WORKPLACE PRACTICES & SOURCE RELEASE ASSESSMENT

OVERVIEW: The survey of workplace practices and source release assessment is the process of: (1) identifying and collecting data on workplace activities that may contribute to worker exposure; and (2) identifying the sources and amounts of environmental releases. The collected data are analyzed to determine the sources, nature, and quantity of both on-site releases (e.g., chemicals released to the sewer, evaporative, or fugitive emissions from the process, etc.) and off-site transfers (e.g., discharges to publicly owned treatment works).

GOALS:

- Collect workplace practices data through discussions with industry experts, review of existing information, the performance demonstration project, or the dissemination of a questionnaire to industry.
- Create a profile of a typical or model facility which can be used as the model for source release and exposure assessment calculations.
- Perform a source release assessment on the model facility to identify and characterize both on-site and off-site chemical releases and transfers.
- Provide data needed for the Exposure Assessment module which estimates possible exposure concentrations to human health and the environment.

PEOPLE SKILLS: The following lists the types of skills or knowledge that are needed to complete this module.

- In-depth knowledge of the process under review, including waste streams and their point sources.
- Understanding of the concepts of material balances.
- Knowledge of the workplace activities associated with the operation of the process.
- Experience with exposure assessment guidance and methodology.
- Understanding of chemical fate, transport modeling and exposure modeling.
- Knowledge of chemistry or environmental science.
- Knowledge of surveying techniques and methodologies if a survey is utilized.

Within a business or DfE project team, the people who might supply these skills include a process engineer, a process operator or specialist, a statistician, an industrial hygienist, an environmental engineer, and a chemist or environmental scientist. Vendors of equipment or chemicals used in the process may also be a good resource.

DEFINITION OF TERMS:

Basis: The reference point chosen for the calculations made in any particular problem.

Material Balance: An accounting of the flow of material in and out of a system, derived from the generalized law that the mass of a material is conserved throughout a process. A material balance can be used to identify the sources and quantities of chemical released to the environment.

Mole: The weight of a substance, in kilograms, equal to that substance's molecular weight in atomic mass units.

Periodic Table: A list of elements in order of increasing atomic number, arranged in tabular form such that elements having similar properties appear in vertical columns.

Stoichiometry: The quantitative relationship between constituents in a chemical substance or reaction.

APPROACH/METHODOLOGY: The following presents a summary of the approach or methodology for collecting workplace practices data and conducting a source release assessment. Further methodology details for Steps 2, 3, 5, and 12 follow this section. Two examples of workplace practices questionnaires can be found in Appendix A.

Survey of Workplace Practices

Step 1: Obtain the unit operations and process flow diagram from the Chemistry of Use & Process Description module. The process flow diagram and unit operations provide the framework from which the workplace practices questionnaire can be generated.

Step 2: Identify the data needed to perform both the source release and exposure assessments. Information regarding industry pollution prevention practices should also be collected.

Step 3: Create a workplace practices questionnaire to obtain the information identified in Step 2 for this and subsequent modules. Existing information, such as industry literature, published studies and industry or scientific databases, should be checked and data used when applicable, to prevent the survey from becoming unduly long.

Step 4: If time and resources permit, conduct a test-run of the questionnaire by either distributing it to a small group of test facilities, or by performing site visits at selected facilities to assist them with the completion of the questionnaire. The goals of the test-run are to:

- Identify problems that may exist with the questionnaire (i.e., questions that are unclear, etc.).
- Verify that the data collected from the survey are reasonably representative and complete and that relevant data are not excluded from the results (i.e., all pertinent waste streams are included in the questionnaire, workplace practices that may contribute to worker exposure are represented, etc.).
- If site visits are performed, collect verified data that can be used as a guideline for identifying errant questionnaire data that may be collected during the survey.

Step 5: Collect industry data using the workplace practices questionnaire from the appropriate source(s). Typical sources of data include industry experts, performance demonstration sites, and/or individual industry facilities. The methods used to collect the data depend mostly on the source and include:

- Completing the questionnaire through discussions with a group of industry experts.
- Using the questionnaire as an observer data sheet to be completed during the performance demonstration (see the Performance Assessment module for more information on this process).
- Disseminating the questionnaire to a representative sample of industry facilities.

Step 6: Tabulate the data, preferably in a computer data base, so that it may be readily compared and analyzed. Data to be tabulated may include questionnaire responses, performance demonstration results, and any established data found to be relevant.

Step 7: Inspect the tabulated data for reasonableness and consistency using professional judgment. Collected data that appear unreasonable (i.e., outlying data that are inconsistent with the majority of the data) should be verified with the facility or person responsible for reporting the data point. Data generated from site visits performed in Step 4 may be used as a guide for evaluating the survey data.

Step 8: Provide a list of chemical names collected from the questionnaire data to the Chemical Properties module for comparison against the chemical substitutes list. If additional chemical substitutes are identified from the questionnaire results, they should be included in the entire CTSA process (e.g., collect chemical properties, hazard data, etc.).

Step 9: Create a profile of an average (model) facility from the tabulated data in Step 6. This is done by computing the average or other representative value of the appropriate survey data collected during the survey (i.e., number of workers employed, number of shifts operated, amount of chemical used, amount of chemical released to air, etc.). The profile will be used as the model facility for source release and exposure assessment calculations.

Source Release Assessment

Step 10: Using the data from the model facility, the process flow diagram, and the results of the site visits, identify the sources of chemical releases to the environment. The sources of some of the releases will be clearly identified in the questionnaire while others, such as open containers of volatile chemicals that result in air emissions, will have to be modeled using other data, such as chemical properties data from the Chemical Properties module, together with the workplace practices data. In a CTSA, the modeling of chemical releases or transfers that cannot be explicitly estimated from the survey data (i.e., volatization of volatile organic compounds [VOCs] from open containers, etc.) is usually done in the Exposure Assessment module.

Step 11: Characterize each of the chemical releases identified in Step 10 by determining the following attributes:

- Location of the release; on-site (i.e., fugitive or evaporative process releases to air, stack emissions, etc.) or off-site (i.e., air releases from contaminated rags that have been sent to a cleaning service, etc.).
- Media to which the release takes place (i.e., air, water, or land).
- Quantity of the release. (In some cases, such as evaporative losses of VOCs from open containers, the quantity of release will need to be estimated using mathematical models. See the Exposure Assessment module for information on models used by EPA.)
- Composition of the release (e.g., weight or volume percent), if known or reported.

Peer-Review and Data Transfer

Step 12: Verify the accuracy and consistency of the source release and exposure assessment profile created for the model facility by using any or all of the following methods:

- Perform a physical examination on one or more facilities with similar characteristics to the model facility.
- Have knowledgeable industry representatives review the profiles.

- Perform data quality checks such as checking that the reported value for the amount of chemical disposed does not exceed the amount of chemical purchased.
- Perform material balances on the model facility and check the model for reasonableness.

Step 13: Submit the survey and source release results for peer-review by industry experts. Clearly state all assumptions used in calculating the releases, as well as any sources of uncertainty.

Step 14: Provide source release and workplace practices data collected by the questionnaire to the Exposure Assessment and Pollution Prevention Opportunities Assessment modules; source release data to the Control Technologies Assessment module; chemical handling data and process operating practices to the Process Safety Assessment module; and source release data to the Risk, Competitiveness & Conservation Data Summary module.

METHODOLOGY DETAILS: This section presents the methodology details for completing Steps 2, 3, 5, and 12. If necessary, additional information on conducting a source release assessment can be found in the published guidance.

Details: Step 2, Identifying Data Requirements

An important step in the performance of both the source release and exposure assessments is the identification of the data that must be collected. Data types that are typically collected for use in this or other CTSA modules include, but are not limited to, the following:

<u>Facility and Employee Information</u>

- Total population of workers in the industry.
- Number of workers at the facility.
- Number of workers at the facility who are potentially exposed to the chemicals in the use cluster.
- Number of operating days per year.
- Number of shifts run per day.
- Number of hours per shift.
- Number of hours of worker exposure to use cluster chemicals per shift.
- Dimensions of the operating area in which chemical exposure may occur.

<u>Worker Exposure Information</u>

- Name of chemical.
- Concentration of chemical.
- Operations/activities leading to potential chemical exposure.

- Duration of potential chemical exposure.
- Frequency of potential chemical exposure.
- Personal protective equipment used.

Source Release Information

- Amount of chemical purchased per year.
- Amount of chemical used per day.
- Total chemical releases by facility per year.
- Location of release (on-site or off-site).
- Media of chemical release.
- Amount of chemical releases per site per day.
- Frequency of chemical releases.
- Duration of chemical releases.

Other Information

- Pretreatment standards and discharge permits.
- Types of in-process engineering controls used to reduce exposures.
- Types of end-of-pipe control technologies used to reduce releases and exposures.
- Types of pollution prevention practices used to reduce or prevent releases.
- Types of recycling used in waste streams or elsewhere to mitigate releases.

Details: Step 3, Creating a Workplace Practices Questionnaire

The workplace practices questionnaire is the primary tool in the CTSA process for gathering data from industry. Because the information to be collected is often case-specific, the ideal questionnaire is tailored to the selected industry, and it results from the collaborative efforts of individuals possessing the people skills listed in this module.

The required exposure and source release data may be obtained directly from the questionnaire, or indirectly through calculations using the questionnaire results, together with other information. Data should be collected and presented on a per unit production basis, or some other basis that allows a comparative evaluation of the baseline and alternatives. The workplace practices questionnaire should not be unduly lengthy, as this will influence the quality and quantity of the responses that will be received.

Details: Step 5, Disseminating the Workplace Practices Questionnaire to Industry

Surveys should be disseminated to facilities of various sizes and production levels in a manner that will ensure the confidentiality of the facilities responding. Trade associations can fulfill this role by providing a list of target facilities to participate in the survey, and by acting as an intermediate, assuring the confidentiality of those facilities that participate. Trade associations have been responsible for disseminating the questionnaires for all of the previously performed CTSAs.

Details: Step 12, Verifying Accuracy and Consistency: Material Balance Principles

A material balance is an accounting of the flows of a material into and out of a system. Performing a material balance involves the following steps:

(1) Define a system boundary around which the material balance will be calculated. The boundary of the system for the material balance can be chosen as the entire process or any portion of the process where material streams enter or leave the system. Typically, for this type of application, the entire process shown in the process flow diagram created in the Chemistry of Use & Process Description module is selected.

(2) Develop a set of material balance equations that include terms for all of the streams entering or leaving the system boundary. A material balance can be performed using a:

- Material or substance (e.g., lubricating oil, plastic pellets, etc.).
- Chemical compound (e.g., water [H_2O], hydrochloric acid [HCl], natural gas [CH_4], etc.).
- Individual chemical element (e.g., Hydrogen [H], Carbon [C], Sodium [Na], etc.).

The material balance equation states that the inputs of the material must equal the outputs of the material plus any accumulation. This condition holds true as long as there is not a chemical reaction taking place.

(3) Enter quantities for known input and output streams into the set of material balance equations. Stream data can come directly from questionnaire data that have been collected or from individual company records if the questionnaire data on a stream are inconclusive. Input stream data can be typically obtained from purchase or inventory information. Output stream data can be obtained from reported waste stream information or calculated from chemical properties together with chemical use data.

(4) Mathematically solve the set of equations for any unknown or unquantified terms that remain. Only one unknown term for each material balance equation can be quantified. Therefore, there must be at least as many different material balance equations as there are unknown streams in order to solve the equation set. If there are more unknown terms than equations, and the system boundary cannot be redrawn to correct the situation, then performing a material balance is not possible and the unknown release will have to be modeled. In cases where the equation cannot be made to balance because of inaccuracies in data, then the releases, again, will have to be modelled.

For cases in which a chemical reaction occurs within the system, a material balance must consider the rate of consumption or production of the chemical constituents (see combustion example below). The balanced chemical equation is used to determine the limiting reactant of the chemical reaction. The limiting reactant is the reactant that is consumed entirely as the chemical reaction occurs. Through the use of a properly balanced chemical equation and molar ratios, the unknown reactant and product streams can be quantified. For additional assistance with applications involving chemical reactions consult a chemical engineering text (see Published Guidance section).

Shown below are two examples of material balance equations. The first is an example of a situation where a chemical reaction is not present in the process. Finally, a typical combustion problem is used as an example of a situation involving a chemical reaction within the system boundary.

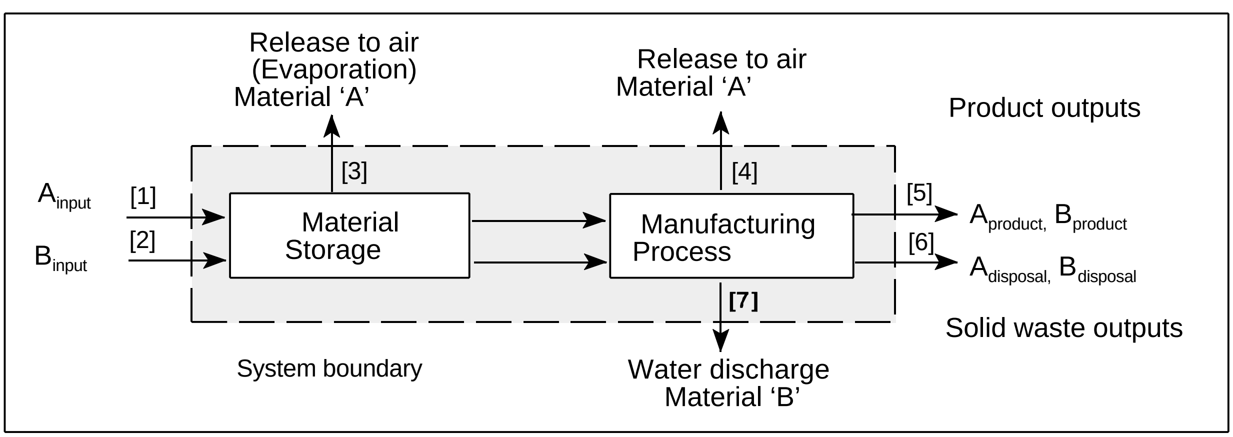
Example, Material Balance Without a Chemical Reaction Present

Figure 6-1 is an example of a material storage and component manufacturing process. The process is being run at steady-state so there is no accumulation of material within the system boundary. No chemical reaction occurs in the process.

Material Balance for Material 'A'
Mass In = Mass Out - Mass Accumulation
Mass In = Mass A_{Input} [1]
Mass Out = Mass A_{evap} [3]+ Mass A_{air} [4]+ Mass A_{prod} [5]+ Mass A_{disp} [6]
Mass A Accumulation = 0

Material Balance for Material 'B'
Mass In = Mass Out - Mass Accumulation
Mass In = Mass B_{Input} [2]
Mass Out = Mass B_{prod} [5] + Mass B_{disp} [6] + Mass B_{water} [7]
Mass B Accumulation = 0

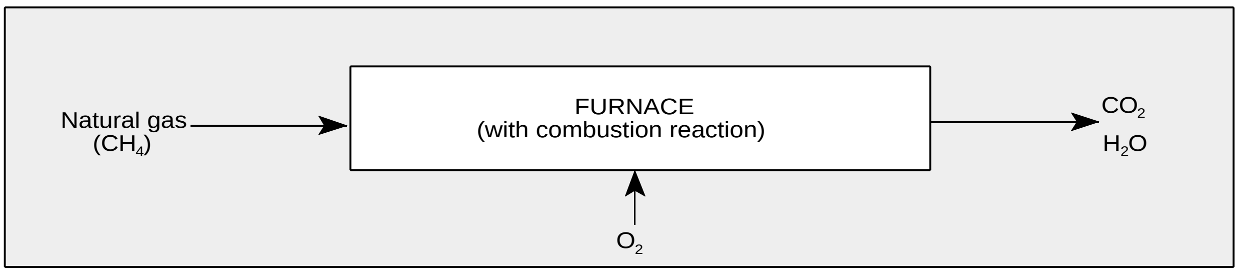
FIGURE 6-1: FLOW DIAGRAM OF MANUFACTURING PROCESS WITHOUT A CHEMICAL REACTION



Example, Chemical Reaction Present Within the System Boundary

In a material balance in which a chemical reaction is involved, the moles of a species (chemical compound) and the total moles of the reaction are not conserved. The mass balance must be made around the total mass and the mass or moles of each atomic species. In the example below, a total mass balance, and a carbon, hydrogen, and oxygen balance can be written. Figure 6-2 is an example of a furnace where the combustion of natural gas represents the reaction. The combustion of natural gas (CH_4) takes place in the presence of excess oxygen (O_2) which is typically supplied by air. Therefore, natural gas represents the limiting reactant and will be the basis for all calculations.

FIGURE 6-2: NATURAL GAS FURNACE PROCESS DIAGRAM



The combustion process is described by the following balanced chemical reaction:

Balanced Chemical Reaction: $CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

This equation shows that for every one mole of CH_4 that reacts with two moles of O_2, one mole of carbon dioxide (CO_2) and two moles of water (H_2O) are produced. From this information, and using the basis of 100 kilograms (kg) per hour of CH_4, the following data can be calculated:

(1) Calculate the moles of natural gas (CH_4) consumed using the molecular weight for CH_4. The molecular weight can be found by consulting a periodic table and totaling the individual atomic weights of one carbon atom (C = 12) and four hydrogen atoms (H = 1).

Molecular weight of CH_4: 12 + 4 (1) = 16

Moles of CH_4: 100 kg ÷ 16 kg/mol = **6.25 moles of CH_4**

(2) Calculate the moles of reactant consumed and reaction products produced by using the molar ratios defined by the chemical equation. In this case, the equation shows that for every one mole of CH_4 consumed, two moles of O_2 are consumed, one mole of CO_2 is produced, and two moles of H_2O are produced.

Moles of CO_2 produced:	moles of CH_4 = moles of CO_2
	6.25 moles CH_4 = 6.25 moles CO_2
	6.25 moles CO_2 produced
Moles of H_2O produced:	2 x moles of CH_4 = moles of H_2O produced
	2 x 6.25 moles CH_4 = 12.5 moles H_2O produced
	12.5 moles H_2O produced
Moles of O_2 reacted:	2 x moles of CH_4 = moles of O_2 reacted
	2 x 6.25 moles CH_4 = 12.5 moles O_2 reacted
	12.5 moles O_2 reacted

(3) Calculate the flow rates of unknown input and output streams using the molecular weights for each of remaining streams. The molecular weights for CO_2, H_2O, and O_2 were calculated using method of step 1 above. The input flow rate of oxygen is supplied by:

Molecular weights:	CO_2 = 12 + 2 (16) = 44 kg/mol
	H_2O = 2 (1) + 16 = 18 kg/mol
	O_2 = 2 (16) = 32 kg/mol
kg of CO_2 produced:	6.25 moles CO_2 x 44 kg/mol = **275 kg CO_2**
kg of H_2O produced:	12.5 moles H_2O x 18 kg/mol = **225 kg H_2O produced**
kg of O_2 reacted:	12.5 moles O_2 x 32 kg/mol = **400 kg O_2 reacted**

(4) Calculate the input flow rate of air required to supply the needed oxygen. This quantity differs from the amount of O_2 reacted because air contains only 21 percent oxygen.

Composition of air:	21 percent Oxygen (O_2)
	79 percent Nitrogen (N_2)
kg of air required:	400 kg O_2 ÷ 0.21 kg O_2/kg air = **1904.7 kg air**

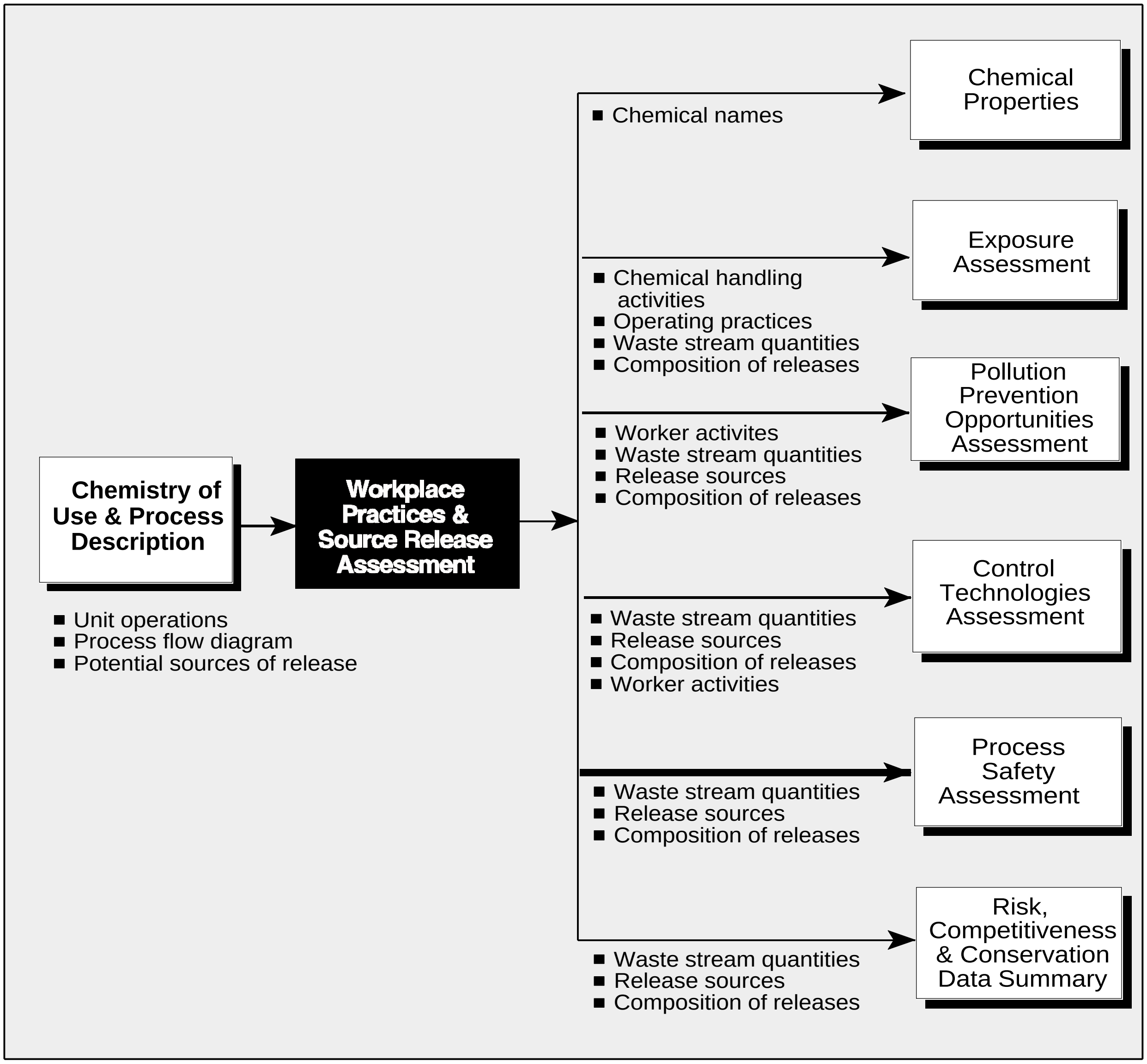
(5) Verify that the mass balance calculation was performed correctly by checking that the total mass of the input streams is equivalent to the total mass of the output streams (i.e., total mass is conserved).

Total kg of input streams:	100 kg CH_4 + 400 kg O_2 = 500 kg input material
Total kg of output streams:	275 kg CO_2 + 225 kg H_2O = 500 kg output material

500 kg Input material = 500 kg Output material

FLOW OF INFORMATION: In a CTSA, this module receives information from the Chemistry of Use & Process Description module and transfers information to the Chemical Properties, Exposure Assessment, Pollution Prevention Opportunities Assessment, Control Technologies Assessment, Process Safety Assessment, and Risk, Competitiveness & Conservation Data Summary modules. Example information flows are shown in Figure 6-3.

FIGURE 6-3: WORKPLACE PRACTICES & SOURCE RELEASE ASSESSMENT MODULE: EXAMPLE INFORMATION FLOWS



ANALYTICAL MODELS: Table 6-1 presents references for analytical models that can be used to perform a source release assessment.

TABLE 6-1: ANALYTICAL MODELS USED TO PERFORM A SOURCE RELEASE ASSESSMENT

Reference	Type of Model
U.S. Environmental Protection Agency. 1992b. *Strategic Waste Minimization Initiative (SWAMI) Version 2.0.*	Software tool for personal computers to aid in preparing a source release assessment.

Note: References are listed in shortened format, with complete references given in the reference list following Chapter 10.

PUBLISHED GUIDANCE: Table 6-2 presents references for published guidance on source release assessments and the use of mass balances.

TABLE 6-2: PUBLISHED GUIDANCE ON SOURCE RELEASE ASSESSMENTS AND THE USE OF MASS BALANCES

Reference	Type of Guidance
Lorton, G.A., et. al. 1988. *Waste Minimization Opportunity Assessment Manual*.	Describes the EPA method for performing a source release assessment.
Luyben, William and L. Wenzel. 1988. *Chemical Process Analysis: Mass and Energy Balances*.	Describes the use of mass balances.
U.S. Environmental Protection Agency. 1987a. *Estimating Releases and Waste Treatment Efficiencies for the Toxic Chemical Release Inventory Form.*	Describes methods to determine waste streams by measurement, mass balance, or estimation.
U.S. Environmental Protection Agency. 1991e. *Chemical Engineering Branch Manual for the Preparation of Engineering Estimates.*	Describes various approaches and data sources for release estimation.
U.S. Environmental Protection Agency. 1992c. *User's Guide: Strategic Waste Minimization Initiative (SWAMI) Version 2.0.*	User's Manual for the SWAMI software package.

Note: References are listed in shortened format, with complete references given in the reference list following Chapter 10.

DATA SOURCES: None cited.