</sub> and PM<sub>10</sub>, the emission factors are a function of the weight % of Sulphur in the fuel, in this example, 3.5%.

The annual emissions may now be calculated using values from Table 4.7.3 into Equation 4.7(lc):

**Table 4.7.4: Annual emissions of CO, NOx, VOCs, SO<sub>2</sub>, SO<sub>3</sub> and PM<sub>10</sub>**

Pollutant	CO	NOx	VOCs	SO <sub>2</sub>	SO <sub>3</sub>	PM10
No 6 FO E <sub>F</sub> [kg/kl]	0.6	6.6	0.03	65.8	0.84	0.434
E <sub>kpvi</sub> [kg/year]	600	6600	30	65800	840	434

### **Example 7: Estimate emission using Emission Factors**

This example illustrates the use of emission factors where the operator has provided sufficient information such that no assumptions, regarding the process itself, need to be made.

**Table 4.7.5: The following information has been obtained from the process operator:**

Process	Waste oil combustion
No of flues	One
Fuel use	Waste oil
Sulphur content	1.8%
Ash content	0.1%
Oil consumption	76 m <sup>3</sup> /yr
Operating hours	1978 hours/year

The basic details supplied by the operator are sufficient for a simple emissions calculation, using the emission factors from the UK emission factor database (EFDB). The emission factors for: sulphur monoxide, nitrogen oxides, carbon monoxide and PM and PM<sub>10</sub> from the UK EFDB are as follows:

**Table 4.7.6: Emission factors for waste oil combustion (units are kg per cubic metre of waste oil)**

Pollutant	SO <sub>2</sub>	NO <sub>x</sub>	CO	PM	PM <sub>10</sub>
Factor	17.6 x S <sup>(a)</sup>	2.28	0.6	7.7 x A <sup>(b)</sup>	79% of PM
<sup>a</sup> S = weight % sulphur in fuel					
<sup>b</sup> A = weight % ash in fuel					

Using this information the following calculation can be made to estimate annual emissions for these pollutants:

$$E_{\text{tot}} = F \times T \dots\dots\dots 4.7(m)$$

Where:

$E_{\text{tot}}$  is the total annual emission for pollutant (kg/yr).

F is the emission factor for waste oil combustion process (kg/m<sup>3</sup>).

T is the annual throughput of waste oil (m<sup>3</sup>/yr).

Using the values from Table 4.7.5 and Table 4.7.6 into equation 4.7(m) results in the following annual emissions estimates:

**Table 4.7.7: Annual emissions from waste oil burner (kg/yr)**

Pollutant	SO <sub>2</sub>	NO <sub>x</sub>	CO	PM	PM <sub>10</sub>
Emission	2408	173	47	59	46

### **Example 8: Estimate emission using Emission Factors**

This example illustrates the use of emissions factors where the operator has provided insufficient information to enable a straight forward calculation of annual emissions from emission factors. This example highlights the limitations of activity data and the nature of the assumptions that may be required in order to complete emission calculations.

**Table 4.7.8: The following information has been obtained from the process operator:**

Process	Waste oil combustion
No of flues	One
Fuel use	Waste oil
Thermal rating	0.5MW

The throughput can be estimated from the thermal rating of a boiler. To calculate the throughput the following information is required:

- Annual operating hours and
- Calorific value of the fuel

In cases where the operating hours are not available, but are necessary to calculate annual emissions, it is reasonable to make an educated guess. The composition of waste oil varies according to its former use and, as such, it is difficult to provide fuel parameters that will be representative for all types of waste oil. In the absence of a detailed fuel specification it is possible to use fuel parameters for Heavy Fuel Oil (HFO)/residual oils.

**Table 4.7.9: Assumptions made to estimate fuel consumption**

Annual operating hours	8 hr/day, 5 day/week, 48 week/yr (1920 hr/yr)
Calorific value of oil	41,808 MJ/m <sup>3</sup>

Using these assumed values the annual throughput can be calculated as follows:

$$T = (R \times 3600 \times H)/C_{val} \dots\dots\dots 4.7(n)$$

Where:

**T** is the annual throughput of waste oil (m<sup>3</sup>/yr).

**R** is the thermal rating of the boiler (MW).

**H** is the annual operating hours (hr/yr).

**C<sub>val</sub>** is the calorific value (of the waste oil) (MJ/m<sup>3</sup>).

In this instance:

**R** = 0.5 MW

**H** = 1920 hr/yr (from Table 4.7.9)

**C<sub>val</sub>** = 41808 MJ/m<sup>3</sup> (from Table 4.7.9)

Thus,

$$T = (0.5 \times 3600 \times 1920)/41808 = 83 \text{ m}^3/\text{yr}$$

It should be noted that in calculating the throughput from the thermal rating of the boiler the following, additional, assumptions have been made:

The engine is continually operating at full load, and that fuel is consumed with 100 percent efficiency.

For this example the operator did not supply a fuel specification thus, it will be necessary to make assumptions about the ash and sulphur content of the waste oil. In the absence of a detailed fuel specification it is possible to use fuel parameters for Heavy Fuel Oil (HFO)/residual oils.

**Table 4.7.10: Assumed fuel specification**

% sulphur in waste oil	2.0%
% ash in waste oil	0.1%

Using the calculated annual throughput (83 m<sup>3</sup>/yr) and values from Table 4.7.10 into equation 4.7(m) results in the following annual emissions:

**Table 4.7.11: Annual emissions from waste oil burner (kg/yr)**

Pollutant	SO <sub>2</sub>	NO <sub>x</sub>	CO	PM	PM <sub>10</sub>
Factor	2922	189	50	64	50

## **5. CONCLUSION AND RECOMMENDATIONS**

The information that the Department has included in the guide should be sufficient to assist facilities to gather the necessary information or resources to monitor and estimate the pollutants for reporting. The guide might not be covering all the processes in the province, but the aim of it is to give a picture of what is required from those who will be reporting.

The onus lies with the employers to get staff that will be able to do the tasks mentioned in the guide so that reliable data will be reported on. Also, the staff will be able to make this information applicable to their environment

Care should be taken with the estimations. The information applicable to that environment should be used and the step-by-step procedure followed and assumptions made for estimation must be kept in a safe place for record purpose.

It should be noted that the list of pollutants to be monitored will increase as time goes on; as a result facilities have to be prepared to deal with that situation in future.

## 6. REFERENCES

Australian National Pollutant Inventory (NPi) (2003). **Emission Estimation Technique Manual for Combustion in Boilers**. Version 1.2. Accessed online from: [http://www.npi.gov.au/handbooks/approved\\_handbooks/pubs/boilers.pdf](http://www.npi.gov.au/handbooks/approved_handbooks/pubs/boilers.pdf)

Environment Canada (2002). **Guide for Reporting to the National Pollutant Release Inventory 2002**. Accessed online from:  
[http://www.ec.gc.ca/pdb/npri/documents/html/Eng\\_Guide\\_2001\\_e/app6.cfm](http://www.ec.gc.ca/pdb/npri/documents/html/Eng_Guide_2001_e/app6.cfm)

Ontario Ministry of the Environment (2001). **Step by Step Guideline for Emission Calculation, Record Keeping and Reporting For Air Borne Contaminant Discharge**. Accessed online from: [http://www.ene.gov.on.ca/envision/gp/4099e\\_a.pdf](http://www.ene.gov.on.ca/envision/gp/4099e_a.pdf)

UNITAR and Inter-organizational Programme for the Sound Management of Chemicals (IOMC). (1998). **Guidance for Facilities on PRTR Data Estimation and Reporting**. UNITAR Series of PRTR Technical Support Materials - No. 2. 60 pp.

United States Environment Protection Agency (USEPA). (1999). **EPA Handbook for Criteria Pollutant Inventory Development: A Beginner's Guide for Point and Area Sources**. Accessed online from: <http://www.epa.gov>

UK National Atmospheric Emissions Inventory.  
Accessed online from: <http://www.naei.org.uk/emissions>

Department for Environment, Food and Rural Affairs. Part IV of the Environment Act 1995 Local Air Quality Management. Technical Guidance. LAQM. TG(03)  
Accessed online from:  
<http://www.defra.gov.uk/environment/airquality/laqm/guidance/pdf/laqm-tg03.pdf>

**USEPA AP-42**

## **ANNEXURE I: Sources and Health Impacts of the priority pollutants**

### **Ammonia (NH<sub>3</sub>)**

Ammonia is a colorless gas with a very sharp odour. It is made both by humans and by nature. It dissolves easily in water and evaporates quickly. It is commonly sold in liquid forms, as a solution in water. Most of the ammonia produced in chemical factories is used to make fertilizers. The remaining is used in textiles, plastics, explosives, pulp and paper production, food and beverages, household cleaning products, refrigerants, and other products. Exposure to high concentrations of ammonia in the air may cause severe burns in your skin, eyes, throat, and lungs. Furthermore, ammonia compounds such as ammonium nitrate and ammonium sulphate aids in the formation of PM<sub>2.5</sub> and contributes. For more on PM<sub>2.5</sub> refer to the relevant section further down.

In extreme cases, blindness, lung damage, or death could occur. Breathing lower concentrations will cause coughing and nose and throat irritation. Swallowing ammonia produces burns in your mouth, throat, and stomach. Concentrated ammonia spilled on the skin will cause burns.

### **BTEX**

BTEX is the acronym for benzene, toluene, ethylbenzene, and xylenes. These compounds are found in petroleum products. Ethylbenzene is a petrol and aviation fuel additive. BTEX are also used extensively in manufacturing processes. Benzene is used in the production of synthetic materials and consumer products, such as synthetic rubber, plastics, nylon, insecticides and paints. Toluene is used as a solvent for paints, coatings, gums, oils, and resins. Ethylbenzene may be present in consumer products such as paints, inks, plastics, and pesticides. Xylenes are used as a solvent in printing, rubber, and leather industries. The term BTEX reflects that benzene, toluene, ethylbenzene and xylenes are often found together at contaminated sites and are hence grouped together in this report. BTEX compounds are nonhalogenated volatile organic compounds (VOCs) and are important precursors to the formation of ozone.

The main source of BTEX contamination of groundwater is the leakage of petrol from faulty and poorly maintained underground storage tanks. Other sources of BTEX contamination are releases from large bulk storage facilities, surface spills, and pipeline leaks. Once released to the environment, BTEX can volatilize (evaporate), dissolve, attach to soil particles or degrade biologically. BTEX can also dissolve into water, allowing it to move in the groundwater. Since BTEX can "stick" to soil particles, these chemicals move slower than the groundwater. If oxygen is present in sufficient quantities, BTEX can also degrade biologically, albeit slowly.

Exposure to BTEX can occur by ingestion, inhalation or absorption through the skin. Acute exposures to high levels of petrol and its BTEX components have been associated with skin and sensory irritation, central nervous system depression, and effects on the respiratory system. These levels are not likely to be achievable from drinking contaminated water, but are more likely from occupational exposures. Prolonged exposure to these compounds has similar effects, as well as the kidney, liver and blood systems. Benzene is a known human carcinogen while toluene and xylene affect the nervous system. Ethylbenzene causes a range of respiratory effects and include dizziness, throat and eye irritation, tightening of the chest, and a burning sensation in the eyes.

## Carbon dioxide (CO<sub>2</sub>)

CO<sub>2</sub> is a colourless gas which occurs naturally in the atmosphere. It is one of the main raw materials (with water) in the photosynthesis process. The main anthropogenic (man-made) source of this gas results from the combustion of organic matter if sufficient amounts of oxygen are present. The main concern of CO<sub>2</sub> is its effect on global climate change since it is a greenhouse gas.

## Carbon Monoxide (CO)

CO is emitted by combustion processes (industrial and vehicle) where the temperature is too low to complete the oxidation of the hydrocarbons in the fuel into water and CO<sub>2</sub>. This may also be due to insufficient time available in the combustion chamber or because there is insufficient oxygen present. CO is an asphyxiant and causes hyperventilation and suffocation. Repeated exposure to CO is dangerous. The health effects of various concentration of CO is presented in the table below.

Exposure (hours)	CO Concentration (ppm) <sup>1</sup>		
	Perceptable	Sickness <sup>2</sup>	Deadly <sup>3</sup>
0.5	600	1000	2000
1	200	600	1600
2	100	300	1000
4	50	150	400
6	25	120	200
8	25	100	150

<sup>1</sup> ppm - parts per million - is defined as the mass of the component in solution divided by the total mass of the solution multiplied by 10<sup>6</sup> (one million)

<sup>2</sup> Typical sickness symptoms are mild headache, fatigue, nausea and dizziness.

<sup>3</sup> A CO concentration of 12-13.000 ppm is deadly after 1-3 minutes. A CO concentration of 1600 ppm is deadly after one hour.

## Carbon tetrachloride/tetrachloroethylene (CCl<sub>4</sub>)

CCl<sub>4</sub> is a clear, nonflammable liquid which is almost insoluble in water. It is very volatile and is regarded as a volatile organic compound. It has a sweet characteristic odour, with an odour threshold above 10 ppm. CCl<sub>4</sub> is produced in large quantities to make refrigerants and propellants for aerosol cans, as a solvent for oils, fats, lacquers, varnishes, and rubber waxes, and resins, and as a grain fumigant and a dry cleaning agent. Individuals may be exposed to carbon tetrachloride in the air from accidental releases from production and uses, and from its disposal in landfills where it may evaporate into the air or leach into groundwater. Acute/short term inhalation and oral exposures to high levels of CCl<sub>4</sub> have been observed primarily to damage the liver and kidneys of humans.

CCl<sub>4</sub> is one of the important gases (greenhouse gas) made reference to in the Montreal Protocol on substances that deplete the ozone layer. Hence, this pollutant contributes to the destruction of the ozone layer.

## Chromium

Chromium is a naturally occurring element in rocks, animals, plants, soil, and volcanic dust and gases. Metal chromium, which is a steel-gray solid, is used mainly for making steel and other alloys and is most commonly emitted by industrial processes. Chromium compounds, in either the chromium (III) or chromium (VI) forms, are used for chrome plating, the manufacture of dyes and pigments, leather and wood preservation, and treatment of cooling tower water. Smaller amounts are used in drilling muds, textiles, and toner for copying machines.

Air emissions of chromium are predominantly of trivalent chromium, and in the form of small particles or aerosols. The most important industrial sources of chromium in the atmosphere are those related to ferrochrome production. Ore refining, waste incineration, chemical and refractory processing, cement-producing plants, automobile brake lining and catalytic converters for automobiles, leather tanneries, and chrome pigments also contribute to the atmospheric burden of chromium. The general population is exposed to chromium (generally chromium [III]) by eating food, drinking water, and inhaling air that contains the chemical. The average daily intake from air, water, and food is estimated to be less than 0.2 to 0.4 micrograms ( $\mu\text{g}$ ), 2.0  $\mu\text{g}$ , and 60  $\mu\text{g}$ , respectively.

Dermal exposure to chromium may occur during the use of consumer products that contain chromium, such as wood treated with copper dichromate or leather tanned with chromic sulfate. Occupational exposure to chromium occurs from chromate production, stainless-steel production, chrome plating, and working in tanning industries; occupational exposure can be two orders of magnitude higher than exposure to the general population.

The chromium (III) compounds are sparingly soluble in water and may be found in water bodies as soluble chromium (III) complexes, while the chromium (VI) compounds are readily soluble in water. Chromium (VI) is much more toxic than chromium (III), for both acute and chronic exposures. Via inhalation, chromium (VI) causes shortness of breath, coughing, wheezing, gastrointestinal and neurological effects. Dermal exposure causes skin burns in humans. Chronic human exposure to high levels of chromium (VI) by inhalation or oral exposure may produce effects on the liver, kidney, gastrointestinal and immune systems, and possibly the blood.

## Cyanide

Cyanides are naturally occurring substances found in a number of foods and plants and produced by certain bacteria, fungi, and algae. It is present in a number of compounds such as hydrogen cyanide, sodium cyanide, and potassium cyanide. Hydrogen cyanide is a colorless gas or liquid with a faint, bitter almond odour. Sodium cyanide and potassium cyanide are both colorless solids that possess the slight odour of bitter almonds.

The major uses of hydrogen cyanide are an intermediate in the production of a number of chemicals and as an insecticide for fumigating enclosed spaces. The two most important uses of other cyanide compounds are in electroplating and metal treatment. The primary source of cyanide in the air is from car exhaust. Other airborne sources include emissions from chemical processing, other industries, and municipal waste incinerators. Cyanide may be found in water from discharges from organic chemical industries, iron and steel works, and wastewater treatment facilities.

Cyanide is extremely toxic to humans. Acute (short-term) inhalation exposure to 100 milligrams per cubic meter ( $\text{mg}/\text{m}^3$ ) or more of hydrogen cyanide will cause death in humans. Acute exposure to lower concentrations (6 to 49  $\text{mg}/\text{m}^3$ ) of hydrogen cyanide will cause a variety of effects in humans, such as weakness, headache, nausea, increased rate of respiration, and eye

and skin irritation. Chronic exposure to cyanide in humans via inhalation results in effects on the CNS, such as headaches, dizziness, numbness, tremor, and loss of visual acuity.

### **Dioxins & Furans**

Dioxins and furans are some of the most toxic chemicals known to science. Dioxin is a general term that describes a group of hundreds of chemicals (75 dioxins and 135 furans) that are highly persistent in the environment. The Stockholm Convention on Persistent Organic Pollutants (POPs) includes dioxins and furans as being highly persistent in the environment.

The most toxic compound is 2,3,7,8-tetrachlorodibenzo-p-dioxin or TCDD, which is a carcinogen. The toxicity of other dioxins and chemicals like PCBs that act like dioxin are measured in relation to TCDD. Dioxin is formed as an unintentional by-product of many industrial processes involving chlorine such as waste incineration, chemical and pesticide manufacturing and pulp and paper bleaching.

Dioxins and furans are formed by burning chlorine-based chemical compounds with hydrocarbons. The major source of dioxin in the environment comes from waste-burning incinerators of various sorts and also from backyard burn-barrels. Dioxin and furan pollution is also affiliated with paper mills which use chlorine bleaching in their process and with the production of Polyvinyl Chloride (PVC) plastics and with the production of certain chlorinated chemicals (like many pesticides). Since dioxin is fat-soluble, it bioaccumulates, climbing up the food chain and it is mainly (97.5%) found in meat and dairy products such as beef, dairy products, milk, chicken, pork, fish and eggs in that order.

In addition to cancer, exposure to dioxins and furans can also cause severe reproductive and developmental problems (at levels 100 times lower than those associated with its cancer causing effects). Dioxins and furans are well-known for its ability to damage the immune system and interfere with hormonal systems. Their exposure has been linked to birth defects, inability to maintain pregnancy, decreased fertility, reduced sperm counts, endometriosis, diabetes, learning disabilities, immune system suppression, lung problems, skin disorders, lowered testosterone levels and much more.

### **Hydrogen Sulphide (H<sub>2</sub>S)**

H<sub>2</sub>S is a colorless, flammable gas under normal conditions. It has a rotten egg smell and can be detected at low concentrations. It occurs naturally in crude petroleum, natural gas, volcanic gases, and hot springs. It is also produced by human and animal wastes. H<sub>2</sub>S can also result from industrial activities, such as food processing, paper mills, tanneries, and petroleum refineries. The H<sub>2</sub>S is released primarily as a gas and will spread in the air. When it is released, it forms sulphur dioxide and sulphuric acid in the atmosphere, H<sub>2</sub>S remains in the atmosphere for about 18 hours and is eventually oxidized. In some instances, it may be released as a liquid waste from an industrial facility.

H<sub>2</sub>S is a broad-spectrum poison, meaning it can poison several different systems in the body. Breathing very high levels of H<sub>2</sub>S can cause death within just a few breaths. There could be loss of consciousness after one or more breaths. Exposure to lower concentrations can result in eye irritation, a sore throat and cough, shortness of breath, and fluid in the lungs. These symptoms usually go away in a few weeks. Long-term, low-level exposure may result in fatigue, loss of appetite, headaches, irritability, poor memory, and dizziness.

### **Iron oxide (red dust)**

Natural iron oxide is not uncommon. Synthetic iron oxide is emitted when iron ore is mined and heated to separate the iron from its other elements that it was bonded to (i.e. as at iron and steel plants). The pure iron that is produced will immediately start reacting with the oxygen in the air to become a stable compound, iron oxide. Iron oxide is commonly used as a pigment, a catalyst, magnets as well as a source of heat. It can be harmful if inhaled or absorbed through the skins, cause eye irritations and is also harmful if swallowed. Iron oxide in high concentrations (dust or fumes) can cause metal fume fever, which usually only lasts from 12 to 48 hours. Extended inhalation of iron oxide in high concentrations (dust or fumes) can cause pulmonary effects, eventually resulting in siderosis (inflammation of the lungs).

### **Lead (Pb)**

Lead is a naturally occurring bluish-gray metal found in small amounts in the earth's crust. Lead can be found in all parts of our environment. Much of it comes from human activities including burning fossil fuels, mining, and manufacturing. It is used in the production of batteries, ammunition, metal products (solder and pipes), and devices to shield X-rays. Leaded petrol is currently the main source of lead emissions, in the form of particulates emitted from vehicle exhausts. Due to health concerns, the sale of leaded petrol is scheduled to stop in January 2006. Lead does not break down, but lead compounds are changed by sunlight, air, and water. When lead is released to the air, it may travel long distances before settling to the ground. It falls onto soil; it usually sticks to soil particles.

Lead can affect almost every organ and system in your body. The most sensitive is the central nervous system, particularly in children. Lead also damages kidneys and the reproductive system. The effects are the same whether it is breathed or swallowed. At high levels, lead may decrease reaction time, cause weakness in fingers, wrists, or ankles, and possibly affect the memory. Lead may cause anemia, a disorder of the blood. It can also damage the male reproductive system. The connection between these effects and exposure to low levels of lead is uncertain.

Exposure to lead is more dangerous for young and unborn children. Unborn children can be exposed to lead through their mothers. Harmful effects include premature births, smaller babies, and decreased mental ability in the infant, learning difficulties, and reduced growth in young children. These effects are more common if the mother or baby was exposed to high levels of lead.

### **Mercury (Hg)**

Mercury is a naturally occurring metal, which has several forms. The metallic mercury is a shiny, silver-white, odourless liquid. If heated, it is a colorless, odourless gas. Mercury combines with other elements, such as chlorine, sulphur, or oxygen, to form inorganic mercury compounds or "salts," which are usually white powders or crystals. Mercury also combines with carbon to make organic mercury compounds. Mainly microscopic organisms, in the water and soil, produce the most common one methyl mercury. More mercury in the environment can increase the amounts of methyl mercury that these small organisms make. Methylmercury biaccumulates in the ecosystem.

Metallic mercury is used to produce chlorine gas and caustic soda, and is also used in thermometers, dental fillings, and batteries. Mercury salts are sometimes used in skin lightening creams and as antiseptic creams and ointments. [Air emissions from Medical Waste Incinerators, coal fired power plants, etc]

The nervous system is very sensitive to all forms of mercury. Methylmercury and metallic mercury vapors are more harmful than other forms, because more mercury in these forms reaches the brain. Exposure to high levels of metallic, inorganic or organic mercury can permanently damage the brain, kidneys, and developing fetus. Effects on brain functioning may result in irritability, shyness, tremors, changes in vision or hearing, and memory problems. Short-term exposure to high levels of metallic mercury vapors may cause effects including lung damage, nausea, vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes, and eye irritation.

Very young children are more sensitive to mercury than adults. Mercury in the mother's body passes to the fetus and may accumulate there. It can also pass to a nursing infant through breast milk. Mercury's harmful effects that may be passed from the mother to the fetus include brain damage, mental retardation, in co-ordination, blindness, seizures, and inability to speak. Children poisoned by mercury may develop problems of their nervous and digestive systems, and kidney damage.

### **Nitrogen oxides (NO<sub>x</sub>)**

Nitrogen oxides are a mixture of gases that are composed of nitrogen and oxygen. Two of the most toxicologically significant nitrogen oxides are nitric oxide (NO) and nitrogen dioxide (NO<sub>2</sub>); both are nonflammable and colorless to brown at room temperature. NO is a sharp sweet-smelling gas at room temperature, whereas NO<sub>2</sub> has a strong, harsh odour and is a liquid at room temperature, becoming a reddish-brown gas above 21 °C.

A mixture of NO and NO<sub>2</sub> (NO<sub>x</sub>) are released to the air from the exhaust of motor vehicles, the burning of coal, oil, or natural gas, and during processes such as arc welding, electroplating, engraving, and dynamite blasting. They are also produced commercially by reacting NO with metals or cellulose. NO<sub>x</sub> are used in the production of lacquers, dyes, and other chemicals. NO<sub>x</sub> are also used in rocket fuels, nitration of organic chemicals, and the manufacture of explosives.

The reaction of NO<sub>2</sub> with chemicals produced by sunlight leads to the formation of NO, which is a major constituent of acid rain, ozone and smog conditions in the air we breathe.

Low levels of NO<sub>x</sub> in the air can irritate your eyes, nose, throat, and lungs, possibly causing you to cough and experience shortness of breath, tiredness, and nausea. Exposure to low levels can also result in fluid build-up in the lungs 1 or 2 days after exposure. Breathing high levels of NO<sub>x</sub> can cause rapid burning, spasms, and swelling of tissues in the throat and upper respiratory tract, reduced oxygenation of body tissues, a build-up of fluid in your lungs, and death.

### **Ozone (O<sub>3</sub>)**

O<sub>3</sub> occurs naturally in the stratosphere and forms a layer that protects life on earth from the sun's harmful rays. Ground level O<sub>3</sub> is an air pollutant that damages human health and the environment. It is formed by the reactions of volatile organic compounds (VOC's) and NO<sub>x</sub> in the presence of sunlight. Hence NO<sub>x</sub> is a source of O<sub>3</sub>. These pollutants (VOC's and NO<sub>x</sub>) are produced from vehicle and engine exhaust, industrial facilities, combustion from electric sources, petrol vapors, chemical solvents. Intense sunlight, which usually occurs in the summer, causes ground-level O<sub>3</sub> to form in harmful concentrations in the air.

Exposure to O<sub>3</sub> can aggravate lung diseases such as asthma. Active children are the group at highest risk from playing outdoors. O<sub>3</sub> affects vegetation and ecosystems, leading to reductions in and other environmental stresses (e.g., harsh weather). In long-lived species, these effects may become evident only after several years or even decades and may result in long-term effects on forest ecosystems.

## **Particulate Matter (PM)**

PM is the general term used for a mixture of solid particles and liquid droplets found in the air. Some particles are large enough to be seen as dust or dirt. Others are so small they can be detected only with an electron microscope. PM<sub>2.5</sub> describes the "fine" particles that are less than or equal to 2.5 µm in diameter. PM<sub>10</sub> refers to all particles less than or equal to 10 µm in diameter (about one-seventh the diameter of a human hair). PM can be emitted directly or formed in the atmosphere. "Primary" particles, such as dust from roads or black carbon (soot) from combustion sources, are emitted directly into the atmosphere. "Secondary" particles are formed in the atmosphere from primary gaseous emissions. Examples include sulfates formed from SO<sub>2</sub> emissions from power plants and industrial facilities; nitrates formed from NO<sub>x</sub> emissions from power plants, vehicles, and other combustion sources; and carbon formed from organic gas emissions from automobiles and industrial facilities. The chemical composition of particles depends on location, time of year, and weather. Generally, coarse PM is composed largely of primary particles and fine PM contains many more secondary particles.

PM<sub>10</sub> can cause numerous health problems and have been linked with illness and death from heart and lung disease. Various health problems have been associated with long-term (e.g. multiyear) exposures as well as daily and, potentially, peak (e.g. 1-hour) exposures to particles. Particles can aggravate respiratory conditions such as asthma and bronchitis and have been associated with cardiac arrhythmias (heartbeat irregularities) and heart attacks. Particles of concern can include both fine and coarse-fraction particles, although fine particles have been more clearly linked to the most serious health effects. People with heart or lung disease, the elderly, and children are at highest risk from exposure to particles.

PM<sub>2.5</sub> is the major cause of reduced visibility in many parts of the world. Airborne particles also can impact vegetation and ecosystems and can cause damage to paints and building materials as well.

## **Phenol**

Phenol is a manufactured substance. It is a colorless-to-white solid when pure. The commercial product is a liquid. It has sickeningly sweet and tarry odour. One can taste and smell it at levels lower than those that are associated with harmful effects. Phenol evaporates more slowly than water, and a moderate amount can form a solution with water. Phenol is flammable and is used primarily in the formation of phenolic resins. It is also used in the manufacture of nylon and other synthetic fibers. It is also used in slimicides (chemicals that kill bacteria and fungi in slimes), as a disinfectant, as an antiseptic, and in medicinal preparations, such as mouthwash and sore throat lozenges.

Children are at greater risk of accidentally ingesting home products that contain phenol. The effects of exposure to phenol on the human fetus are not known. Pregnant animals that drank water containing high concentrations of phenol gave birth to babies that had low birth weights and minor birth defects.

## **Polychlorinated Biphenyls (PCBs)**

PCBs comprise of a group of 209 different chemicals. Around half of these have been identified in the environment. The more highly chlorinated PCBs are the most persistent and account for the majority of those polluting the environment. PCBs were produced as industrial chemicals that were mainly used as a heat transfer medium in electrical equipment. Production of PCBs has almost totally ceased worldwide, although there are reports of it continuing in Russia. At least one third of PCBs that have been produced are estimated to have entered the environment. The other

two thirds remain in old electrical equipment currently in use and in waste dumps from where they continue to leach into the environment. Although this is the major source of PCB pollution in the environment today, some PCBs are also produced as by-products of incineration and certain chemical processes involving chlorine.

The most commonly observed health effects in people exposed to large amounts of PCBs are skin conditions such as acne and rashes. Studies in exposed workers have shown changes in blood and urine that may indicate liver damage. PCB exposures in the general population are not likely to result in skin and liver effects. Animals that ate food containing large amounts of PCBs for short periods of time had mild liver damage and some died. Animals that ate smaller amounts of PCBs in food over several weeks or months developed various kinds of health effects, including anemia; acne-like skin conditions; and liver, stomach, and thyroid gland injuries. Other effects of PCBs in animals include changes in the immune system, behavioral alterations, and impaired reproduction. PCBs are not known although suspected to cause birth defects. Few studies of workers indicate that PCBs were associated with certain kinds of cancer in humans, such as cancer of the liver and biliary tract

### **Polycyclic Aromatic Hydrocarbons (PAHs)**

PAHs are a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco or charbroiled (braai) meat. PAHs are usually found as a mixture containing two or more of these compounds, such as soot.

Some PAHs are manufactured. These pure PAHs usually exist as colorless, white, or pale yellow-green solids. PAHs are found in coal tar, crude oil, creosote, and roofing tar, but a few are used in medicines or to make dyes, plastics, and pesticides. They are found throughout the environment in the air, water, and soil.

Mice that were fed high levels of one PAH during pregnancy had difficulty reproducing and so did their offspring. These offspring also had higher rates of birth defects and lower body weights. It is not known whether these effects occur in people. Animal studies have also shown that PAHs can cause harmful effects on the skin, body fluids, and ability to fight disease after both short- and long-term exposure. But these effects have not been seen in people. According to the Western Cape Profile and the type of industries in the province, these PAHs have been identified:

- acenaphthene
- acenaphthylene
- anthracene
- benz[a]anthracene
- benzo[a]pyrene
- benzo[e]pyrene
- benzo[b]fluoranthene
- benzo[g,h,i]perylene
- benzo[k]fluoranthene
- dibenz[a,h]anthracene

- fluoranthene
- fluorene
- phenanthrene
- pyrene

### **Sulphur dioxide/ sulphur oxides (SO<sub>2</sub>/SO<sub>x</sub>)**

SO<sub>2</sub> is a colorless gas with a pungent odour. It is a liquid at ambient temperatures when under pressure, and it dissolves in water very easily. SO<sub>2</sub> in the air comes mainly from activities such as the burning of coal and oil at power plants or from copper smelting. Naturally, SO<sub>2</sub> can be released to the air from volcanic eruptions and forms sulphuric acid in the atmosphere resulting in acid rain.

Exposure to very high levels of SO<sub>2</sub> can be dangerous. Exposure to 100 ppm is considered immediately dangerous to life and health. Burning of the nose and throat, breathing difficulties, and severe airway obstructions occurred in miners who breathed SO<sub>2</sub> as a result of an explosion in a copper mine.

Long-term exposure to persistent levels of SO<sub>2</sub> can affect your health. Lung function changes were seen in some workers exposed to low levels of SO<sub>2</sub> for 20 years or more. However, these workers were also exposed to other chemicals, so their health effects may not have been from SO<sub>2</sub> alone. Asthmatics have also been shown to be sensitive to the respiratory effects of low concentrations of SO<sub>2</sub>. Animal studies also show respiratory effects from breathing SO<sub>2</sub>.

### **Volatile Organic Compounds (VOCs)**

VOCs are organic compounds that easily become vapors or gases at ambient temperatures. Along with carbon, they contain one or more elements such as hydrogen, oxygen, fluorine, chlorine, bromine, sulphur or nitrogen. VOCs are released from burning fuel, such as petrol, wood, coal, or natural gas. They are also emitted from storage tanks. They are also released during the production and use of solvents, paints, glues, and other products that are used and stored at home and at work. Many VOCs are also hazardous air pollutants. Some are responsible for the formation of ground-level O<sub>3</sub> or smog. Examples of VOCs are petrol, benzene, formaldehyde, solvents such as toluene and xylene, and perchloroethylene (or tetrachloroethylene), the main solvent used in dry cleaning. Many VOCs are commonly used in paint thinners, lacquer thinners, moth repellents, air fresheners, hobby supplies, wood preservatives, aerosol sprays, degreasers, automotive products, and dry cleaning fluids.

The health effects of VOCs can vary greatly according to the compound, which can range from being highly toxic to having no known health effects. The health effects of VOCs will depend on nature of the compound, the level of exposure, and length of exposure. Benzene is known to be a human carcinogen; formaldehyde and perchloroethylene are "reasonably anticipated to be carcinogens." People at the highest risk of long-term exposure to these three VOCs are industrial workers who have prolonged exposure to the compounds in the workplace; cigarette smokers; and people who have prolonged exposure to emissions from heavy motor vehicle traffic.

Long-term exposure to VOCs can cause damage to the liver, kidneys and central nervous system. Short-term exposure to volatile organic compounds can cause eye and respiratory tract irritation, headaches, dizziness, visual disorders, fatigue, loss of coordination, allergic skin reactions, nausea, and memory impairment.

References:

Agency for Toxic Substances and Disease Registry (ATSDR). (2005). **Toxicological Profile Information Sheet**. Available from: <http://www.atsdr.cdc.gov/toxpro2.html>

U.S Environmental Protection Agency (USEPA). (2005). **Air and Radiation**. Available from: [www.epa.gov/oar/oaqps.monring.html#hazardous](http://www.epa.gov/oar/oaqps.monring.html#hazardous)

DioxinFact.org. (2005). **Dioxin in Depth**. Available from: [www.dioxinfacts.org](http://www.dioxinfacts.org)

Office of Environmental Health Hazard Assessment (OEHHA). (2003). **Chronic Toxicity Summary: Methanol**. Available from: [www.oehha.ca.gov/air/chronic\\_rels/pdf/67561.pdf](http://www.oehha.ca.gov/air/chronic_rels/pdf/67561.pdf)

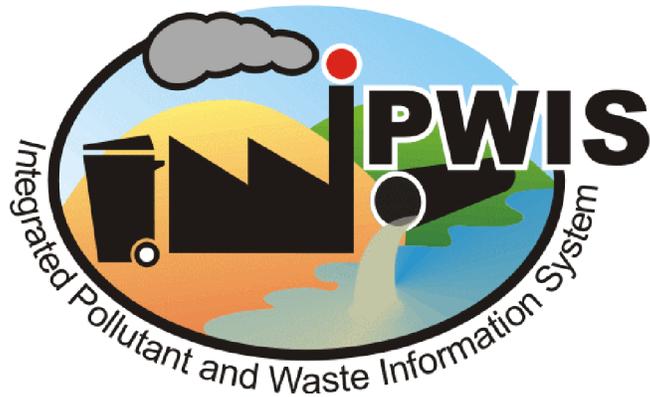
University of Wisconsin-Madison. (2003). **Chemical of the week: Ethanol**. Available from: <http://scifun.chem.wisc.edu/chemweek/ethanol/ethanol.html>

ESPIMETALS. (2005). **Material Safety Data Sheets (MSDS)**. Available from: [www.espimetals.com](http://www.espimetals.com)

## ANNEXURE II: Acronyms and Abbreviations

Abbreviation / Acronym	
<b>IPWIS</b>	Integrated Pollution and Waste Information System
<b>AP - 42</b>	US EPA Compilation of Air Pollutant Emission Factors
<b>CEMS</b>	Continuous Emission Monitoring System
<b>DEADP</b>	Department of Environmental Affairs and Development Planning
<b>FIRE</b>	Factor Information Retrieval System
<b>HAP</b>	Hazardous Air Pollutant
<b>ID</b>	Internal Diameter
<b>IOMC</b>	Inter – organizational Programme for the Sound Management of Chemicals
<b>MSDS</b>	Material Safety Data Sheet
<b>NEMA</b>	National Environmental Management Act
<b>NPi</b>	National Pollutant Inventory (Australian)
<b>NWMS</b>	National Waste Management Strategy
<b>PEM</b>	Predictive Emission Monitoring
<b>PRTR</b>	Pollutant Release and Transfer Register
<b>SPECIATE</b>	VOC/Particulate Matter (PM) Speciation Database Management System
<b>UNITAR</b>	United Nations Institute for Training and Research
<b>USEPA</b>	United States Environmental Protection Agency
<b>USES</b>	Uniform System for the Evaluation of Substances, version 1.0. (Netherlands)
<b>WHO</b>	World Health Organization
<b>WIS</b>	Waste Information System

# **PART D: The Emission Reporting Form**



**DIRECTORATE: POLLUTION AND WASTE  
MANAGEMENT**

**REPORTING FORM FOR POLLUTANT RELEASE  
AND TRANSFER REGISTER (PRTR)**

**Please send complete reporting forms to:**

<b>6<sup>th</sup> Floor</b>	<b>or</b>	<b>P/Bag X9086</b>
<b>Property Centre</b>		<b>Cape Town</b>
<b>3 Dorp Street</b>		<b>8000</b>
<b>Cape Town</b>		
<b>8 000</b>		

**Or faxed to (021) 483 4425**

**Reporting Forms may also be accessed from TO BE  
CONFIRMED**



*Department of Environmental Affairs and Development Planning  
 Departement van Omgewingsake en Ontwikkelingsbeplanning  
 Isebe leMicimbi yeNdalo esiNgqongileyo noCwangciso loPhuhliso*

**This request for information is in accordance with Section 32 (1) of the Constitution, Sections 31 of National Environmental Management Act 107 of 1998 and Section 11(1), 46 (a) (b) and 50 of the Promotion of Access to Information Act No. 2 of 2000.**

**This form should be used in conjunction with the attached reporting guideline document**

SECTION A: FACILITY IDENTIFICATION INFORMATION			
<b>1. IPWIS ID Number</b>			
<b>Section A1: REPORTING YEAR</b>			
<b>Reporting period</b>	<b>3 months</b>	<b>6 months</b>	<b>Annually</b>
<b>Section A2: CERTIFICATION: (Read and sign after completing all form sections)</b>			
I hereby certify that I have reviewed the attached documents and that, to the best of my knowledge, the submitted information is true and complete and that the amounts and values in this report are accurate based on reasonable estimates using data available to the preparers of this report.			
<b>1. Name and official title of owner/operator or senior management official</b>	<b>2. Signature</b>	<b>3. Date</b>	
		_ / _ / _	
<b>Section A3: FACILITY IDENTIFICATION</b>			
<b>1. Registered Company Name</b>			
<b>2. Facility Name (if different from Registered Name)</b>			
<b>3. Company/Business Number</b>			
<b>4. Registered Address of the facility</b>			

5. Postal Code		
6. Street/Postal Address of the facility		
7. Postal Code		

<b>8. Facility Location (Latitude/Longitude co-ordinates)</b>							
<b>9. Latitude</b>	<b>a. Degrees</b>	<b>b. Minutes</b>	<b>c. Seconds</b>	<b>10. Longitude</b>	<b>a. Degrees</b>	<b>b. Minutes</b>	<b>c. Seconds</b>
<b>11. Standard Industrial Classification (SIC) Code (use Dept of Trade &amp; Industry code)</b>							
<b>12. Briefly describe the main activities/processes conducted at this facility</b>							
<b>13. The number of employees during the reporting period?</b>							
<b>14. How long was the facility operational during the reporting period?</b>							
<b>15. Operating days of the week</b>				<b>16. Hours</b>			
<b>Section A4: COMPLAINTS &amp; GENERAL PUBLIC ENQUIRIES</b>							
<b>1. Public Contact Name 1</b>							
<b>Telephone Number</b>							
<b>Fax</b>							
<b>E-mail</b>							
<b>Web</b>							
<b>1. Public Contact Name 2</b>							
<b>Telephone Number</b>							
<b>Fax</b>							
<b>E-mail</b>							
<b>Web</b>							
<b>2. PARENT COMPANY INFORMATION</b>							
<b>3. Name of Parent Company</b>				<b>4. NA</b>			
<b>Section A5: ADDITIONAL INFORMATION</b>							
<b>1. What was the total output from the main economic activity during the reporting period?</b>							
<b>a. Product of the <u>main</u> activity</b>							
<b>b. Quantity</b>							
<b>c. Unit used</b>							

2. What was the consumption of the following during the reporting period?		
a. Electricity		
b. Gas		
c. Oil		
<b>D. COAL</b>		
E. Other		
f. Water		
3. Storage facilities for raw materials, intermediates and products (e.g. name, volume, characteristics, building features, enclosures, dimensions, etc). Provide brief description.	Yes	No
4. Storage facilities for waste and effluent generated by the facility during the reporting period. Provide brief description	Yes	No
5. Please provide a brief description of the socio-economic characteristics of the area/vicinity		
6. Are any of the following located on or near the site/ facility?		
Feature	Yes / No	Distance
a. Central Business District (CBD)		
b. High potential agricultural land/soil		
c. River, dam, lake, estuary or wetland		
d. Currently used or potentially valuable groundwater resources		
e. A floodplain or within:  1:50 floodline /  1:100 floodline		
f. Outfalls to sea / Marine life		
g. A formal or informal residential area		
h. A community facility (school, hospital, sports hall/fields)		

**SECTION B: POLLUTANT RELEASE INVENTORY FORM**

1. Pollutants	2. Usage (per reporting period)	3a. Emissions to Air (tonnes/day)					3b. Emissions to Water (in tonnes/day)					3c. Emissions to Land (in tonnes/day)								
		4. Total Releases	5. Estimation Technique codes*					4. Total Releases	5. Estimation Technique codes*					4. Total Releases	5. Estimation Technique codes*					
			1	2	3	4	5		1	2	3	4	5		1	2	3	4	5	
Benzene																				
Toluene																				
Ethylbenzene																				
Xylene																				
Carbon tetrachloride																				
Iron Compounds																				
Lead compounds																				
Mercury compounds																				
Chromium III & IV compounds																				
Cyanide compounds																				
PM <sub>10</sub>																				
PM <sub>2.5</sub>																				
PCBs (any applicable PCBs)																				
PAHs (any applicable PAHs)																				
Dioxins & Furans (any applicable)																				
Ammonia																				
Carbon dioxide																				
Carbon monoxide																				
Nitrogen dioxide / NO <sub>x</sub>																				
Ozone																				
Phenol																				
Sulphur dioxide																				

\* **Estimation Technique Codes**

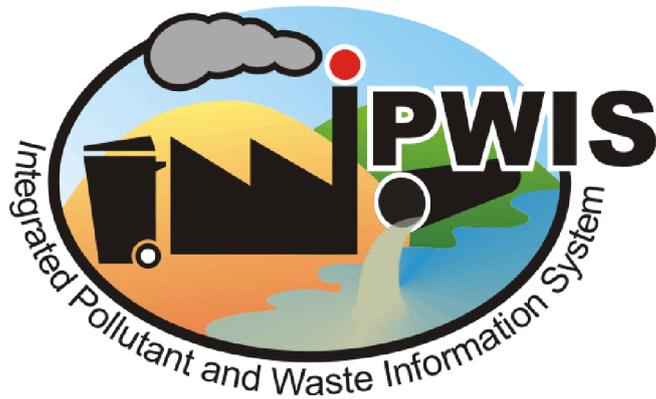
1 = Direct measurement    2 = Mass balance    3 = Engineering Calculation    4 = Emission Factors    5 = Other







**PART E: REPORTING FORM  
GUIDELINE DOCUMENT**



**DIRECTORATE: POLLUTION AND WASTE  
MANAGEMENT**

**REPORTING FORM GUIDELINE DOCUMENT**

**FOR THE (PRTR)**

**Please send complete reporting forms to:**

6 <sup>th</sup> Floor	or	P/Bag X9086
Property Centre		Cape Town
3 Dorp Street		8000
Cape Town		
8 000		

Or faxed to **(021) 483 4425**

Reporting Forms may also be accessed from **TO BE  
CONFIRMED**



*Department of Environmental Affairs and Development Planning  
Departement van Omgewingsake en Ontwikkelingsbeplanning  
Isebe leMicimbi yeNdalo esiNgqongileyo noCwangciso loPhuhliso*

DEFINITIONS

A **central business district (CBD)** is an area of very high land valuation characterized by a high concentration of retail businesses, service businesses, offices, theaters, and hotels, and by a very high traffic flow (United States Census Bureau, 2001).

**Cleaner Production:** Cleaner production is the continuous application of an integrated preventative strategy applied to processes, products and services to increase eco-efficiency and reduce risks to humans and the environment. Production processes can conserve raw materials and energy, eliminating toxic raw materials and reducing the quantity and toxicity of all emissions and wastes. Products can reduce the negative impacts along the life cycle of a product, from raw material extraction to its ultimate disposal. Services can incorporate environmental concerns into designing and delivering services (United Nations Environment Programme, 2001).

**Emissions** are a release of pollution/dischARGE of a substance into the environment from a source. Emissions can be discharged into the atmosphere from smokestacks, other vents, and surface areas of commercial or industrial facilities; from residential chimneys; and from motor vehicle, locomotive, or aircraft exhausts (National Safety Council, 2005).

**Facility** is a real property entity consisting of one or more of the following: a building, a structure, a utility system, pavement, and underlying land. A facility is also a fixed, mobile, or transportable structure, including all installed electrical and electronic wiring, cabling, and equipment and all supporting structures, such as utility, ground network, and electrical supporting structures (Alliance for Telecommunications Industry Solutions (ATIS), 2001).

**Floodlines** are lines that are hypothetically produced by engineers where flood risks exist. These floodlines are predicted on the basis of catchment area characteristics, available historical rainfall and event data. For example, a 50 yr floodline is the line defining the extremity of a flood event which is likely to occur within a fifty year period. Similarly a 100 year flood, which would be greater, could be expected on average once in 100 years, and is also a determining factor in planning issues. In addition 10 and 20yr floods could be predicted as well as 500 and possibly even 1000 year events. Flood lines are used as part of the criteria (by engineers and planners) to determine which areas of land can be safely used for residential purposes or whether or not the area is subject to flooding (Hout Bay River Forum, 2001).

**Inventory** is a descriptive list of items or groups of items in a collection (Cataloger's Reference Shelf, 2000).

**Pollutant** is a waste matter that contaminates the water or air or soil (WordReference.com, 2002). Pollutants are substances which directly or indirectly damage us or the environment; can cause the destruction of areas of the environment which are protective to us; imbalances environmental processes by causing an excess of a compound which is already present naturally and have a poisonous effect on the body. Some pollutants are not so dangerous by themselves until they combine with other naturally present compounds (DictionaryLaborLawTalk.com, 2002).

**Release** Is a discharge of a pollutant to the environment. A facility can release chemicals to the air, water and land or inject them underground. An off-site release is a facility sending chemicals to disposal at another site (PollutionWatch, 2003).

**Thresholds** The limit or point that when exceeded begins producing a given effect or result or to elicit a response. If a processes and/or sources of a given pollutants reached and /or exceeds a threshold, all the facilities that emit the pollutant/s from all sources must be reported (Answers.com, 2004).

**Transfers** A facility can also send chemicals off site to another facility for treatment, sewage, energy recovery or recycling (PollutionWatch, 2003).

**Where to send the completed forms:**

The completed reporting forms must be sent to the Department of Environmental Affairs and Development Planning, Pollution and Waste Management Directorate via post, facsimile, email or web page.

**SECTION A: FACILITY IDENTIFICATION INFORMATION**

**1. IPWIS ID Number**

This refers to the Integrated Pollutant and Waste Information system (IPWIS) identification number that has been allocated to the each company upon login to the IPWIS database when registering.

**Section A1: Reporting year**

This refers to the year during which the reporting period falls within. Each company/facility has the option of reporting every 3 months, 6 months or annually and an indication should be made in respect of the above.

**Section A2: Certification**

This section applies *after* the document has been read and after completing all form sections. This certification must be completed *prior* to submission of the reporting form

**1. Name and official title of owner/operator or senior management official**

This refers to the title, first name and surname of the owner/operator or senior management official as it appears in his/her Identity Document.

**2. Signature**

This refers to the signature of the owner/operator or senior management official.

**3. Date**

This refers to the date on which this document is signed by the /operator or senior management official.

**Section A3: Facility Identification**

**1. Registered Company Name**

This refers to the Company Name that the company has become "known as" to the general public.

**2. Facility Name (if different from Company Name)**

This refers to the facility name if it is different from the registered name that the company has become “known as” to the general public.

**3. Company/Business Number**

This refers to the number issued to the company once it has been registered.

**4. Registered Address of the Facility**

This refers to the Registered Address, Suburb and Postal Code.

**5. Postal Code**

This refers to the Postal Code of the facility.

**6. Street/Postal Address of the facility**

This refers to the Street Address/Postal Address and Suburb of the facility.

**7. Postal Code**

This refers to the Postal Code of 6. above.

**8. Facility Location (Latitude, Longitude co-ordinates)**

This refers to the geographical place or position of the facility with regard to latitude, longitude, degrees, minutes and seconds.

**9. Latitude**

This refers to the angular distance of a place north or south of the equator.

**10. Longitude**

This refers to the angular distance of a place east or west of a standard meridian, especially the Greenwich Meridian.

**9a. and 10a. Degrees**

This refers to a unit of measurement of angles, equivalent to one ninetieth of a right angle. (Symbol °)

**9b. and 10b. Minutes**

This refers to a sixtieth of degree of angular measurement. (Symbol ‘)

**9c. and 10c. Seconds**

This refers to a sixtieth of a minute of angular distance (Symbol “)

**11. Standard Industrial Classification (SIC) Code**

This refers to the Department of Trade and Industry allocated SIC codes.

**12. Briefly describe the main activities/processes conducted at this facility**

This refers to the main activities/processes that produce the main products of the facility.

**13. The number of employees you employed during the reporting period**

This refers to the number of people employed on a day-to-day basis by the facility up till the end of the specific reporting period. This information is useful in determining the size of the facility and the applicable threshold limits for the emissions.

**14. How long was the facility operational during the reporting period?**

This refers to the time period that the facility was in or ready for use and is measured in hours.

**15. Operating days of the week**

Specify the days when production and operation occurs, i.e. weekdays only, weekdays and weekends, including public holidays, etc.

**16. Hours**

Specify how many hours per day operation and production occurs, i.e. 8 hours/day, 24 hours per day, etc.

**Section A4. Complaints or general public enquiries**

**In terms of complaints or general public enquiries emanating from the company/facility who are the public contact persons?**

**1. Public contact name1 & 2:**

At least 2 names and contactable information, such as telephone numbers, fax numbers, email address and if possible a web page address must be provided.

**2. Parent Company Information**

This refers to an organisation or company, which owns or controls a number of subsidiaries.

**3. Name of Parent Company**

This refers to the name of the organisation or company, mention in 3. above.

**4. NA**

This refers to information that is not applicable to the company/facility.

## **Section A5: Additional Information**

**This refers to any extra information that the company/facility would like to relate to the Department of Environmental Affairs and Development Planning, Directorate: Pollution and Waste Management.**

### **1. What was the total output from your main economic activity?**

This refers to the total amount or number of the chief product that is being produced during the specific reporting period.

#### **1a. Product of the main activity**

This refers to the substance that is chief in size or importance and is the main product/activity during the natural, chemical or manufacturing process.

#### **1b. Quantity**

This refers to a certain amount or number.

#### **1c. Unit used**

This refers to a standard quantity in terms of which other quantities may be expressed.

### **2. What was your annual consumption of the following during the reporting period?**

This refers to the total usage of electricity, gas (petrol), oil, coal, water and other fuel sources used during the reporting period by the facility.

#### **2a. Electricity**

This refers to the supply of electric current to a facility for heating, lighting, etc. that is used by the facility

#### **2b. Gas**

This refers to the refined petroleum used as a fuel by the facility.

#### **2c. Coal**

This refers to a consumable black rock consisting mainly of carbonized plant matter and used as a fuel by the facility.

#### **2d. Oil**

Refers to Heavy Furnace Oils (HFO) as a fuel source.

#### **2e. Other**

This includes other fuel sources such as wood, paraffin, etc.

#### **2f. Water**

Refers to water used on site.

### **3. Storage facilities for raw materials and products (name, volume, characteristics and building features, enclosures, dimensions, etc). Provide brief description.**

This refers to the storage facilities of raw materials and products that may be gaseous, liquid or solid or any combination thereof. If storage of these materials or products does occur on site, "Yes" should be indicated and provision of a brief description must be submitted. The name and volume of the storage facilities must be provided together with dimensions. Characteristics and building features of the storage facilities such as enclosures, roofs, lining or containment areas, etc must be provided.

**4. Storage facilities for solid waste and effluent generated by the project. Provide brief description.**

This refers to the storage facilities of products that originate from domestic, commercial or industrial activities and include sewage sludge, radioactive waste, building rubble as well as mining, metallurgical and power station generation waste. If "Yes" is indicated, provision of a brief description is required. The facilities' solid waste and effluent must be identified and the information on their storage must be provided.

**5. Please provide a brief description of the socio-economic characteristics of the area.**

This refers to the interaction of social and economic factors of the area/vicinity/town. That is, the social and economic make up of the area, such as settlements, developments, zones (residential, agricultural, industrial, mixed, etc.), etc.

**6. Are any of the following located on or near the facility/site?**

**6a. Central Business District (CBD)**

Refers to the businesses and town services in the area. See definition.

**6b. High potential agricultural land/soil**

Refers to land/soil that is used or will be used for agricultural purposes.

**6c. River, dam, lake or wetland and estuaries**

These refer to a watercourse as defined in the National Water Act, No 36 of 1998 and are bodies of fresh water.

**6d. Currently used or potentially valuable groundwater resources**

This refers to subsurface water which may feed into wells and springs and that is currently used or has the capacity to develop into something valuable.

**6e. A floodplain within - 1: 50 floodline, 1:100 floodline**

This refers to an area of low-lying ground adjacent to a river that is subject to flooding.

**6f. Outfalls to any marine life**

Refers to any outfall/outlet pipe that enters a water body that sustains marine life

**6g. A formal or informal residential area**

Refers to areas where people are dwelling

**6h. A community facility (school, hospital, sports hall/fields)**

This refers to a building or area where people from the surrounding area gather for educational or recreational purposes.

## **SECTION B: POLLUTANT RELEASE INVENTORY FORM**

### **1. Pollutants**

Refers to the 20 priority pollutants (in no order of priority/preference) as identified by DEADP and documented in the Department's "Report on Integrated Pollutant and Waste Information System (IPWIS) Priority Pollutants." This report together with DEADP's "Guide to reporting and estimating emissions for the IPWIS" mentions these pollutants in greater details (sources and health effects).

### **2. Usage per reporting period**

Refers to the consumption of either the raw material or product that produces the pollutant/s during each reporting period.

### **3. Emissions to air, water and land**

This refers to the emissions to the air, water and land/soil either determined by monitoring these emissions or estimation the emissions using estimation techniques (coded 1 – 4) in tonnes/day per pollutant.

### **4. Total releases**

This refers to the estimated average volume/amount of the pollutant/s in tonnes/day over the reporting period. The

### **5. Estimation code**

The reporter must specify what method of estimation was used in order to report on the amount of the emissions. There are 5 codes with each representing a particular method of estimation. These codes are dependent on the "Guide to reporting and estimating emissions for the IPWIS." For more information on these techniques, please obtain or consult a copy of the report. The codes are as follows:

**1 = Direct measurement**

**2 = Mass balance**

**3 = Engineering Calculation**

**4 = Emission Factors** and

**5 = Other** (such as Predictive Emission Monitoring (PEM); Source Testing; Emission Estimation Model, etc.)

## **SECTION C: POLLUTANT TRANSFER INVENTORY**

**NB: This section is applicable to storage facilities ONLY, i.e. NO possessing of any chemicals occurs on site**

### **1. Substances**

Refers to either the raw material or product that produces the pollutant/s during each reporting period. Here the name, both common and scientific if possible, must be provided. *Examples include Solvents, HFO, etc..*

### **2. Chemicals**

Refers to the individual chemicals in the substance. **Example: where the *substance* is a *solvent*, the *chemical* may be *acetone*,**

### **3. Phase**

Refers to the state that the pollutant is, i.e. solid, liquid or gas. Here an S, L or G can be filled in where

S = Solid

L = Liquid and

G = Gas

**Example, the *acetone (chemical)* in the *solvent (substance)* is in a *liquid* phase.**

### **4. On site and 5. Off site**

This requires the quantities if the substance either/ both on site of the facility reporting to the PRTR or off site (not on facility property).

The units of measurements here depend on the phase that the substance is in. For Solids, units must be in kilograms (kg); for liquids in litres (l) and for gases cubic metres (m<sup>3</sup>).

### **6. Off site location name and address**

The name and physical address of the off site storage location/ facility must be provided here.

## SECTION D: EMISSION REDUCTION ACTIVITIES

These activities/equipment modifications describe the ways in which a facility has reduced emissions to air, water and/ or land of the substances used or produced on site. Note that the activity/ technique chosen represents current practice at your facility, whether it has been in place for some time or only recently adopted.

### 1. Cleaner Production Activities (Source reduction)

*These activities include any or a combination of the following:*

- **Improved housekeeping**

Improved housekeeping is a procedure within a service or manufacturing operation, which results in a reduction in waste generation.

Proper materials handling and storage ensures that raw materials reach the production process without spills, leaks or other types of losses, which could result in waste generation.

- **Process efficiency**

Process efficiency is a method of doing more with less by designing new systems or modifying existing ones, the most effective means of conserving materials and resources.

- **Material substitution**

Involves replacing hazardous chemicals with less toxic alternatives that are equally or more effective.

- **Inventory control**

Inventory control reduces product losses due to product expiration and overstocking.

- **Preventative maintenance**

Includes any activity that might prevent equipment malfunctions and minimise environmental releases.

- **In-process recycling**

In-process recycling is performed when materials are redirected back into the production process.

**The following can be reduced through a Source Reduction approach:**

- Raw materials usage
- Hazardous waste generation
- Solid waste generation
- Inventory losses
- Spills and accidental releases
- Energy usage
- Water usage
- Environmental releases

## 2. Installation of pollution control equipment (End of pipe reduction)

This refers to the installation of any equipment that will control emissions especially at the end of pipe such as:

- Electrostatic precipitator
- Water / steam injection (gas turbines)
- Fabric filter
- Lean / staged combustion
- Scrubber
- Flue gas recirculation
- Cyclone
- Biofilter
- Low NO<sub>x</sub> burner
- Activated carbon filter
- Selective catalytic reduction
- Incineration
- Selective non-catalytic reduction
- Other pollution control equipment (please specify below)

## 3. Other emission reduction activities

In this section, you are encouraged to fill in any other emission reduction activities/approaches (that are not mentioned above) that have resulted in the reduction of the emissions prior to this reporting period.

## References

Alliance for Telecommunications Industry Solutions (ATIS). (2001). **Facility**. <http://www.atis.org/tq2k/facility.html>

Answers.com. (2004). **Threshold**. <http://www.answers.com/topic/threshold>

Cataloger's Reference Shelf. (2000). **Inventory**. <http://www.itsmarc.com/crs/grph0362.htm>

DictionaryLaborLawTalk.com. (2002). **Pollutants**. <http://encyclopedia.laborlawtalk.com/pollutant>

Hout bay River Forum. (2001). **Some of the 50yr floodline violations of the past**. <http://www.zsd.co.za/~houtbay/river/50year1.htm>

National Safety Council (NSC). (2005). **Environmental Glossary**. [www.nsc.org/ehc/glossary.htm](http://www.nsc.org/ehc/glossary.htm)

PollutionWatch. (2003). **Frequently Asked Questions**. <http://www.pollutionwatch.org/tools/faq.jsp>

United Nations Environment Programme (UNEP). (2001). **Cleaner Production – Key Elements**. [http://www.unepie.org/pc/cp/understanding\\_cp/home.htm](http://www.unepie.org/pc/cp/understanding_cp/home.htm)

United States Census Bureau. (2001). *Central **Business Districts: 1982 Census of Retail Trade***. <http://www.census.gov/geo/www/cbd.html>

WordReference.com. (2002). **Pollutant**.  
<http://www.wordreference.com/definition/pollutant>