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Alternatives for Measuring Hazardous Waste Reduction

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PREFACE

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CONTENTS

CONTENTS (continued)

TABLES

Table **Page**

FIGURES

Figure **Page**

CHAPTER 1
INTRODUCTION

To protect human health and the environment, both the Illinois and federal governments regulate how facilities can manage and dispose of their hazardous waste. To further reduce the risk these wastes pose to human health and the environment, to improve quality of life, and to conserve resources, both government and industry have adopted policies to reduce or eliminate the generation of hazardous waste at its source.

In Illinois, the Toxic Pollution Prevention Act, as amended, directs the Illinois Environmental Protection Agency and Hazardous Waste Research and Information Center to develop methods for assessing waste reduction progress. Using data on hazardous waste reduction activities at industrial facilities, policymakers could evaluate the current status of waste reduction and determine the need for further programs to encourage hazardous waste reduction. Measures of progress could be used by both government and industry to determine which policies or industries are effective at reducing hazardous waste generation and to determine where additional reduction efforts are needed.

The purpose of this report is to evaluate alternatives for measuring progress at reducing hazardous waste generation. In this chapter, we define hazardous waste reduction and introduce alternative measures of waste reduction progress. Chapter 2 discusses methods of measuring hazardous waste reduction. In Chapter 3, we look at available data on waste reduction to identify problems with measuring hazardous waste reduction progress. Finally, Chapter 4 includes specific recommendations on measuring hazardous waste reduction progress.

1.1 DEFINITION OF HAZARDOUS WASTE REDUCTION

Determining which measures are most appropriate for assessing progress at hazardous waste reduction depends in part on which activities are included in the definition of hazardous waste reduction. Similarly, the methods for defining and measuring hazardous waste reduction can influence industry's choice of activities to reduce hazardous waste. Facilities have an incentive (within a regulatory framework) to reduce those types of waste and to undertake those activities for which progress is assessed. Therefore, hazardous waste and hazardous waste reduction should be defined to reflect the objectives of policymakers. This section discusses alternative definitions of hazardous waste and hazardous waste reduction. The definitions of these terms used in this report are also discussed.

1.1.1 Hazardous Waste

The term hazardous waste is used in this report to include all wastes that pose a risk to human health or the environment, regardless of the environmental medium to which the waste is released. This multimedia definition is used to ensure that measures of hazardous waste reduction reflect actual improvements in environmental quality. Under a more limited definition of hazardous waste, for example, if one waste defined as hazardous is reduced while another waste not defined as hazardous is increased, there may be no net improvement in environmental quality. Under such a limited definition, a measure of hazardous waste reduction will not reflect the net effect of these changes because the definition does not include all wastes of concern.

One limited definition of hazardous waste is that used by the U.S. Environmental Protection Agency (USEPA). EPA regulates some hazardous wastes under the Resource Conservation and Recovery Act (RCRA) of 1976 and its subsequent amendments. Under RCRA regulations hazardous wastes are limited to

- solid wastes that possess a hazardous characteristic (i.e., ignitability, corrosivity, reactivity, or extraction-procedure toxicity), and

- solid wastes that are specifically listed as hazardous.

Because RCRA focuses on solid and some liquid wastes that can be land-disposed, this definition does not take a multimedia approach. In addition, the RCRA definition excludes some solid and liquid wastes that pose a hazard (e.g., polychlorinated biphenyls and dioxins). Consequently, measuring hazardous waste reduction according to the EPA definition of hazardous waste will not necessarily reflect all impacts on human health and the environment.

Recognizing the limitations of the RCRA definition of hazardous waste, several states have expanded the definition of hazardous waste. The State of Illinois regulates the management and disposal of almost all solid waste generated by industry (i.e., special wastes). Illinois waste reduction policies could encourage reductions in the generation of all special wastes, with greater priority given to wastes considered hazardous under RCRA. Nonetheless, because this approach does not include releases to all environmental media (only solid wastes are included), reductions in special wastes released to one environmental medium that result in increased releases to other media may not represent a net decrease in risk or net waste reduction.

Title III of the Superfund Amendments and Reauthorization Act (SARA) requires specified facilities to report releases of chemicals specified as toxic in the regulations. SARA does cover releases to all environmental media; however, the list of toxic chemicals is not exhaustive. Therefore, this list of substances of concern is also limited.

To properly measure hazardous waste reduction, "a comprehensive, multi-media (air, water, land) definition for hazardous waste is necessary" (Office of Technology Assessment, 1986). The two reasons for this conclusion are to

- avoid creating opportunities for shifting waste from one environmental medium to another, possibly unregulated or less regulated medium, and

- include wastes that are not currently regulated, such as most toxic air emissions.

The definition of hazardous waste used by the Office of Technology Assessment (1986, p. 11) is "all nonproduct hazardous outputs from an industrial operation into all environmental media, even though they may be within permitted or licensed limits."

While the measures discussed in this report can be used to evaluate reductions in any type of waste, only a definition of hazardous waste that covers all wastes released to all environmental media accurately characterizes reductions in the risk wastes pose to human health and the environment and progress at resource conservation.

1.1.2 Hazardous Waste Reduction

Measures of hazardous waste reduction often include the following activities:

- Toxics use reduction: reduction in the use of toxic materials as raw materials in industry or as consumer products.
- Source reduction: reduction in the generation of hazardous waste at its source (prior to treatment) due to changes in production processes or procedures.
- Closed-loop recycling: in-process recovery and reuse of hazardous materials — hazardous materials do not exit the production process and are not released to the environment. This activity is often included as a source reduction technique.
- Wastewater reduction: reductions in the net use of water in processes that yield hazardous wastewater.
- Onsite recycling/reuse: onsite, out-of-process recovery and reuse of constituents from hazardous waste onsite.
- Offsite recycling/reuse: offsite, out-of-process recovery and reuse of constituents from hazardous waste offsite.

In general, these options are listed in order of increasing potential risk to human health and the environment, all other things equal. Thus, toxics use reduction is the preferred method of reducing the risk posed by hazardous wastes. No consensus exists, however, on which of these methods should be included in measures of hazardous waste reduction. Also, some of the activities listed above are difficult to define and may overlap.

The federal Pollution Prevention Act of 1990 states that source reduction, which is defined to include toxics use reduction, should be implemented whenever feasible. When toxics use and source reduction are not feasible, USEPA favors implementation of the other activities in the order they are listed above.

The Office of Technology Assessment (OTA) takes a similar view of hazardous waste reduction. OTA includes in its definition only in-plant process modifications that reduce the generation of hazardous waste and some onsite, "closed-loop" recycling of hazardous waste. In particular,

> when recycling is environmentally acceptable and is an integral part of the waste generating industrial process or operation OTA considers it waste reduction... But recycling is not considered waste reduction if waste exits a process, exists as a separate entity, undergoes significant handling, and is transported from the waste generating location to another production site [perhaps a part of a large plant] for reuse, or to an offsite commercial recycling facility or waste exchange (OTA, 1986).

In USEPA's National Biennial Hazardous Waste Report, waste minimization includes source reduction and both onsite and offsite recycling activities. These methods are also included in USEPA's National Survey of Hazardous Waste Generators (Generator Survey). Table 1-1 lists the specific methods included in the Generator Survey.

Table 1-1. Waste Minimization Activities Included in the National Survey of Hazardous Waste Generators

- Better Housekeeping and Maintenance
- Waste Stream Segregation
- Modification and or Substitution of Input and/or Raw Material
- Reformulation or Redesign of Product
- Equipment or Technology Modification
- Process or Procedure Modification and/or Substitution
- Wastewater Reduction
- Onsite Recycling or Recovery for Reuse
- Offsite Recycling or Recovery for Reuse (materials exchange)

This report defines hazardous waste reduction as a reduction in the quantity or the hazard of wastes generated and subsequently recycled, treated, or disposed of. This definition includes toxics use reduction and source reduction activities, including closed-loop recycling. This is consistent with the definition recommended by OTA and by USEPA's Pollution Prevention Office. In addition, we recommend using separate measures to evaluate progress at onsite recycling and offsite recycling. Further study is needed to identify and evaluate measures of recycling progress.

1.2 MEASURES OF HAZARDOUS WASTE REDUCTION PROGRESS

Any measure of waste reduction progress attempts to characterize the amount of waste that was not generated due to waste reduction activities or the amount of waste that would have been generated if the waste reduction activities had not been undertaken. Because measuring this amount directly is not feasible, measures of progress have focused on evaluating changes in waste generation over time. The presumption is that if the quantity of or the hazard posed by wastes generated decreases over time (usually adjusted for changes in production activity), waste reduction progress has been achieved.

In this section, we describe four alternative measures of waste reduction progress:

- Change in quantity
  - —actual change
  - —adjusted change
  - —throughput ratio
- Changes in the level of hazard

1.2.1 Actual Quantity Change

The change in the quantity of waste generated is one method of measuring progress in hazardous waste reduction. This measure implies that facilities with greater decreases in the quantity of hazardous waste generated have made more progress at waste reduction. This measure does not consider the difficulty of implementing the source reduction activity, changes in process efficiency or production levels, or the resultant reduction in risk.

The actual quantity change is the quantity of waste generated in the current reporting year less the quantity generated in the previous year. The advantage of measuring the actual quantity change is that it is straightforward, easy to understand, and relatively easy to calculate. As a measure of the change in waste generation, the actual quantity change is useful for a variety of applications. For example, it is useful for assessing changes in the risk to human health and the environment posed by hazardous waste generation. Also, the measure is needed to evaluate hazardous waste management capacity demands.

The actual quantity change does not consider the effects on the quantity generated of changes in the level of business or production activity (e.g., due to the introduction of a new product, changing market conditions for a product, or plant shutdown), changes in product quality, or other changes in operating conditions unrelated to specific source reduction activities. The actual quantity change will overstate progress if a facility's business activity has declined and understate progress if activity has increased.

1.2.2 Adjusted Quantity Change

The adjusted quantity change is a measure of hazardous waste reduction progress that accounts for changes in the level of production, service, or other business activity for the processes that generate waste. The adjusted quantity change uses an index (known as the activity index) of the change in the level of business or production activity from the prior reporting year to the current year to adjust the actual quantity change for changes in business or production activity. This method assumes that the amount of waste generated is directly proportional to the amount of product produced and that this relationship is constant unless waste reduction is implemented. That is, the method assumes that

- waste generation and the production level are linearly related,

- no fixed amounts of waste are generated that are independent of production levels,
- no factors other than the amount of production activity and waste reduction affect the amount of waste generated, and
- the measure of production activity used is consistent over time (e.g., there are no changes in the products produced or in product quality).

Chapters 2 and 3 of this report describe instances in which these assumptions are not correct.

To calculate the adjusted quantity change, we multiply the previous year's quantity of waste by the activity index to obtain an estimate of the quantity of waste that would have been generated during the reporting year if source reduction activities had not been implemented. Subtracting this number from the actual quantity generated during the reporting year gives the adjusted quantity change. Figure 1-1 shows an example of this calculation.

	1988 (tons)	1989 (tons)
Quantity of hazardous waste generated	50	75
Quantity of product produced	150	250

Activity Index = products produced in 1989 ÷ products produced in 1988
= 250 ÷ 150
= 1.67

Adjusted Change = 1989 quantity generated –
(1988 quantity generated x activity index)
= 75 – (50 x 1.67)
= – 8.5

Figure 1-1. Example Using the Adjusted Quantity Change to Measure Hazardous Waste Reduction

Note: Example shows an adjusted quantity decrease of 8.5 tons, or approximately 10 percent. This indicates waste reduction progress.

1.2.3 Throughput Ratio

A third measure of the quantity of hazardous waste reduction progress is to compare the throughput ratio over time. This measure uses throughput to adjust the quantity of waste generated for changes in production activity. The throughput ratio is the ratio of the quantity of a chemical in waste before treatment to the quantity of throughput for that chemical. The quantity of throughput is the total quantity of a chemical used onsite, including both productive uses (e.g., the quantity of chemical incorporated in the product or transformed during the production process) and non-productive uses (i.e., the quantity of chemical in the waste). Equation 1 illustrates this throughput ratio.

$$\text{Throughput Ratio} = Q_W \div (Q_W + Q_P) \qquad (1)$$

where Q_W = the quantity of chemical Q generated as waste before treatment, and
Q_P = the quantity of chemical Q that goes to productive uses.

The lower the throughput ratio, the more efficient the production processes are in using the chemical. A lower throughput ratio indicates that a smaller portion of the total chemical used (throughput) is going to waste and a higher portion of the total chemical used is going to productive uses. Improvements in the efficiency of production processes indicate hazardous waste reduction progress. That is, lower throughput ratios indicate that for a given level of production activity (in this case, the measure of production activity is throughput), less waste is generated. Thus, comparing throughput ratios over time gives a measure of hazardous waste reduction progress. Reductions in the throughput ratio indicate that progress in hazardous waste reduction has been made.

The advantage of using throughput as a measure of waste reduction progress is that it shows how efficiently a facility is using each chemical by indicating the percentage of the total quantity of material used that is lost through releases to the environment. Because releases to the environment represent unproductive uses of a chemical, decreasing these releases improves the efficiency of production processes.

1.2.4 Changes in the Level of Hazard

Changes in the level of hazard of a waste are not reflected in the actual change, the adjusted change, or throughput. Currently, no method exists to easily and economically assess changes in *all* factors that affect the level of hazard of a waste. Because of the number of factors that would have to enter into such a calculation, developing such a methodology is infeasible at the present time. Factors that should be considered include the following:

- toxicity, ignitability, corrosivity, and reactivity of the waste;
- location of release;
- environmental medium of release;
- extent of human or environmental exposure to the waste; and
- rate at which waste decomposes or dissipates.

Ideally, a hazardous waste reduction measure would incorporate all of these factors in a cardinal hazard index. A cardinal hazard index that incorporates each of the criteria listed above does not exist currently.

The Degree of Hazard (DOH) ranking system developed by the Illinois Department of Energy and Natural Resources provides a limited means for incorporating level-of-hazard considerations into a waste reduction measure. Factors affecting the hazard of a waste that are incorporated into the DOH system include

- toxicity of hazardous components,
- concentration of hazardous components in a waste,
- quantity of waste,
- rate at which the waste decomposes,
- presence of infectious materials in the waste, and
- possibility of fire hazard or leachate hazard.

By considering a wide variety of factors, all of which contribute to the risk posed by a waste to human health and the environment, this ranking provides a sound scientific basis for classifying wastes according to their degree of hazard. The system places waste streams into "high," "moderate," "low," or "negligible" hazard categories.

The DOH system was developed to provide a sound scientific basis for classifying waste streams according to their degree of hazard. It has two important uses. First, it is a valuable tool for differentiating waste streams that should be stringently regulated (because of the level of hazard) from waste streams that should be less stringently regulated (primarily, these are non-RCRA hazardous wastes with a negligible level of hazard). This function was one of the principal objectives for developing the DOH system (Plewa et al., 1986). Second, the DOH system is very useful for identifying waste streams and constituents in those waste streams that should receive the greatest attention in waste reduction efforts. Determining the ability to target the most hazardous wastes weighted by the quantity of waste generated is a powerful capability of the DOH system.

Even though the DOH system has important uses in waste reduction policy analyses, the DOH system is not as useful in actually *measuring* waste reduction because it places wastes into categories of hazard rather than quantifying the level of hazard. Consequently, if the amount of waste in the "high" category falls while the amount in the "moderate" category increases, there is no practical way to determine the extent of waste reduction in total (including hazard considerations) using DOH. The DOH system is designed to monitor changes in the potential risk of a particular waste stream based on changes in quantity and chemical constituents. It is not as useful for broader analyses (e.g., by industry or for the state).

Other hazard indexes have been developed for classifying hazardous wastes. These include the following:

- State of Washington Waste Classification Scheme
- State of Rhode Island Waste Classification Scheme
- Michigan Rank-Order Assessment of Critical Materials
- JRB Environmental Containment Waste Classification Scheme
- State of California Waste Classification Scheme
- State of Texas Waste Classification Scheme
- Chemical Manufacturers Association Waste Classification Scheme

Of these, only the Michigan system includes both a numerical score and a consideration of the quantity of the hazardous wastes. For more information on these hazard indices, see K. R. Reddy, *Special Waste Categorization Study*, 1985.

An alternative to measuring the total change in the level of hazard is to assess changes in the individual factors that contribute to the level of hazard for each waste. Data on the toxicity, ignitability, corrosivity, and reactivity of a waste can be reported annually and used to assess changes in these factors over time. Monitoring all these factors gives a more complete and accurate description of the effects of waste reduction. However, the costs of implementing this method may be preclusive and reporting the necessary data may be burdensome for facilities.

The remainder of this report focuses on measuring changes in the quantity of hazardous waste generated, primarily because these measures have been the focus of evaluations of waste reduction progress. Chapter 4 provides recommendations on incorporating assessments of the level of hazard in measures of progress.

CHAPTER 2

METHODS FOR CALCULATING CHANGES IN THE QUANTITY OF HAZARDOUS WASTE GENERATED

Chapter 1 described three quantitative measures of hazardous waste reduction: actual quantity change, adjusted quantity change, and throughput ratio. In this chapter, we identify and evaluate different methods for calculating each of these measures of hazardous waste reduction progress. The criteria we use to evaluate these methods include

- accuracy;
- consistency over time;
- applicability to different types of processes, facilities, and/or industries;
- ease of aggregating within facilities, industries, and/or a region;
- availability of data for the method; and
- likelihood that the data are (or would be claimed as) confidential.

2.1 ACTUAL QUANTITY CHANGE

The actual quantity change in hazardous waste generation can be calculated using several methods, including the change in

- weight (or mass) of hazardous waste generated,
- volume of hazardous waste generated, and
- number of units (e.g., barrels) of hazardous waste generated.

The selection of one of these methods is often based on the physical form of the hazardous waste. Solid waste materials and gaseous emissions are usually measured by weight (e.g., pounds, tons, kilograms, or metric tons). Aqueous waste streams are usually measured by volume (e.g., gallons, cubic yards, or liters). The number of units of hazardous waste is used by some plants that store hazardous waste in barrels. Of course, a volumetric measure of a liquid waste can be converted to a weight measure if the density of the liquid waste is known. Similarly, if the weight or volume of hazardous waste in each unit is known, the number of units can be converted to a measure of weight or volume.

Both the change in weight and the change in volume accurately describe the actual quantity change. The change in the number of units of hazardous waste is less accurate because the amount of waste in a unit and the size of the units can vary.

Although these methods are commonly used, they are not accurate at describing the amount of hazardous waste reduction because they do not distinguish changes in the quantity of hazardous waste generated due to hazardous waste reduction activities from changes due to other factors (e.g., changes in product quality or production level). To illustrate this shortcoming, suppose that a facility generates a hazardous waste due to its production of widgets (see Table 2-1). In 1988, the facility generated 200 tons of hazardous waste while manufacturing 1,000 widgets. In 1988, production of widgets at the facility decreased to 500 widgets. Because of the large decrease in production, the quantity of hazardous waste generated also decreased. Using the actual quantity change measure, it appears that this facility made hazardous waste reduction progress (100 tons of hazardous waste were not generated in 1989). However, the facility did not implement any toxics use reduction or source reduction activity. The quantity of hazardous waste generated per unit of output did not change.

Table 2-1. Actual Quantity Change for a Facility with a Decrease in Production

Year	Number of Widgets	Quantity of Hazardous Waste	Tons of Hazardous Waste per Widget
1988	1,000	200 tons	0.2
1989	500	100 tons	0.2

Note: Table shows a facility that had an actual decrease in the quantity of hazardous waste generated but did not implement a hazardous waste reduction activity. The quantity of hazardous waste generated per unit of output did not change.

Actual Quantity Change = 200 tons – 100 tons = 100 ton decrease
Change in Quantity per Unit of Output = 0.2 tons/widget – 0.2 tons/widget = 0 (no change)

Each method of calculating the actual quantity change is applicable to all types of hazardous wastes, facilities, and industries. The actual quantity change calculated using any of the methods (i.e., weight, volume, or number of units) can be easily aggregated within facilities, industries, or regions. Facilities generally do not consider this information confidential business information.

Data on the volume or weight of regulated hazardous wastes generated are used by USEPA, state agencies responsible for regulating specific hazardous wastes, and businesses that generate hazardous waste. For example, USEPA's Biennial Hazardous Waste Report obtains information on the volume or weight generated of solid wastes considered hazardous under RCRA. However, to calculate the actual quantity change, these data collections must be modified to focus on the generation of *all* hazardous wastes released to *all* environmental media.

2.2 ADJUSTED MEASURES

The adjusted quantity change measure uses an activity index to adjust the actual quantity change to account for changes in business activity. Any of the methods described in Section 2.1 can be used to calculate the actual quantity change. In this section, we evaluate methods for calculating the activity index.

The activity index is a ratio of the level of activity during the current year to the level of activity during the previous year for the activities that generated a hazardous waste. The method used to measure the activity level in each year should reflect changes in the quantity of waste generated.

For hazardous wastes generated through production activities, measures of the production level are most appropriate for calculating the activity index. Measures of production are the most commonly used methods for calculating the activity index and can include either measures of inputs or measures of outputs (see Table 2-2). When methods that use a dollar value are used, the dollar value should be reported in constant dollars (i.e., corrected for inflation).

Table 2-2. Examples of Measures of Production Activity

Input Measures	Output Measures
Weight of raw materials used	Number of units of product
Volume of raw materials used	Weight of product
Dollar value of raw materials used	Volume of product
Number of employees	Surface area of product
Number of labor hours	Dollar value of product

The specific measure of production that should be used for a particular waste is the measure that is most highly correlated with changes in waste generation. In general, the types of production measures that should be used depend on the use of the hazardous materials at a plant. Businesses can be classified into three categories based on their use of hazardous substances that generate hazardous wastes:

- primary producers
- secondary producers
- other producers

Primary producers of hazardous substances are businesses that use various raw materials to produce a hazardous material for sale to other businesses. For example, methylene chloride, a chlorinated solvent, is a hazardous material manufactured for sale by some producers (Wolf, 1989). The residual portion of methylene chloride that is not sold as a product (e.g., methylene chloride that evaporates, spills, or is off-spec) is a hazardous waste. For such primary producers, an appropriate measure for normalizing the quantity of hazardous waste is the total amount of methylene chloride produced.

Secondary producers of hazardous substances are businesses that use a hazardous substance as an input to form a product that incorporates the substance. For example, some formulators of aerosol paints use methylene chloride as an input, and most of this input leaves the plant in the paint product. The residual portion of methylene chloride that is not incorporated in the product is hazardous waste. An appropriate production measure of production for this hazardous waste may be the amount of paint produced or the amount of methylene chloride incorporated in the paint.

Finally, other producers include businesses that use a hazardous substance in their production process, but produce a product that does not contain any of the hazardous substance. Manufacturers of lighting fixtures are an example. They may use methylene chloride to degrease metals prior to machining, but none of the methylene chloride leaves the plant in or on the light fixtures. All of the methylene chloride used by these producers is potentially a hazardous waste when discarded or released. The measure of production appropriate for such a waste can be the number of light fixtures produced, the number of metal parts degreased, or the surface area of the metal parts.

The method that should be used to calculate an activity index depends on the source of the particular hazardous waste. In general, the method should reflect changes in the activity that generated the hazardous waste. For example, for hazardous wastewater generated from cooling processes at a constant rate whenever the facility is operational, the appropriate measure of the activity level may be the number of days the plant was operational during the year. Similarly, if hazardous waste is generated from solvents used to wash the floors in a plant, appropriate measures of activity level include the number of times the floor was washed or the total square area that was washed annually.

The data needed to calculate an activity index using these production measures may not be available. While aggregate data on raw material usage and on production levels is generally available at all facilities, the information may not be available at the level of detail needed to calculate an accurate activity index. The activity index should include only the level of activity for the processes that generated the hazardous waste, which may not be consistent with the overall facility activity level.

The adjusted quantity change accurately and consistently measures waste reduction progress only if *all* the assumptions specified above in Section 1.2.2 hold true. The adjusted quantity change is not accurate if the production measure used does not reflect changes in hazardous waste generation or if factors other than production changes or hazardous waste reduction activities affect hazardous waste generation. This method is not appropriate if the quantity of hazardous waste generated is affected by factors such as changes in operating conditions or product design or product quality. This problem is discussed in greater detail in Chapter 3.

When the quantity of the hazardous waste generated is not directly proportional to the level of production activity, the method described above is not appropriate. One example of such a waste is waste generated from one-time activities such as closing down a production process. Because these wastes are not generated through recurring activities, comparing the quantity of these wastes generated over time is not relevant. Therefore, these wastes should not be included in an adjusted measure of waste reduction. Because the generation of these hazardous wastes can pose a significant risk to human health and the environment, they should be reported separately and absolute measures of waste reduction should be used.

The most appropriate method to calculate an activity index for wastes not related to production activity must be determined for each individual waste. A single method will not be applicable for all types of hazardous wastes. Depending on the method used, adequate data may not be available or may be confidential. Finally, the adjusted quantity change calculated using these methods accurately measures hazardous waste reduction if the activity index accurately reflects changes in waste generation and if no other factors affected the quantity of hazardous waste generated. Chapters 3 further discusses problems with the adjusted quantity change measure.

2.3 THROUGHPUT RATIO

A third quantitative measure of hazardous waste reduction compares changes in the throughput ratio over time. The throughput ratio is the ratio of the quantity of a chemical released as waste before treatment to the total quantity of the chemical used (i.e., throughput), including both productive and non-productive (i.e., waste) uses of the chemical. Equation 1 in Chapter 1 describes the calculation of the throughput ratio. Decreases in the throughput ratio over time indicate hazardous waste reduction progress.

Throughput is defined as the total quantity of a chemical used onsite. The method for calculating throughput is to sum the quantity of chemical that was used for all uses of the chemical. Equation 2 shows this method for calculating throughput.

$$\text{Throughput} = Q_W + Q_C + Q_O \qquad (2)$$

where Q_W = the quantity of chemical Q generated as waste before treatment,
Q_C = the quantity of chemical Q consumed, and
Q_O = the quantity of chemical Q incorporated in the output of the production process (i.e., in the product).

In Equation 2, Q_C and Q_O are productive uses of the chemical. The sum of these equals Q_P (the quantity of chemical going to productive uses) in Equation 1, above. The *throughput ratio* equals throughput divided by the quantity of chemical generated as waste (Q_W).

One major problem with the throughput ratio that can lead to inaccurate assessments of waste reduction progress is that the measure does not show progress at toxics use reduction. An extreme example of this problem is in the use of cleaning solvents. As mentioned above, 100 percent of this material often becomes hazardous waste after use. A facility can reduce hazardous waste generation by redesigning its production processes to use less solvents (toxics use reduction). The throughput ratio would show that no hazardous waste reduction progress had been achieved, because although less solvent is used, 100 percent of the solvent that is still used becomes hazardous waste.

The throughput ratio is similar to the adjusted quantity change in that both use measures of production activity to normalize changes in waste generation. (For the throughput ratio, the production measure used is throughput.) As such, the throughput ratio may be affected by changes in product quality or operating conditions. Chapter 3 further describes these problems.

Calculating the amount of throughput and the throughput ratio can be useful for evaluating waste management practices, tracking toxic chemicals used onsite, and identifying waste reduction opportunities. However, because of the problems described above, the throughput ratio may not be consistent or accurate as a measure of waste reduction. Also, the measure is not applicable when 100 percent of a chemical used in a process eventually becomes waste. Finally, the level of technical knowledge required to gather and interpret the data make the throughput ratio a relatively expensive option. For further analysis of the use of throughput data, refer to *Tracking Toxic Substances at Industrial Facilities* (National Research Council, 1990).

CHAPTER 3

PROBLEMS IN USING QUANTITATIVE MEASURES OF HAZARDOUS WASTE REDUCTION PROGRESS

In a study conducted for USEPA, RTI used data from the Generator Survey to evaluate the effectiveness of quantitative measures of hazardous waste reduction progress. The Generator Survey data included the quantity of hazardous waste generated in the reporting year and the previous year (1986 and 1985, respectively), the activity index (the percentage change in waste-generating activity from 1985 to 1986), and the waste reduction activities implemented during the reporting year for each hazardous waste. These data can be used to calculate both the actual quantity change and the adjusted quantity change.

This chapter summarizes the results of RTI's study and suggests possible solutions to the problems identified. Although the focus of the study was on the adjusted quantity change, many of the problems identified also apply to the actual quantity change and other quantitative measures of waste reduction progress. Table 3-1 summarizes this discussion.

3.1 PROBLEMS DETERMINING A MEASURE OF BUSINESS ACTIVITY OR PRODUCTION

To provide an accurate measure of the activity index, facilities must calculate the index to accurately reflect changes in the level of the activity or process that generated the waste. For some waste-generating activities, defining an appropriate measure of the activity level is difficult. Such activities include laboratory research, some service activities, and cases in which many different products or processes contribute to the generation of a single waste stream (multi-product manufacturing). Also, comparing activity levels over time is difficult if the product or product quality has changed.

Respondents to the Generator Survey also had difficulty identifying the appropriate measure of activity level for activities not directly related to the level of production. For example, if wastewater was generated at a constant rate as long as the plant was operational, the index should have reflected changes in the hours the plant operated rather than changes in the level of product production. However, facilities often reported the change in product production. Finally, respondents to the Generator Survey often reported the index to reflect changes in output levels for the entire facility, rather than for the processes generating a particular waste. This can be a problem if a facility's production levels vary widely among its processes. Because of these problems, there is a growing recognition that the activity index is not appropriate for all wastes at all facilities. One way to compensate for this is for policymakers to use the measure of adjusted quantity change only for wastes for which the measure appears to work. The national

Table 3-1. Problems with Measuring Hazardous Waste Reduction

Measurement Problem	Possible Solutions
Difficulty determining a measure of the level of business activity or production associated with waste generation	Carefully define the activity index to facilities and include examples of appropriate measures in questionnaires. Allow facility to use an alternative measure of waste reduction if unable to define an appropriate activity measure.
Difficulty measuring the level of activity or production associated with waste generation	Allow facility to use an alternative measure of waste reduction (other than adjusted difference) such as the actual quantity change.
Delayed effects of waste reduction	Assess quantity data over several consecutive years.
Process and product development	Gather qualitative data on waste reduction incorporated into the design of the product or process.
Chemical substitutions	Look at changes in all wastes generated by a facility.
Changes not reflected in the activity index	Gather qualitative data on factors other than waste reduction that affected the quantity of waste generated.
Difficulty summing increases and decreases	Aggregate only facilities with progress as well as all facilities.
Influence of largest facilities	Look at the median values and percentage changes in addition to the aggregate quantities.

report on the 1987 data collected under the Community Right-to-Know Act, *The Toxics-Release Inventory: A National Perspective* (USEPA, 1989), used in its evaluation of progress only the chemical-specific responses that met established criteria.

Another way to identify wastes for which the adjusted quantity change is not an appropriate measure is to simply ask respondents whether the measure is appropriate for each of the wastes they report. The 1987 USEPA National Biennial Hazardous Waste Report began this practice, and the 1989 USEPA Biennial Report continues it. Nevertheless, this area needs further study to enable policymakers to more clearly understand and describe the circumstances in which the adjusted quantity change is appropriate and to identify other measures that are appropriate for specific circumstances.

For some wastes, defining an appropriate measure of the activity level is not feasible. For example, one chemical facility RTI contacted had a single waste stream that combined non-contact cooling water, storm water runoff, and sanitary sewage wastewater with wastewater from all production processes at the plant. The wastewater varied by the amount of rainfall (for storm runoff), the number of hours the plant was operational (cooling waster), the number of times an employee took a shower (sanitary sewage), and the amount of production activity. Reflecting all these factors in a single activity index is not feasible. For such a waste, it is appropriate to use actual change in the quantity generated as the measure of waste reduction rather than the adjusted change. Alternatively, a facility could be encouraged to develop a measure of waste reduction activity appropriate for its waste. (Segregating and metering the facility's wastewater at its source may enable the facility to identify an appropriate measure of the activity level for each waste, but this may be burdensome for the facility.)

3.2 MEASURING THE LEVEL OF WASTE-GENERATING ACTIVITY

For some waste-generating activities, the difficulty lies not in defining a measure of activity but in actually calculating that level. An example of this is a wastewater generated from cleaning and coating steel wire. One appropriate measure for such an activity is the change in the total surface area coated, but the surface area coated varies hourly. Wire of all different sizes may be run on a given day, even at the same time, further complicating measurement of total surface area. Other cases in which calculating the level of activity is difficult include wastes from multiproduct processes and aggregated wastes from many different waste-generating activities. Facilities commonly combine wastes from a number of processes, which complicates or makes impossible the measurement of the effect of a change in one process line.

Installing extensive waste tracking equipment may permit facilities to calculate an activity index for many of these wastes, but the amount of resources that would have to be devoted to such a system may detract from resources available for waste reduction activities themselves. For wastes such as these, respondents can be given the option to develop some alternative measure of waste reduction progress that does not require an activity index. The latter option was available in the 1987 Biennial Report and is available in the 1989 report as well.

3.3 DELAYED EFFECTS OF WASTE REDUCTION

The quantitative measures of waste reduction described in this report only consider changes in the quantity of waste generation which occur during the calendar year in which a facility implements a waste reduction activity. If a facility implements an activity late in the year, the facility may not realize any benefits until the following year and thereafter. RTI's study of Generator Survey responses revealed that this complication does occur. Waste reduction may result in a systematic reduction in waste generation over the life of a production process, yet these beneficial effects cannot be assessed with only two years of quantity data. Tracking the results of waste reduction efforts over several consecutive years would provide a more complete assessment of waste reduction progress. In addition, asking facilities to report the month they implemented a waste reduction activity may help in the analysis of progress.

3.4 PROCESS DESIGN AND PRODUCT DEVELOPMENT

Measures of waste reduction progress characterize changes in waste generation for existing processes. These measures do not recognize efforts to design a new process or product that minimizes waste generation. Quantifying the results of these activities is difficult, because information on how much waste would have been generated without the waste reduction is difficult to estimate and verify. Measures of the change in the quantity of waste generated cannot be used because the facility has no prior year quantities of waste to compare with current waste generation. For some industries, the production processes may change completely every few years.

Waste reduction activities for new processes or products can be qualitatively evaluated by developing a list of these waste reduction activities and asking facilities to identify which of those activities they implemented. In addition to allowing policymakers to identify the extent to which waste reduction is incorporated into product and process design, this question would serve as a suggestion to respondents on ways to incorporate waste reduction into process design and thus encourage these activities.

3.5 ASSESSING CHEMICAL SUBSTITUTIONS

A frequently used waste reduction activity is to substitute less hazardous or less toxic raw materials for those currently in use. The effect of this substitution is very difficult to quantify. Substitutions may significantly reduce or even eliminate one waste, but this progress may be tempered by the introduction of a new waste. Substitutions may also reduce the toxicity of a waste while the quantity of the waste remains constant or even increases. Section 1.2.4 describes some of the difficulties with measuring changes in toxicity.

Policymakers may be able to observe that raw material substitution is taking place by looking at changes in all wastes generated by a facility (this requires a comprehensive definition of hazardous waste). Quantifying the reduced hazard or toxicity of the new waste would be burdensome to both policymakers and facilities and may not be possible.

3.6 CHANGES NOT REFLECTED IN THE ACTIVITY INDEX

If we use the adjusted quantity change as the measure of waste reduction, we assume that, without waste reduction, the quantity of waste generated would change at the same rate as the level of production or business activity. However, many other changes in operating conditions not reflected in the activity index may also affect the quantity of waste generated. Examples of such changes include

- raw material quality,
- throughput rates,

- worker productivity, and
- weather conditions.

Studying wastes in the Generator Survey that had no change in waste-generating activity reported (wastes with a 0 percent change in activity level between 1985 and 1986) demonstrates the effect of these other factors on the quantity of waste generated. For such wastes, the adjusted change in the quantity generated equals the actual change because there is no change in business or production activity. Table 3-2 shows the actual change in the quantity generated for wastes with no change in production. If no other factors affected the quantity of waste generated, waste reduction activities should have been implemented for all wastes with decreases in the quantity generated. Conversely, all wastes with increases in the quantity generated should not have undergone waste reduction. We found that 32 percent of the wastes with no change in production activity did not have the expected change in quantity generated based on whether waste reduction has been implemented. Wastes with changes in the quantity generated that do not correspond to what would be expected are shown in bold type in Table 3-2. These wastes illustrate RTI's conclusion that the activity index and the waste reduction activities implemented do not completely explain all changes in the quantity of waste generated.

Table 3-2. Change in the Quantity Generated for Wastes with No Change in Activity Level

Percentage Change in Quantity of Waste	Number of Wastes	Wastes with Source Reduction	Wastes with No Source Reduction
over 200%	544	**104 (19%)**	440 (81%)
101% or more	231	**40 (17%)**	191 (83%)
51% to 100%	505	**59 (12%)**	446 (88%)
31% to 50%	196	**34 (18%)**	162 (82%)
11% to 30%	411	**91 (22%)**	320 (78%)
1% to 10%	352	**68 (19%)**	284 (81%)
no change	3,691	**464 (13%)**	3,227 (87%)
-1% to -10%	357	57 (16%)	**300 (84%)**
-11% to -30%	574	118 (21%)	**456 (79%)**
-31% to -50%	475	83(17%)	**392 (83%)**
-51% to -100%	899	243 (27%)	**656 (73%)**
TOTAL	8,236	1,361 (17%)	6,875 (83%)

Note: All else equal, wastes that underwent source reduction should show negative changes (decreases) in quantity and wastes that did not undergo source reduction should show no change or positive changes (increases) in quantity.
Bold numbers indicate wastes for which the change in quantity does not correspond to their source reduction activity.

Isolating the effect of operating conditions and other factors on the quantity of waste generated may not be possible. But requiring facilities to indicate that operating conditions have affected the quantity generated is a necessary step to understanding what factors affect waste generation. Including a question in future data collection efforts asking facilities to identify any factors other than waste reduction that affected the quantity of waste generated would aid policymakers in understanding and compensating for these factors.

3.7 SUMMING INCREASES AND DECREASES IN THE QUANTITY GENERATED

To aggregate the change in the quantity of waste generated for all facilities, both increases and decreases in waste generation are added together. This gives the *net change* for all facilities, those that reduced the quantity of waste generated and those that did not. If many facilities had increases in waste generation over the time period, the nation as a whole may not show hazardous waste reduction progress even though some individual facilities showed significant progress. Conversely, the nation as a whole could show progress even when there are many facilities or individual wastes that showed increases in quantity.

Figure 3-1 illustrates the difference between the net change in the quantity generated for all facilities and the aggregated decrease in the quantity generated for facilities that show hazardous waste reduction. The figure includes only wastes that underwent hazardous waste reduction activities during 1986 and for which the quantities of waste generated in 1985 and in 1986 were reported. If only the net change is used, the data show a 50,000 ton decrease in the quantity generated, or a decrease of less than one percent. But the data also indicate that 56 percent of the wastes had an increase in the actual quantity of waste, giving a total increase of 9.67 million tons. The remaining 44 percent of wastes show a decrease of 9.72 million tons.

To obtain an aggregate measure of how much *progress* had been made at hazardous waste reduction, it is helpful to look at the total change in waste generation for two groups of facilities: (1) only those facilities with reductions in hazardous waste generation and (2) all facilities (i.e., net change). Reporting both these indicators gives a more complete description of source reduction progress. It also allows policymakers to study those wastes that do show waste reduction progress (i.e., decreases in quantity) and to target those wastes that show increases in quantity.

3.8 INFLUENCE OF THE LARGEST FACILITIES

The Generator Survey data include a few very large facilities in terms of the quantity of waste generated. For example, of all wastes with source reduction activities implemented prior to and during 1986, the largest waste stream generated was 48,851,000 tons. In comparison, the median waste stream for the same group of wastes was only 10 tons.

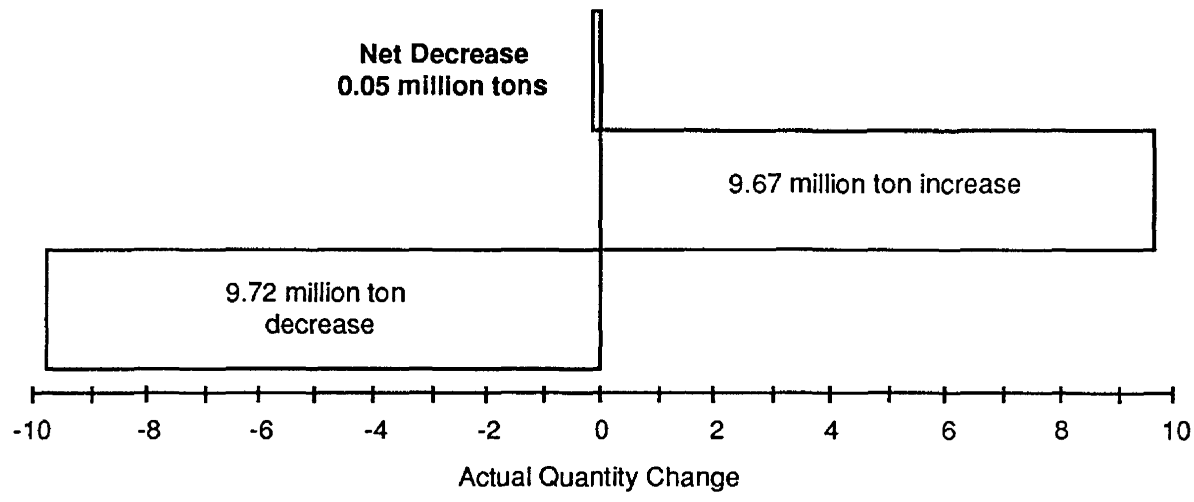

Figure 3-1. Aggregating Increases and Decreases in the Quantity of Waste

Note: Includes all wastes undergoing source reduction in 1986 that did not result in decreases in the toxicity of the waste and for which the quantity generated in 1985 and 1986 was reported.

Of those wastes, 44% show actual decreases in quantity totaling 9.72 million tons; 56% show actual increases in quantity totaling 9.67 million tons. The total actual quantity change for all wastes included is a 50,000 ton decrease.

Because these data are so heavily skewed, a handful of the largest waste generators disproportionately influence aggregate quantities of waste generation and of hazardous waste reduction. Because the risk posed by wastes from small and medium-sized facilities may be as great or greater than that posed by large facilities, an aggregate measure alone does not completely describe changes in the risk posed by hazardous wastes. Using a measure such as the median quantity change or the percentage change in addition to the total quantity change for all wastes provides a more complete description of progress. Descriptive information on the number of facilities showing progress in source reduction should not be affected by the skewness of the data.

CHAPTER 4
RECOMMENDATIONS

This report describes alternative measures of hazardous waste reduction progress and problems with these measures. In this chapter, we recommend specific techniques for measuring hazardous waste reduction based on the problems described throughout this report.

4.1 ACTUAL QUANTITY CHANGE

The actual quantity change is useful for assessing changes in the quantity of hazardous waste generated. However, the measure alone does not provide any insight into the causes of such changes in quantity. It does not provide information on the portion of the change that was caused by hazardous waste reduction activities. Thus this measure cannot be used alone to measure the amount of progress achieved at hazardous waste reduction.

4.2 ADJUSTED QUANTITY CHANGE

Because the adjusted quantity change controls for changes in waste generation that are caused by changes in business activity, the measure provides a more accurate assessment of the change in waste generation resulting from waste reduction activities than the actual quantity change. However, the adjusted quantity change does not control for changes in operating conditions that also affect the quantity of hazardous waste generated. For wastes affected by operating conditions, the adjusted quantity change is not an accurate measure of hazardous waste reduction progress. Also, facilities may not be able to calculate the adjusted quantity change for all hazardous wastes.

For hazardous wastes for which the adjusted quantity change is relevant and can be calculated, we recommend using the adjusted quantity change to measure hazardous waste reduction progress. For all other wastes, facilities could be given the option of developing a measure of hazardous waste reduction progress appropriate for their wastes. Alternatively, the actual quantity change could be used to provide some indication of the change in waste generation for these wastes. In all cases, facilities should be asked to provide information on the factors that affected the quantity of the wastes they generated. These data would increase policymakers' understanding of the effect of these factors on hazardous waste generation and would provide a more complete description of changes in hazardous waste generation.

4.3 THROUGHPUT

While throughput data can indicate the efficiency with which materials are used in production processes, it is not an appropriate measure of hazardous waste reduction progress. The measure does not indicate whether toxics use reduction has occurred.

Also, the throughput ratio is similar to the adjusted quantity change in that it does not control for changes in factors such as product quality or operating conditions. We do not recommend using throughput data to measure hazardous waste reduction progress.

4.4 CHANGES IN THE LEVEL OF HAZARD

Currently, no measure exists to easily and economically measure changes in *all* factors that affect the level of hazard of a waste. Any measure of the level of hazard will require large amounts of data both to develop the measure and to evaluate hazardous waste reduction progress. One problem with the DOH system or any evaluation of toxicity is the lack of sufficient data on the toxicity of many chemicals. The costs of developing a measure and the burden on facilities of reporting the necessary data must be carefully evaluated.

The DOH ranking system classifies wastes into three categories based on the level of hazard and can be used to monitor changes in the quantity of waste generated in each category. However, it gives no indication of changes in the level of hazard within a single category. One option is to modify the DOH system to provide a numerical measure of the level of hazard.

An alternative to measuring the total change in the level of hazard is to assess changes in the individual factors that contribute to the level of hazard for each waste. Data on the toxicity, ignitability, corrosivity, and reactivity of a waste can be reported annually and used to assess changes in these factors over time. Although no algorithm exists to assess the net effect of changes in several factors, monitoring all these factors gives a more complete and accurate description of the effects of waste reduction.

We recommend further study of both these options. Such a study should address the accuracy of the measures, the costs of developing and implementing the measures, and the ease of implementation. The study should determine what data are needed to develop and implement these measures, and it should evaluate the burden on facilities of reporting the data.

4.5 MULTIMEDIA SCOPE

Any assessment of hazardous waste reduction progress should be multimedia in scope. That is, the definition of hazardous waste used should encompass releases to all environmental media. If only one environmental medium is covered, the transfer of waste to another medium not covered would appear to be a reduction in hazardous waste generation. Such transfers are not hazardous waste reduction activities and may not represent a reduced risk to human health and the environment.

4.6 LONGITUDINAL DATA

We recommend that policymakers evaluate longitudinal data (data from several years) to evaluate hazardous waste reduction progress. Data on hazardous waste generation and reduction should be gathered for several consecutive years. All the benefits of a hazardous waste reduction activity may not be observed in the year the activity is implemented. Therefore, an assessment of hazardous waste reduction progress based on one year's data may underestimate the amount of progress achieved. Tracing the effects of an activity over several years would provide a more complete description of hazardous waste reduction progress.

4.7 WASTE REDUCTION GOALS

Because no single measure of waste reduction is accurate for all facilities and all wastes, it is not appropriate to mandate a specific level of hazardous waste reduction based on any single measure. One option for policymakers to consider is specifying the use of different measures for different types of waste generated by different types of facilities or different production processes. Such a study would require large amounts of resources, and sufficient data may not be available.

If an appropriate measure of hazardous waste reduction for a given waste is defined, the measure may not be accurate if changes in factors such as operating conditions or product design occur. This is because the quantity of waste generated (and therefore measures of hazardous waste reduction progress) can be affected by factors other than hazardous waste reduction and changes in business activity.

Rather than establishing mandatory waste reduction levels, we recommend that policymakers establish general waste reduction goals. If a facility or industry does not achieve this goal, as measured by a specified measure of waste reduction progress, policymakers could evaluate why the goal was not met. Changes in factors other than waste reduction that affect the quantity of waste generated should be considered in such an evaluation. This analysis would allow policymakers to determine whether a facility has made progress at hazardous waste reduction. It would also provide valuable insight into how operating conditions and other factors affect waste generation, and could aid in the development of more accurate measures of hazardous waste reduction.

4.8 MULTIPLE INDICATORS OF PROGRESS

This study demonstrates that no single measure of waste reduction progress is accurate for all facilities and all wastes. Waste-generating activities and waste reduction opportunities vary too greatly, and too many factors affect the quantity of waste generated. Therefore, we recommend that policymakers evaluate several different indicators of hazardous waste reduction progress and that facilities report data on a variety of factors that affect waste generation.

Evaluating a variety of indicators can give a more accurate and complete description of hazardous waste reduction progress. If all measures of progress evaluated are consistent, the conclusion that progress has occurred is more certain. However, inconsistencies among factors may indicate that one of the measures is inaccurate; data reported on changes in other factors that affect waste generation could then be evaluated to draw conclusions about waste reduction progress.

For example, Figure 4-1 shows the quantity of waste generated and the quantity of product produced at a facility during 1988 and 1989. For this facility, production increased from 1988 to 1989 but the quantity of waste generated remained constant. The adjusted quantity change indicates that waste reduction took place, but the actual quantity change shows no change in waste generation. This is an example of a facility that incorrectly reported the change in plant production for a waste that remains constant regardless of the level of output. Careful study of all the data available for the facility reveals that no progress at waste reduction occurred.

	1988 (tons)	1989 (tons)
Quantity of hazardous waste generated	30	30
Quantity of product produced	75	100

Actual Change = 1989 quantity generated – 1988 quantity generated
= 0 tons (no change)

Activity Index = products produced in 1989 ÷ products produced in 1988
= 1.33

Adjusted Change = 1989 quantity generated –
(1988 quantity generated x activity index)
= –10 tons

Figure 4-1. Example Comparing the Adjusted Quantity Change to the Actual Quantity Change

Although no single rule can prescribe how to draw conclusions about waste reduction progress from contradictory indicators, we suggest these general guidelines:

Progress is *likely* if one of the following scenarios applies:

1. Source reduction activities implemented, actual quantity generated decreased, and adjusted quantity generated decreased; or

2. Source reduction activities implemented, actual quantity generated increased, adjusted quantity generated decreased, and other information indicates that the adjusted measure is appropriate for the facility; or

3. Source reduction activities implemented, actual quantity generated decreased, adjusted quantity generated increased, and other information indicates that the adjusted measure is not appropriate for the facility.

Progress is *questionable* and further review is needed if one of the following scenarios applies:

1. Source reduction not implemented, and one or both of the quantity measures indicate a decrease; or

2. Source reduction implemented, and both quantity measures indicate an increase.

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