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RCRA, Superfund & EPCRA Hotline Training Module

Introduction to:

Toxics Release Inventory: Estimating Releases

(EPCRA §313; 40 CFR Part 372)

Updated June 1997

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TOXICS RELEASE INVENTORY: ESTIMATING RELEASES

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1. INTRODUCTION

Section 313 of the Emergency Planning and Community Right-to-Know Act of 1986 (EPCRA) and the Pollution Prevention Act (PPA) of 1990 mandate the development of a national inventory of releases of and other waste management activities involving certain toxic chemicals into the environment. Under this section, owners and operators of certain facilities that manufacture, process, or otherwise use listed toxic chemicals must annually report releases and transfers of, and waste management activities involving, these chemicals using the Form R or Form A. Specifically, facilities must provide information on fugitive and point source air emissions, water discharges, land disposal activities, and off-site chemical transfers. Owners and operators of covered facilities must also include any on-site or off-site recycling, energy recovery, or treatment of reportable chemicals. Completed forms are then sent to both EPA and the designated state agency (i.e., the State Emergency Response Commission (SERC)), through which the information is made available to the general public and to Federal, state, and local government entities.

This module provides an overview of general techniques that owners and operators of reporting facilities may use to estimate their toxic chemical releases. Although the guidance on estimation techniques is provided primarily for calculating release quantities, it can also be used to determine the amount of toxic chemical involved in recycling, treatment, or energy recovery activities. Hotline callers often need assistance not only in determining if they have to report, but also determining how to report. This module will identify some of the resources that owners and operators can use to estimate releases for Form R reporting. It also familiarizes EPCRA Information Specialists with common estimation methods.

When you have completed this module you will be able to:

- Explain the basic release estimation techniques used to determine the chemical quantities reported on the Form R
- Use those techniques, along with fundamental chemical or physical principles and properties, to estimate releases of, and other waste management activities involving, listed toxic chemicals
- Convert units of mass, volume, and time
- State the rules governing significant figures and rounding techniques
- Reference the general and industry-specific guidance documents.

Use this list of objectives to check your knowledge of this topic after you complete the training session.

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2. REGULATORY SUMMARY

EPCRA §313 (40 CFR Part 372) requires owners and operators of certain manufacturing facilities to annually report the quantities of listed toxic chemicals released into the environment, transferred to other locations, recycled, treated, or burned for energy recovery. To complete the Form R, the owner or operator must calculate or estimate the quantity of toxic chemicals involved in each of these waste handling activities. Several techniques may be used in making this determination, including analysis of monitoring data, mass balance calculation, use of emission factors, and calculation based on engineering equations and judgment. All routine and non-routine sources of releases and waste management activities, including fugitive and point source air emissions and liquid sources, should be considered when estimating the quantity of toxic chemical released or managed as waste. This module defines and provides examples of each estimation method, and identifies the suggested applicability of each technique. EPA also prefers that estimates reported on the Form R be rounded to no more than two significant figures, since the accuracy of most estimates cannot justify the use of more than one or two significant figures. This module, therefore, includes guidance on significant figures and rounding techniques. Finally, this module discusses the general and industry-specific guidance documents developed by EPA to aid reporting facilities in completion of the Form R.

2.1 RELEASE REPORTING REQUIREMENTS

Owners/operators must use all readily available data concerning the reportable toxic chemicals when estimating the releases and transfers of, and other waste management activities involving, a toxic chemical. Monitoring quantities or concentrations of toxic chemicals is not specifically required for the purpose of completing the Form R, although such information can be extremely helpful in quantifying chemical activities. When relevant data are not readily available, the reporting facility must make reasonable estimates of reportable toxic chemical quantities using one or a combination of four basic techniques: analysis of monitoring data, mass balance, emission factors, and engineering calculations. All quantities calculated or estimated for reporting on the Form R must satisfy two requirements. First, all figures must be specific to the listed toxic chemical rather than to the wastestream as a whole. Second, all quantities must be reported as pounds per year. It may be necessary for the facility owner/operator to make reasonable assumptions and manipulate available data to meet these criteria. The methods for estimating releases and examples of such calculations are presented throughout this module. It is important to note, however, that many types of releases may require case-by-case analysis and simply cannot be covered in this module.

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2.2 ANALYSIS OF MONITORING DATA

The most straightforward method of estimating releases for the Form R is to calculate the amounts of listed toxic chemicals using actual measurements made during the reporting year. Although monitoring data are not specifically required under EPCRA §313, pertinent information may be coincidentally generated as part of routine plant operations or to meet other environmental requirements. If monitoring data are available for releases of a given toxic chemical, simple calculations may yield an acceptable estimate. The facility purchasing department may maintain inventory information. Waste disposal records may be available in the accounts payable or environmental management offices. The facility may generate monitoring data for permitting purposes (e.g., the National Pollutant Discharge Elimination System and the National Emission Standards for Hazardous Air Pollutant permits), or to demonstrate compliance with Clean Air Act emission standards and Resource Conservation Recovery Act land disposal restrictions. All data used in release calculations should be representative of the facility as it operated during the reporting year. Sample results outside the normal range of operations should be disregarded in favor of more accurate data from other sources or from other testing periods. Whenever monitoring data are used as the primary tool in estimating releases, the code "M" should be reported as the basis of estimate on the Form R.

As stated previously, all data on the Form R must be reported as pounds per year, but measurements may only be available for the wastestream by volume (e.g., gallons per hour) or as chemical concentrations (e.g., parts per million, milligrams per liter). Thus, before monitoring data can be reported on the Form R, they may have to be manipulated into the proper format. In such cases, it is necessary for the owner/operator to convert the original data into pounds per year using density information and other appropriate conversion factors from Estimating Releases and Waste Treatment Efficiencies for the Toxic Chemical Release Inventory Form. Example 1 illustrates how these conversions are made.

EXAMPLE 1 - DIRECT MEASUREMENT

A wastewater stream containing five parts per million (ppm) lead is discharged to the local publicly-owned treatment works (POTW). Monitoring data indicate an average wastewater flow rate of 10 gallons per minute. The density of the wastewater is the same as that of water, 8.34 lb/gallon. If the plant operates 24 hours a day, 330 days a year, how much lead is discharged to the POTW in this wastestream?

KNOWN QUANTITIES:

Concentration lead in wastewater = 5 ppm
Wastewater flowrate = 10 gallons/minute
Hours of operation per day = 24 hours/day
Days of operation = 330 days/year
Density of wastewater = 8.34 pounds/gallon

STEP 1: Convert the measured volumetric flow rate from gallons/minute to pounds/year.

Convert the volumetric flow rate (V) to a mass flow rate:
mass flow rate (lbs/min) = V (gal/min) x density (lbs/gal)
= (10 gal/min)(8.34 lbs/gal)
= 83.4 lbs/min

Now, convert the mass flow rate to an annual mass flow rate:
annual mass flow rate (lbs/yr) = (83.4 lbs/min)(60 min/hr)(24 hr/day)(330 days/yr)
= 3.96×10^7 lbs wastewater discharged per year

STEP 2: Using concentration information, determine the quantity of lead discharged in wastewater per year.

5 ppm lead = 5 parts lead per 1 million parts wastewater
= 5 lbs lead per 1 million lbs wastewater

(3.96×10^7 lbs ww discharged/year)(5 lbs lead/1 million lbs ww)
= 198 lbs lead discharged per year

ANSWER: Accounting for significant figures as discussed in Section 2.7 of this module, an estimated 200 pounds of lead are discharged annually in the wastewater transferred to the POTW.

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In addition to manipulating data to reflect the proper units, many manufacturing facilities must first calculate the amount of toxic chemical in the wastestream. To do this, the weight of the wastestream, derived from monitoring data, should be multiplied by the mass fraction of the toxic chemical in that wastestream. The owner or operator may again have to convert associated units, or may need to employ basic chemical or physical equations such as the Charles' Law to derive an appropriate figure. Example 2 details this type of calculation.

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EXAMPLE 2 - DIRECT MEASUREMENT

Measurements are taken at the oxychlorination vent of a plant producing dichloroethylene (DCE) under normal operating conditions. The concentration of DCE in the gas is 0.22 grams/cubic meter. Based on the size of the vent and the speed of the waste gas exiting the vent, the owner has calculated the flow rate of the exiting gas at 59,400 ft^3/hr. The facility is in operation 2,000 hours each year. Calculate the annual releases of DCE from this vent.

KNOWN QUANTITIES:

Gas flow rate = 59,400 cubic feet/hour
Concentration DCE in gas = 0.22 grams/cubic meter
Operating hours = 2,000/year

STEP 1: Convert the DCE concentration from metric units (grams per cubic meter) to English units (pounds per cubic foot).

Measured DCE concentration = 0.22 g/m^3

Conversion factors: 1 pound = 454 grams
1 ft^3 = 0.028 m^3

DCE concentration = (0.22 g/m^3)(1 lb/454 g)(0.028 m^3/ft^3)
= 1.36×10^{-5} lbs DCE per cubic foot of vent gas

STEP 2: Determine the quantity of DCE released per hour.

DCE emission rate
= DCE conc. in waste gas (lbs/ft^3) x waste gas flow rate (ft^3/hr)
= (1.36×10^{-5} lbs DCE/ft^3 gas)(59,400 ft^3 gas/hr)
= 0.808 pounds DCE released per hour

STEP 3: Calculate annual releases of DCE.

Annual DCE emissions
= DCE flow rate (lbs/hr) x operating time (hr/yr)
= (0.808 lbs DCE/hr operation)(2,000 hr of operation/year)
= 1,600 lbs DCE/year

ANSWER: 1,600 pounds of DCE were released during the reporting year from the oxychlorination vent.

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2.3 MASS BALANCES

The second estimation technique takes into account the law of conservation of mass, and provides a means of accounting for all the inputs and outputs of a particular toxic chemical throughout a facility or process. Since mass can be neither created nor destroyed, the amount of chemical entering the system must equal the amount of chemical exiting the system in one form or another. The general equation for mass balance is:

Input + Generation = Output + Amount Reacted + Accumulation

For the purposes of Form R reporting, input is the total amount of toxic chemical available at the beginning of the year plus the amount purchased during the year. Generation is the amount manufactured at the facility. Output is the amount of toxic chemical that left the facility as product, was released on site, or was transferred off site as a waste for treatment, recycling, or disposal. Amount reacted is the amount of the toxic chemical that was converted into another chemical on site, such as in waste treatment or as a reactant. Accumulation is the amount of the chemical left in inventory at the end of the calendar year. Example 3 illustrates how these pieces can be used in mass balance calculations to estimate releases for the Form R. The code "C" should be reported as the basis for estimate on Form R for all quantities derived from mass balance calculations.

EXAMPLE 3 - MASS BALANCE

A specialty steel manufacturer processes nickel in production operations. In a year, the facility produced 24,000 pounds of product containing 20 percent nickel (Ni) by weight. During the calendar year, 8,000 pounds of nickel were purchased, and inventory records show that 4,000 pounds of nickel were left over from the preceding year. The process generated 10,000 pounds of scrap containing 10 percent nickel by weight; this waste is sent off site for recycling. At the end of the calendar year, 2,000 pounds of nickel were left in inventory. An unknown amount of nickel was disposed of off site in the facility's solid waste. Using mass balance calculations, estimate this unknown quantity.

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KNOWN QUANTITIES:

Amount of product = 24,000 pounds
Concentration Ni in product = 20 percent by weight
Amount Ni purchased = 8,000 pounds
Initial Ni inventory = 4,000 pounds
Amount of scrap = 10,000 pounds by weight
Concentration of Ni in scrap = 10 percent
Final inventory = 2,000 pounds

STEP 1: Input = Amount Ni Purchased + Amount Ni in Inventory
= 8,000 lbs + 4,000 lbs
= 12,000 lbs Ni

STEP 2: Output = (Ni in product) + (Ni in scrap) + (Ni in solid waste)
= 20 wt%(24,000 lbs product) + 10 wt%(10,000 lbs scrap) + X lbs in solid waste
= 5,800 lbs Ni + X lbs Ni in solid waste

STEP 3: Accumulation = Amount left in inventory
= 2,000 lbs Ni

STEP 4: No nickel is reacted or generated at the facility in this scenario. (These terms are generally not relevant to mass balances for metals.)

STEP 5: Complete the mass balance equation, solving for X.

Input + Generation = Output + Amount Reacted + Accumulation
12,000 lbs + 0 = 5,800 lbs + X + 0 + 2,000 lbs
X = 4,200 lbs Ni

ANSWER: Accounting for significant figures, 4,200 pounds of nickel are sent off-site for disposal.

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2.4 EMISSION FACTORS

An emission factor is an average value that describes the quantity of a chemical released to the atmosphere as a function of the specific process or equipment used at a facility. Emission factors are frequently expressed as a ratio of chemical released to chemical throughput or amount of product produced. Depending on the exact measurements being compared, emission factors can be expressed in various units (e.g., pounds of chemical released per pound of product output, pounds of chemical released per hour of operation, or pounds of chemical released per pound of chemical circulating in the system).

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Emission factors are derived from monitoring data on chemical operations. To calculate an emission factor, data are collected on both the amount of toxics being processed through the system and the amount of chemical being released. From these data, a ratio (emission factor) is created. Emission factors are based on the assumption that similar operations will have approximately the same ratio of releases to throughput of a given chemical, even though the operations may be on a different scale. Factors have been developed for specific volatile organic compounds (VOCs), particulates, and some specific toxic chemicals. These commonly used emission factors are found within the guidance document Compilation of Air Pollutant Emission Factors (AP-42). This document can be downloaded through the Clearinghouse for Inventories and Emission Factors (CHIEF) bulletin board system by calling (919) 541-5742, or may be downloaded from the Technology Transfer Network (TTN) on the World Wide Web. AP-42 is also available through Fax CHIEF at (919) 541-0548.

Example 4 employs a chemical-specific emission factor to estimate releases from a process. Facilities using this estimation technique would choose code "E" as the basis of estimate on Form R.

EXAMPLE 4 - EMISSION FACTOR

Air emissions from the blast furnace at a primary lead smelting facility are controlled by a fabric filter system. This specific industry is discussed in section 7.6 of the document Compilation of Air Pollutant Emission Factors (AP-42). Data listed in this section include an emission factor for uncontrolled particulate releases from a blast furnace of 361 pounds per ton of lead produced. A particulate removal efficiency range of 95-99 percent is also given for fabric filter air pollution control devices, which are used in many primary lead smelting operations.

Calculate the total releases of lead from the particulate emissions, assuming that the particulates are 30.7 percent lead, that 31,500 tons of lead are produced annually, and that a fabric filter control device is used.

KNOWN QUANTITIES:

Particulate emission factor = 361 pounds of particulate/ton of lead (Pb) produced
Efficiency range of fabric filter control device = 95-99%
Concentration of lead in particulate = 30.7 percent dry weight
Annual production of lead = 31,500 tons/year

STEP 1: Adjust uncontrolled emission factor to account for air pollution control device.

Adjusted emission factor
= original emission factor (lbs/ton) x average efficiency of fabric filters (%)
= 361 lbs total particulates/ton Pb produced x 3% uncontrolled emissions

= 10.83 lbs uncontrolled particulates released /ton Pb produced

STEP 2: Calculate poundage of uncontrolled particulates released per year

Uncontrolled particulate emission rate
= adjusted emission factor (lbs/ton) x amount produced per year (tons/year)
= (10.83 lbs/ton Pb produced)(31,500 tons Pb produced/year)
= 341,145 lbs uncontrolled particulates released/year

STEP 3: Calculate quantity of lead in particulate emissions.

Uncontrolled lead emissions
= annual particulate emission rate (lbs/yr) x percent Pb in particulates
= (341,145 lbs particulates/year)(30.7% Pb in particulates)
= 104,731.5 lbs Pb released/year

ANSWER: Accounting for significant figures, 105,000 pounds of lead are estimated to be released to air annually as particulates from the facility's blast furnace.

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2.5 ENGINEERING CALCULATIONS

Specific data required to estimate releases will sometimes be unavailable or unreliable. Sometimes parameters related to emissions cannot be directly measured. In these situations, estimates may be based on best engineering judgment or calculations. For example, facility operators may use physical and chemical properties of the materials involved, equipment design information, or emission information from similar processes to estimate the releases of a toxic chemical. Engineering calculations are generally used to supplement the information needed for one of the other release estimation techniques. EPA guidance indicates that estimates based on nonchemical-specific factors should be considered as engineering calculations with the code of "O" (Question 364, *EPCRA Section 313 Questions and Answers*, November 1997). Use of unpublished or facility-specific factors would also fall under the category of engineering calculations. The following examples illustrate engineering calculations that incorporate some of the concepts, such as air emission factors and monitoring data, discussed previously in this module.

EXAMPLE 5 - ENGINEERING CALCULATION

A chemical plant uses benzene in its production operations. Benzene is a light liquid with a vapor pressure greater than two pounds per square inch (psia). Process equipment at the facility includes six pipe valves, three open-end valves, four flanges, two pumps, one compressor, and one pressure-relief valve. During the

reporting year, the facility operated 24 hours a day for a total of 250 days.

Estimate fugitive emissions to air from equipment leaks using emission factors.

KNOWN QUANTITIES:

Operating hours = 24 hours/day Operating days = 250 days/year

STEP 1: Compile appropriate emission factors for the process units.

All equipment is subject to leakage, especially at places such as connection points, seals, and valves. The quantity of chemical released in this manner is dependent upon the quality and frequency of equipment maintenance. Poorly maintained equipment has higher leakage rates and higher emission factors than well-maintained equipment. To estimate the releases due to leakage, we have chosen to use average fugitive emission factors for the synthetic organic chemicals manufacturing industry (SOCMI). These emission factors represent the quantity of chemical released to air from leaks in process components such as valves, seals, and flanges. The following SOCMI emission factors may be found in Appendix D of Estimating Releases and Waste Treatment Efficiencies for the Toxic Chemical Release Inventory Form.

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SOCMI EMISSION FACTORS (as listed in Appendix D):

6 Pipe valves (in light liquid service) = 0.016 pounds/hour each
3 Open-end valves = 0.0037 pounds/hour each
4 Flanges = 0.0018 pounds/hour each
2 Pump seals (in light liquid service) = 0.11 pounds/hour each
1 Compressor seal = 0.50 pounds/hour
1 Pressure-relief valve = 0.23 pounds/hour

STEP 2: Each emission factor above represents pounds of leakage per unit. Since some components are present at several points in the process, it is necessary to calculate the aggregate emission factor.

Total fugitive emission factor from process
= (6 x 0.016) + (3 x 0.0037) + (4 x 0.0018) + (2 x 0.11) + (0.50) + (0.23)
= 1.064 lbs/hr

STEP 3: Calculate annual releases of benzene.

Annual emission rate
= (1.064 lbs/hr)(24 hr/day)(250 days/year)
= 6,385.8 lbs/year

ANSWER: Rounding off to 2 significant figures, 6,400 pounds of benzene are released to air annually in fugitive emission leaks from process equipment at the chemical plant.

* * * * *

When making engineering calculations, the facility owner or operator will often incorporate some monitoring data, and it may be unclear which code should be reported on the Form R as the basis of the estimate. In most cases, analysis of monitoring data primarily involves manipulation of direct measurements to extract data in the proper units or on a particular chemical. For quantities derived in this manner, "M" is the estimate code that should be used. Alternatively, when the focus of the estimation is on chemical or physical principles, regardless of the use of measured data, the basis of estimate should be reported as "O." The following scenario provides an example of engineering calculations supplemented by monitoring data.

EXAMPLE 6 - ENGINEERING CALCULATION

A facility had an episodic event during which a wastestream containing nitric acid (HNO_3) fell from a typical pH of 6.0 to an average pH of 1.6. During the 10-minute episode, the wastewater was discharged to a river at a rate of 106 gallons per minute. Estimate the quantity of HNO_3 discharged to the river during this episodic release.

KNOWN QUANTITIES:

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pH of discharge = 1.6 Length of episode = 10 minutes Rate of discharge = 106 gallons/minute

STEP 1: Explain the chemical relationship between hydrogen ion concentration $[H^+]$ and the nitric acid concentration $[HNO_3]$. (The symbol $[H^+]$ indicates hydrogen ion concentration, and $[HNO_3]$ represents nitric acid concentration, both expressed in moles/liter.)

Nitric acid dissociates according to the equation:

$$[HNO_3] \longleftrightarrow [H^+] + [NO_3^-]$$

Although the equation indicates an equilibrium between HNO_3, hydrogen ions, and nitrate ions, since HNO_3 is a strong acid, the equilibrium actually lies far to the right. This means that in a solution, most of the acid will readily dissociate into the individual ions and thus, the total molar concentration of nitric acid is equal to the hydrogen ion concentration.

STEP 2: Explain the chemical relationship between pH and hydrogen ion concentration.

pH is a logarithmic measure of the hydrogen ion concentration in a solution. As the pH drops, the solution becomes more acidic. As the pH rises, the solution becomes more basic. The mathematical relationship is:

$$pH = -\log_{10} [H^+]$$
$$[H^+] = 10^{-pH} = [HNO_3]$$

STEP 3: Calculate the wastestream concentration of nitric acid in pounds per gallon using a pH of 1.6.

$$[HNO_3] = 10^{-1.6} = 0.025 \text{ moles } HNO_3 \text{ per liter}$$

Molecular weight: 63.01 grams HNO_3 per mole

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Conversion factors: 3.784 liters per gallon
1000 grams per kilogram
2.205 pounds per kilogram

[HNO_3] in lbs/gallon
= (0.025 mol/L)(63 g/mol)(3.784 L/gal)(1 kg/1000 g)(2.205 lbs/kg)
= 0.0131 lbs/gal

Note: Although the calculation above is presented for clarification, Table 1 of Estimating Releases for Mineral Acid Discharges Using pH Measurements can be used to directly match pH values with [HNO_3] in pounds per gallon. Information is also provided for other mineral acids.

STEP 4: Determine total quantity of nitric acid released during the reporting year.

Release of HNO_3 during the episode
= (Effluent flow rate)(HNO_3 in effluent)(Flow duration)
= (106 gal/min)(0.0131 lbs/gal)(10 min)
= 13.9 lbs/episode

ANSWER: If this is the only episode during the reporting year, the facility should report a total annual discharge of HNO_3 to the river of 14 pounds (after rounding to significant figures). Although a small amount of nitric acid is released in wastewater at pH 6, the Form R instructions (p. 25) state that a facility can report "0" for discharges of neutralized mineral acids (pH 6 or above).

2.6 MODELS AND COMPUTER PROGRAMS

Various models and computer programs may be used by facilities to estimate releases or waste generation sources. These models and programs include, but are not limited to, CHEMDAT8, TANKS, TSCREEN, and WATER8. These four models and programs are specifically mentioned in EPA's industry-specific guidance for newly added facilities under the Toxic Release Inventory phase 2 expansion. Facilities can download all four models and programs, along with a corresponding users manual, from the World Wide Web.

CHEMDAT8

Consisting of several analytical models assembled into a spreadsheet, CHEMDAT8 estimates organic compound emissions via various pathways from water and waste management units. Facilities may also use the models to estimate the magnitude of site air emissions for regulatory purposes. Several area emission sources are incorporated into the analytical models. Area emission sources include non-aerated

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impoundments (e.g., surface impoundments and open top wastewater treatment tanks), aerated impoundments (e.g., surface impoundments and wastewater treatment tanks), disposal impoundments (e.g., non-aerated disposal impoundments), land treatment, and landfills.

TANKS

The TANKS program estimates organic chemical emissions from several types of storage tanks on an annual or partial year basis. The program relies on a chemical database of over 100 organic liquids and a meteorological database which includes over 250 cities within the United States. The calculations within the program are performed according to AP-42. Facilities within SIC code 5171 (i.e., petroleum bulk storage facilities) and other facilities storing EPCRA Section 313 toxic chemicals in underground and aboveground storage tanks may benefit from using TANKS.

TSCREEN

The TSCREEN model, which includes the TSCREEN computer program used in conjunction with the EPA document entitled Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants (Revised, 1992a), estimates emissions from tailing piles, as well as other types of possible releases. Facilities within SIC code 10 (i.e., metal mining facilities) may benefit from using the TSCREEN model.

WATER8

WATER8, a DOS computer program, estimates the fate of organic compounds in various wastewater treatment units, including collection systems, aerated basins, and other units. The computer program links treatment units to form a treatment system, considers recycling among units, and generates and saves site-specific compound properties.

2.7 APPLICABILITY OF ESTIMATING METHODS

Although any technique described in this module can be used to estimate releases for the Form R, all methods may not be applicable to or appropriate for all types of releases. The approach selected will be based on the type of release involved (i.e., the medium to which the chemical is released), and to a lesser extent, the specific toxic chemical being released.

Fugitive Air Emissions

Measurement data on fugitive air emissions will rarely be available. Furthermore, fugitive emissions from most sources are small compared to the total amount of chemical handled during the year, and these losses are difficult to estimate.

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accurately if mass balance techniques are attempted. For these reasons, the use of emission factors and engineering calculations are the most widely used method for determining fugitive releases to air. Emission factors are available for many specific chemicals, processes, and types of equipment. Of course, if these data are unavailable for the particular chemical or unit involved, another estimation technique must be chosen.

Point Source Air Emissions

Since point source air emissions are enclosed, these releases are more likely than fugitive emissions to have been measured and quantified. Analysis and manipulation of monitoring data (e.g., chemical concentrations and exhaust gas flow rates) is thus a common method for estimating these types of releases. If monitoring data are unavailable or do not represent normal operations at the facility, emission factors may be used. When these approaches are not possible, point source release estimates can be based on mass balance equations. As with fugitive emissions, however, the toxic chemical quantities released may be insignificant when compared to the total throughput at the facility, and mass balance techniques may provide somewhat inaccurate estimates.

Releases to Water

Many of the listed toxic chemicals under EPCRA §313 are also subject to a variety of other federal, state, and local environmental laws. To ensure compliance with these programs, water discharges are often monitored, and releases can be calculated using these data. If no monitoring is conducted, the facility can use either mass balance calculations or engineering calculations. The mass balance technique is an option for water releases if there are not too many input and output streams.

Releases to Land

Land disposal of waste is typically regulated under RCRA, and requires the preparation and maintenance of shipment records. These records or manifests should contain information on the quantity and type of waste transferred off site, as well as the location to which the wastes were sent. For purposes of hazardous waste identification, the concentration of certain chemicals in the waste may have been measured. Mass balance calculations or monitoring data analysis can be used to estimate releases when appropriate records are available.

2.8 SIGNIFICANT FIGURES

Most measurements of any physical quantity will have some degree of error. The size of this error will depend on the sensitivity of the tool used to take the measurement. For example, if a rock weighing exactly 479.555 pounds is measured on a scale that is calibrated in 1-pound intervals, the scale would read that the rock

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weighed 480 pounds. If the rock was then measured on a scale calibrated in 0.1-pound intervals, the weight would then be displayed as 479.6 pounds. The more sensitive the measuring instrument, the more digits (significant figures) the instrument will use to express the measured quantity.

To determine the number of significant figures in a given value, we count the digits. All digits other than zero are always considered significant. A zero may or may not be considered significant, depending on its position in the value relative to other digits and the decimal point. The following rules apply to zeros:

- A zero is significant if it is both preceded and followed by a nonzero digit. According to this rule, the value 10.203 has five significant figures, and 1.002 has four significant figures.

- A zero is not significant if it is not preceded by a nonzero digit. For example, the first 0 in the value 0.123 is not significant, nor are the zeros in 0.0001. These zeros are necessary only to indicate where the decimal point lies.

- Final zeros to the right of the decimal point are significant. Thus, 1.000 has four significant figures, and 0.010 has two significant figures.

- Final zeros in a whole number may or may not be significant. If the number is followed by a decimal point, as in 1200., all four digits are counted as significant. If no decimal point is included, however, the value 1200 would contain only two significant figures.

When completing the Form R, EPA requires a degree of accuracy no greater than two significant figures (53 FR 4514; February 16, 1988). Even though calculators may be used to make release calculations and estimates providing results containing many digits, such estimates should be rounded off to two significant digits in order not to imply false accuracy of the reported estimate. If more than two significant figures are available, the facility may use its best reasonable estimate or degree of accuracy with which it feels comfortable (within reason). If the facility does not release a toxic chemical to a specific environmental media or off-site location and there was no possibility of a release, NA should be reported. If a release to a specific medium or off-site location could have occurred, but either did not occur or the annual aggregate release is less than 0.5 lbs., zero should be reported. A facility reporting zero releases must provide a basis of estimate on the Form R. In sections 5 and 6 of the Form R, a facility can avoid the issue of significant figures altogether by reporting using range codes (rather than using a specific number) for releases between 1 and 1,000 pounds.

Before rounding reported quantities, the following rules should be consulted:

- If the first digit to be dropped is greater than 5, the last significant figure should be rounded up. If the digit to be dropped is less than 5, the number

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should be rounded down. According to these rules, 1.62 would be rounded down to 1.6, while 1.67 would be rounded up to 1.7.

- When the first digit to be dropped is 5, always round to the nearest even number. If the value 1.35 is rounded to two significant figures, the reported value would be increased to 1.4, but if the value 1.25 is rounded to two significant figures, the reported value would be decreased to 1.2. The value 0.5 would be rounded down to 0.

In performing a calculation of two or more steps, it is desirable to retain additional digits for intermediate answers. This ensures that small errors from rounding do not appear in the final result. Therefore, reported quantities should be rounded only after all calculations have been made.

ADDING AND SUBTRACTING

When adding and subtracting measured quantities, we should give the same number of decimal places in the answer as there are in the measurement with the least number of decimal places. The following example illustrates this technique:

A test tube is weighed on a scale that is calibrated in 0.001 pound intervals. According to this scale, this test tube weighs 1.225 pounds. Water is weighed on a scale that is calibrated in 1-pound intervals. A 5-pound sample of the water is placed in the test tube. If these two quantities were added together, the answer would be 6.225 pounds; however, the final quantity can only be as accurate as the least precise piece of equipment. Since the scale was calibrated in 1-pound intervals, the answer must be as well. Therefore, using significant figures, the answer is 6 pounds.

MULTIPLYING AND DIVIDING

When multiplying or dividing measured quantities, we should give as many significant figures in the answer as there are in the measurement with the least number of significant figures. The following examples illustrate this technique:

The area of a rectangular piece of wood would be calculated by multiplying the piece's width by its length. The width is measured to be 7.9 feet and the length is measured to be 4.334 feet. Therefore, the area would be calculated to be 34.2386 square feet. The answer seems to have the precision to the 0.0001 feet; however, the data's precision does not support the answer's precision. The answer needs to be rounded off to the number of significant figures in the least precise quantity, so the answer using significant figures is 34 square feet.

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3. MODULE SUMMARY

Having completed this module you should now have a basic understanding of the four techniques used to estimate toxic chemical releases to be reported on the Form R. The first method covered was the analysis of monitoring data obtained throughout the reporting year. This technique can be very helpful when estimating air emissions, releases to water, and releases to land. The second technique discussed was mass balance. A mass balance provides a means of accounting for all the inputs and outputs of a particular toxic chemical throughout a facility or process. The third technique, as described in the module, was emission factors which are derived from monitoring data on chemical operations and used primarily to estimate air emissions. The last technique discussed was engineering calculations. Engineering calculations are generally used to "fill in" information needed for one of the other release estimation techniques.

In addition to being familiar with release estimation techniques, you should also be aware of the rules governing significant figures and rounding techniques. EPA requires that release and transfer estimates on the Form R be reported with a degree of accuracy no greater than two significant figures, but facilities may use estimates with a higher degree of accuracy. It is also important to remember that rounding should occur only after all calculations have been completed.

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4. REVIEW EXERCISES

The exercises in this section are designed to help you check your knowledge of the material in this module. Use any reference materials you need to answer the questions. Provide complete citations and write your answers in paragraph form.

EXERCISE 1

Determine the number of significant figures in each quantity and round to two significant figures for Form R purposes. What is EPA's policy on significant figures for the Form R?

1. 2400
2. 2701
3. 23.003
4. 0.00305
5. 235.5

EXERCISE 2

Convert from one unit to another. Conversion factors are listed in *Estimating Releases and Waste Treatment Efficiencies*. Show all work and be sure to round the result off to two significant figures.

1. 411 in = ? meters
2. 5,150 m^3 = ? U.S. gallons
3. 5.7×10^{-3} lbs. = ? mg
4. 125.0 mm Hg = ? psia
5. 203 mph = ? ft/s

EXERCISE 3

Estimating Releases and Waste Treatment Efficiencies contains chemical and physical properties of §313 toxic chemicals. Using this resource, answer the following questions.

All data are found in Appendix B.

1. The specific gravity and density of nitrogen mustard. (Follow the directions on page B-3.)

2. The ambient state of aniline.

3. The molecular weight of benzidine.

4. The vapor pressure of chloroprene. At what temperature?

5. For chemicals newly listed on the EPCRA §313 toxic chemical list, what resources are available for determining the chemical/physical properties of the toxic chemicals?

EXERCISE 4

Determine which release estimation technique would generally be applicable in the following situations. (Note: Depending on case-specific circumstances and information, any method may be selected for a given situation.) Briefly discuss why your choice would be selected, and list possible sources of additional information which may be helpful in making release estimates.

1. Copper is a component of the plating and other process baths at Ebbs electroplating facility. Copper exits the facility only in the finished product (e.g., castings) and as a wastewater discharge.

2. A roll coating facility sends a listed hazardous waste generated during "dry" coating cleanup operations to an off-site landfill. In compliance with RCRA regulations, a manifest always accompanies the waste shipment.

3. Release estimates must be made for a one-time accidental spill of a toxic chemical in the parking lot at Suzie's Colors and Fabrics.

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EXERCISE 5

On July 27, 1998, the operator of a petroleum bulk storage facility pumps an aviation gasoline liquid mixture containing toluene out on an external floating roof tank (EFRT). The level of aviation gasoline in the EFRT drops five feet below its original level once the operator finishes pumping, leaving gasoline exposed on the tank walls. The residual aviation gasoline evaporates from the tank walls into the surrounding air.

1. Is the petroleum bulk storage facility required to file a Toxic Release Inventory (TRI) report for the amount of toluene released from the residual aviation gasoline if the facility repackages 60,000 gallons of aviation gasoline during reporting year (RY) 1998? Explain how you arrived at your answer. [Note: For question 1., assume the petroleum bulk storage facility does not have access to any specific concentration data regarding EPCRA Section 313 chemicals.]

2. Assume the petroleum bulk storage facility exceeds the 25,000 pound process threshold for toluene during RY 1998. How would the evaporative loss of toluene originating from the exposed EFRT walls be reported on the facility's Form R report due July 1, 1999?

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EXERCISE 6

Using the document Compilation of Air Pollutant Emission Factors (AP-42), determine the following emission factors.

1. Releases of ammonia from a carbon dioxide regenerator used at synthetic ammonia plants.

2. Emissions of tetrachloroethylene, a volatile organic compound (VOC), from processing southern pine wood in a plywood veneer dryer during plywood manufacturing operations.

3. Uncontrolled fugitive lead particulate emissions from secondary lead smelting operations.

4. Uncontrolled releases of lead from the manufacturing of Portland cement using kilns in the wet process.

5. Emissions resulting from the cleaning of a tank truck which contained tetrachloroethylene. (You may need to use your Common Synonyms booklet.)

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