Chapter 4

Data and Information for Waste Reduction

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INTRODUCTION

One of the great obstacles to waste reduction policy analysis is scarcity of informational In developing waste reduction policy, Congress and government agencies should have data from many industries on current waste generation, waste reduction accomplished so far, and estimates of possible future waste reduction. Such data would help Congress and the agencies to decide if action is needed, what kinds of actions might be taken, and what kinds of wastes or which industries might be targeted for action. Few of these data exist and those that do, for example waste generation data, are collected in such a way that they reveal little or nothing about waste reduction.

Current waste generation data are inadequate for several reasons. First, the vast majority of waste generation estimates are for only wastes regulated by the Resource Conservation and Recovery Act (RCRA). They do not include emissions into other media; neither do they include releases of nonregulated hazardous wastes.[2] Second, annual waste generation estimates for the Nation vary widely and must be viewed as highly uncertain because they are based on sampling and modeling. Third, virtually all existing estimates of waste generation are estimates of mass, weight or volume only; no attempt is made to estimate the degree of hazard of the waste.

[1] In this chapter the term "data is used to denote numerical measures of or facts about waste reduction. The word "information is used to indicate a broader set of facts about waste reduction, including those that are numerical and those that are nonnumerical. Thus, data are a subset of information here.

[2] OTA's own estimate is that between 255 and 275 million metric tonnes of *RCRA* hazardous wastes are generated each year, but this figure does not even attempt to account for wastes generated under the Clean Air and Clean Water Acts, nor does it include non regulated hazardous wastes, [U.S. Congress, office of Technology}' Assessment, *Technologies and Management Strategies for Hazardous Waste Control*, OTA-M-196 (Washington, DC: U.S. Government Printing Office, March 1983) p. 3.] OTA's forthcoming report, *Wastes in Marine Environments*, will examine data on quantities of wastes regulated under the Clean Water Act.

Simply knowing that a company has reduced the volume or mass of its wastes tells nothing about true waste reduction because no information is given about the hazardous content of the wastes before and after. Many hazardous waste streams are made up principally of nonhazardous substances (often water) and contain only a small amount of hazardous material. Even RCRA sludges frequently contain a substantial amount of water and other nonhazardous materials. Simple dewatering of wastes can produce large volume decreases with no actual decrease in the waste's hazardous substance content.

Finally, waste generation figures are in no way correlated to production. Many companies and some entire industrial sectors recorded less waste generation in the early 1980s than in previous years, but industrial production was down during that period. It is impossible to tell how much reduction in waste generation occurred because of reduced production and how much resulted from implementation of actual waste-reducing measures.

Thus, generation data as they are now **col**lected are not useful for assessing either potential or achieved waste reduction. End-of-pipe generation data do not reveal enough about what is going on inside the plant to allow anyone to differentiate between changes due to waste reduction and those that are caused by changes in production levels, product mix, or even waste treatment methods, all of which may affect the composition and mass of a company's total waste stream.

The crux of this problem is that planning and assessing waste reduction requires fundamentally different sorts of data and information than have been required for traditional pollution control environmental progams. As was discussed in chapter 3, waste reduction is a form of production process or operations improvement. It requires actions at the front end of the process, rather than at the end of the pipe where current pollution control programs focus. *Planning, implementing, and assessing waste reduction are activities that require the same kinds of production information that would be required for any other production improvement. They also require data about the amount of hazardous waste generated per unit of production output, as well as data on costs and savings of the waste reduction actions.*

Companies often do collect this type of information when reducing their waste. However, as this chapter makes clear, this is not the type of information currently being collected by government, a fact which has important implications for the development of waste reduction policy (see ch. 2).

INDUSTRY INFORMATION NEEDS

Almost all information relevant to waste reduction *must* come from industry. Government can affect the kinds of information industry collects through new regulation, and it can also affect the format of collection (specifying periodicity of data, for example), but the fact remains that information must be collected by industry,

Information Needed for a Waste Reduction Audit

A waste reduction audit can provide the information a company needs to reduce its wastes. Many companies do not conduct formal audits prior to instituting waste reduction measures, Waste reduction largely remains a byproduct of other process improvements or is undertaken on an ad hoc basis to address one waste that presents immediate problems or costs. However, as the concept of comprehensive and systematic waste reduction becomes better understood and more effectively implemented, audits will become more common because they provide analytic support for waste reduction decisions. Even when taking ad hoc actions, however, companies usually try to pull together *some* of the information and data discussed below that make it possible to plan and carry out waste reduction in an effective manner (see table 4-1).

Chapter 3 discusses the steps that a company might go through in conducting a waste reduction audit, Following is a description of information generated by each step of the audit.

Step 1: Identification of **Hazardous Substances of Concern in Wastes or Emissions**

Companies must identify the *amounts* and *kinds* of hazardous wastes they generate before they can do anything about reducing them. This analysis can be done at radically different levels of detail and the level of detail of the information required will vary accordingly.

Companies may choose to or may have to make only rough estimates of the kinds and amounts of wastes generated, If only a limited level of waste reduction effort is planned or is possible, this gross analysis may be sufficient.

Better data on the chemical composition and quantities of wastes can be generated, at greater expense, by systematically conducting chemical analyses of the company's waste streams *over time* (an especially important factor in conducting analyses of batch processes where waste streams are not constant). This method of waste identification is now common in industry since many companies already collect chemical analysis data on wastes to help them with plans for waste management, However, the drawback to this method is that companies are unlikely in practice to be able to identify *all* waste streams that must be analyzed, including fugitive emissions, leaks, and spills,

Table 4-1.—Industry Information Needs for Waste Reduction

Waste reduction action	Type of information needed
Identify hazardous substances of concern in wastes or emissions	Kinds of hazardous wastes generated **[Type** W] Amounts of those wastes generated **[Type** W]
Identify source(s) of the hazardous substance(s) of concern	Above, plus process engineering and chemistry [Type T]
Set priorities for actions	Above, plus any regulation affecting wastes generated **[Type** R] Health effects and degree of hazard posed by different wastes [Type H] Ease and expense of implementing waste reduction for any substance (see below)
Analyze and select technically and economically feasible reduction techniques	Above, but more specific process engineering and chemistry information **[Type T]** Potential costs/savings of the waste reduction action **[Type E]** General economic situation of the company [Type E] Market information about the affected product(s) and estimates of any effects waste reduction may have on the product **[Type** E]
Compare economics of waste reduction with waste management alternatives	Above, plus current waste management costs including potential liabilities **[Type E]**
Evaluate waste reduction progress and success	Above, plus waste stream contents **[Type W]** Actual waste reduction costs/savings **[Type E]** Glitches, inconveniences, and unforeseen benefits to waste reduction activities **[Type** T]

KEY Type W - Waste stream data
Type P = Production Information
Type E = Economic information
Type T = Technology Information
Type R = Regulatory Information
Type H = Health and environmental effects Information

SOURCE Office of Technology Assessment, 1986

The most complete and reliable measure of the quantities of specific substances released into the environment is obtained from mass balance calculations. By subtracting the amount of a hazardous substance going out as product (if any) from the amount brought into the plant or process, a company can calculate the total amount that appears as waste and can then attempt to account for this amount through waste stream measurements. Such calculations may contain major uncertainties, a and accounting for all of a substance in a process is usually time-consuming and expensive. Mass balance calculations are done routinely in some industries, but frequently they are not sufficiently sensitive for waste reduction purposes.[4]

[3] Uncertainties in mass balance calculations due to chemical changes within process and to measurement errors are discussed later in the chapter (see discussion accompanying figure 4-1 and discussion of screening for degree of hazard and chemical change).

[4] The CISS Chemicals example noted in the waste reduction audit discussion in ch. 3 shows how significant amounts of waste may fail to be detected by mass balance calculations in a very large operation.

Step 2: Identification of the Source(s) of the Hazardous Substance(s) of Concern

Without knowing exactly which processes are generating which wastes, a company cannot know how to reduce those wastes. Information at this stage may also be collected at varying levels of detail. Companies can informally link their identified wastes with the process or operation(s) already known to produce them without collecting additional information, or they may attempt to trace hazardous substances back to where waste generation is occurring. One effective way to do this is to conduct process level mass balance calculations for hazardous substances and then search processes for points of waste generation or emission until all waste has been accounted for.

Tracing every hazardous substance back through the process and accounting for all wastes and emissions is an overwhelmingly ambitious task. Companies usually attempt to identify waste sources for only some of their wastes.

Since they have limited resources, companies may reasonably decide that they can identify enough waste reduction opportunities without seeking complete, detailed information about all their wastes and waste sources.

Step 3: **Setting Priorities for Waste Reduction Actions**

priorities for waste reduction actions may be influenced by:

- existing regulations affecting particular types of hazardous wastes,
- the need to conserve costly raw materials,
- the ease and expense of implementing waste reduction for particular substances (see Step 4, below), and
- the adverse health effects and degree of hazard of different wastes.

In some cases, one of these factors may override all others. For example, regulations may promote some waste reduction action for a particular substance, in which case information on the others maybe of academic interest only.

Step 4: **Analysis and Selection of Technically and Economically Feasible Reduction Techniques**

Having decided which wastes to target, a company must then decide on the best way to accomplish reduction. Required at this stage is information about process engineering and materials, the costs of waste reduction approaches and the savings possible from their use, the risks involved in making changes, and internal investment conditions.

process engineering and materials information for the target processes is most often provided by in-house personnel but, in some instances, waste reduction information from outside—from other plants, trade associations or State technical assistance programs—may be useful. OTA has found that transfer of waste reduction technology through information provided in publications—as is commonly attempted now—is, or is perceived to be, an unsuccessful method by most companies. A company may be able to adopt a general idea from waste reduction literature but substantial tailoring to onsite conditions must follow in most cases. Direct technical assistance, in the form of a consultant brought onsite, may be more useful (although consultants are often not knowledgeable about a specific plant's operations), but is also more expensive. Offers of such assistance by government may be resisted because of proprietary concerns.

Cost and savings information on waste reduction approaches includes their anticipated effects on the costs of capital, labor, raw materials, and waste management. Potential side effects on production operations and product quality may also be important and must be assessed, Tight estimates of these figures are difficult to make because waste reducing measures are front-end process and operations modifications and may have effects on other parts of the process or operation that are difficult to predict.

Information needed about risks involved in waste reduction actions include the cost of disrupting operations and possible costs associated with changes in product quality.

Step 5: **Economic Comparison of Waste Reduction Alternatives With Waste Management Options**

Waste reduction opportunities must be shown to be economically preferable to more traditional pollution control methods if they are to be judged attractive. Information that will be required to compare waste reduction measures with the alternative of waste management includes data about the technical and economic characteristics of the waste reduction action (discussed in Step 4) as well as information about current waste management costs.

The economic assessment of waste reduction versus management must include some information, however fuzzy, about the potentially enormous costs associated with waste management liability, Quantifying these risks or costs is difficult, but even if the risk of becoming involved in a Superfund site is small, the potential costs are so large that for many companies this becomes the primary motivation for waste reductions

[5] See the results of OTA's industry survey in app. A.

Step 6: Evaluation of the Progress and Success of Waste Reduction Measures

In order to plan future waste reduction intelligently, companies must find out how successful their past and current efforts are. They must know how waste reduction measures have altered the composition and amount of their wastes and what the costs and savings have been. They must also compare actual costs and savings with the estimates that were made in the planning stage to understand how good their planning has been.

Information needed for this step includes:

- enough information on all postreduction waste streams, including their composition, amounts, and fate, to measure reduction and to show to what extent wastes have just been shifted from one environmental medium to another;
- waste reduction costs and savings, including information about unanticipated glitches, inconveniences suffered, and any unforeseen benefits of waste reduction; and
- Step 4 and 5 planning information for comparison with results so that the company can ascertain how good its planning estimates have been.

Charging Full Waste Costs to Processes

To reduce their waste generation, companies need to be able to factor waste-related data into decisions made about actions that will take place at the front end of production. This can be done most effectively by charging each production process with the ultimate costs (including possible liabilities) of managing the wastes it generates. This seems obvious but it is frequently not done, and this neglect exerts a bias against waste reduction. Waste management costs, such as the costs of running a company's onsite treatment, storage, and disposal facility (TSDF), maybe a separate budget item. When management costs are externalized in this way, design engineers, plant managers, and processes engineers have little incentive to reduce wastes, production decisions may be made in favor of more waste-intensive methods *which are not cost-effective* because waste management costs have not been fully factored into the decision. Only when companies develop accounting information on waste costs at the process and operations level can cost-effective decisions and the full economic benefits of waste reduction be demonstrated.

TYPES OF WASTE REDUCTION INFORMATION

We have seen that each company or plant operation requires many different kinds of information if it is going to be effective in reducing the generation of waste. Government and the public, too, will need many types of information to understand how waste reduction is proceeding. OTA has grouped the information discussed above into six types based on its character and source. They are:

1. Type **W**: *Waste stream data.* These data identify the chemical composition of a waste stream and the amount of each hazardous substance present and relate chemical contents to different processes and points within processes.
2. **Type P:** *Production information* on types and amounts of inputs (raw materials) and outputs (product) measured over time and proportions of inputs which end up as hazardous wastes or react to produce hazardous wastes.
3. Type E: *Economic information* including: 1) costs and savings of waste reduction measures; 2) waste management costs, including liability costs; and 3) information on the general economic situation of the company (e. g., available capital, labor costs, production costs).
4. Type T: *Technology information* on the chemistry and engineering of company

processes and on possible waste-reducing changes to those processes.

5. Type R: *Regulatory requirements* that affect the company's operations or that affect proposed waste-reducing changes in those operations.
6. Type H: *Health and environmental effects and degree of hazard information* on hazardous substances. Also included is information about degree of risk, which may comprise a wide range of data about concentrations of substances, disposal methods, and the environmental characteristics of the areas in which wastes are generated, handled, transported, and disposed,

Several characteristics of these information types are particularly critical for formulating policy. First, only the last two, regulation information and health/hazard information [Types R and H], are uniform throughout industry. There is a set of standard government regulations (State and Federal) under which all companies operate. Similarly, standard data on the health effects of different hazardous substances could be compiled.[6] Technology information [Type T] may be generic to some extent, but less so than it is for pollution control programs, For pollution control and management programs (RCRA, Clean Water, Clean Air, Superfund) a discrete set of compliance or cleanup technologies can be identified which can be applied to waste streams, Pollution prevention process improvements can be categorized and common techniques identified, but, as chapter 3 shows, it is-not possible to compile a list of technologies for waste reduction. Economic, production, and waste stream data [Types E, P and W] are clearly specific to operations,

Second, the kinds of information which weigh most heavily in industry decisions about waste reduction tend to be those that are operation-specific, i.e., economic, production, and waste data. Health and degree of hazard information [Type H] are usually less important in industry's decisions about waste reduction; regulatory information [Type R], on waste reduction, is currently quite limited, T

Information that most directly affects industrial waste reduction efforts, particularly economic information about production, waste management costs, and liabilities, is diffuse, specific, and often confidential. As discussed below, this has important implications for government policy,

[6] Degree of risk calculations would have to be more site-specific because these vary with population density, exposure rates and other site-specific data.

[7] Ch. 5 discusses the *voluntary* nature of the current Federal waste minimization program.

INFORMATION NEEDED FOR FEDERAL POLICYMAKING

Industry and government collect different types of information because they play different roles in waste reduction, Industry collects detailed process improvement information for direct application to a specific waste generating processes. The Federal Government, on the other hand, needs to know the sum of all or a great many individual waste reduction actions, whether they represent successes or failures, and how this information relates to larger U.S. industrial, economic, and environmental issues and policies,

All Federal action options require a baseline of information that will yield answers to questions about this big picture. An overall view is required to assess the nature and scope of waste reduction possibilities, to set priorities, and to help determine what kind of Federal action will best serve the public good, In the case of waste reduction, some important questions are:

- How much hazardous waste of all kinds, released into all environmental media, generated in the United States each year?

- How much is that generation figure changing each year?
- To what extent are the changes a reflection of industrial production and to what extent are they the result of waste practices?
- How much waste reduction is possible? When could it be achieved?
- How much do different increments of waste reduction cost? What are the risks? What are the benefits?

TO answer such questions and to paint a big picture of the waste reduction issue, detailed information is needed on many small waste reduction pictures around the country. Doing this without becoming swamped in masses of data is not simple, either in theory or in practice. In order to make sense of masses of waste reduction data, government will need:

- waste reduction information from a significant number of representative generators in a representative cross-section of industrial sectors, company sizes, and geographic locations;
- data standardized in format, collection procedures, and period icity; and
- a data management system to allow analysis of data once collected.

Existing data systems do not come close to satisfying any of these criteria. Neither do they shed much 1 ight on any of the basic questions about the waste reduction situation. Part of the reason for this lies in the way in which we currently collect information about hazardous wastes, but the complexity of gathering waste reduction information itself is also responsible.

Waste Reduction Information Available to Government

Sources of information about hazardous substances i n the public domain and comments on their usefulness for waste reduction are briefly cataloged in table 4-2. The Federal programs under wh ich these data arc collected are discu ssed i n chapter 5.

Usefulness of Current Data for Waste Reduction

Data currently being developed and maintained by the Federal Government for pollution control do not provide any basis for a hazardous waste reduction program. This mass of information provides few insights into current waste reduction rates and no sense of how much waste reduction might be possible in the future. Inadequacies of these data for waste reduction stem from the fact that existing pollution control programs are: not multimedia in nature, address only a limited number of hazardous substances, and address a different set of substances in each environmental medium. The data collected, especially under RCRA, are not usually substance-specific but cover some conglomerate waste, only a portion of which is hazardous,

In addition, the following features combine to seriously limit the applicability of these data to waste reduction analyses:

- While a large amount of data is available on wastes, very little is available on the processes that generate the wastes. This is not surprising given the pollut ion control orientation of current regulations.
- What little production and process information exists is protected as confidential business information (CBI) which limits access to this data by the public and also by the staff of the Environmental Protection Agency for any purpose other than that for which it was explicitly collected. Much of this data was not available to the waste minimization people within EPA.
- There is little uniformity in collection method or time period in the existing data. Much of the most useful data for waste reduction has been collected only on an ad hoc basis, often as part of a contractor's study to support act ion on some single substance or small group of substances. Much of t he national data is extrapolated from a sampling o f represent a tive plants. Samples

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Table 4-2.—Existing Sources of Information Collected by the Federal Government and Their Applicability to Waste Reduction

Sources of potentially useful Information	Limitations on applicability to waste reduction
RCRA:	
General	1. RCRA-defined waste categories for information collection are very broad and often contain large amounts of nonhazardous constituents. 2. RCRA-regulated wastes are only a fraction of total wastes generated in the United States.[a]
Manifest Information including quantities and types of wastes shipped off site [Type W]	1, Data not centrally collected or managed Manifests are dispersed throughout State and EPA regional offices. Data not completely or centrally computerized; often hard copy only. 2. Waste type Identification is not always accurate, 3 No data about waste minimization program is contained in certification 4. Manifested wastes are only a small percentage of total wastes generated in the United States,
Biennial report information (summaries of generator and TSDF activities submitted every 2 years; Includes description of waste minimization activities and program) [Type W, perhaps some of types T&P]	1. States administer biennial reporting and use different definitions, making it impossible to combine data from different States. 2 Descriptions of waste minimization activities included are in a narrative form and quantitative data on waste minimization activities or achievements not standardized. 3. Waste minimization Information only required of generators who ship off site. 4. Waste minimization not defined; can include a wide variety of recycling and other waste management activities in addition to waste reduction,
Hazardous waste permits for TSDFS Including amount and type of waste to be handled [Type W]	1, Broadness of RCRA waste categories and Inclusion of nonhazardous constituents. 2 RCRA-regulated wastes are only a small fraction of total wastes generated in the United States. 3 Permit waste figures are only one-time estimates; no time-series data to indicate changes/trends. 4 Waste minimization Information retained on site of facility.
EPA's Waste Minimization Report [Types W, T, P, R, perhaps H & E]	1 Examines only RCRA-regulated wastes,[a]
Westat Survey (attempt to estimate national waste generation) [Type W]	1, Estimates only RCRA waste generation.[a] 2. Estimates RCRA generation only by waste *group* (F, K,U, etc.), not by waste stream (F001, FO02, etc.). 3. There are quality problems with the data, stemming in part from the sampling method used 4 Survey provides no time-series data; no waste reduction trends can be assessed
Industry studies [Types W,P,T, perhaps E]	1 Completed only for two industrial sectors, underway for only two more 2. Data collected only at only point in time: no trend data developed 3 Data are confidential
Clean Water Act:	
NPDES permit and monitoring Information including amount and contents of discharges as well as process creating toxic pollutants [Types W,P]	1 Data are largely in hardcopy, not computerized, and therefore not easily accessible 2. Most data are kept in regional offices, not easily accessible for national analysis. 3. Data are collected in all States only for conventional pollutants and the 65 CWA-listed toxic pollutants.[a] 4 Data only on permitted discharges, not on actual generation 5 Data from technology-based standards will not be substance-specific. 6. Data reveal nothing about amount of pollutants shifted into landfilled sludge to achieve compliance
Indirect discharge (pretreatment) data	1 Not centralized Each indirect discharger and POTW keeps own data according to its own format.
Information used to set effluent guideline limitations, pretreatment standards, and water quality standards [Type W, some T,E,P]	1. Data developed with diverse collection methodologies by different contractors 2 Data collected over differing periods of time, 3 Data collected only on a limited number of substances,
Clean Air Act:	
NESHAP standard-setting Information [Type W, some T&E]	1 Exists only for a very limited number of substances.[a] 2. Data are mostly confidential 3. Format, collection methods, period of collection of data vary widely
NESHAP Implementation data including emissions amounts and sources [Type W]	1. One-time only data; no time-series data, so no reduction trends. 2. Available on only a small number of substances (six).[a]
Information collected for the Ambient Air Quality program [Type W]	1 Not centrally managed, kept at the State level,

Table 4-2.— Existing Sources of Information Collected by the Federal Government and Their Applicability to Waste Reduction—Continued

Sources of potentially useful Information	Limitations on applicability to-waste reductlon
Toxic Substances Controi Act (TSCA):	
Inventory of 64,000 chemicals including amount produced by individual plants [Type P]	1, Collected only once for any substance, Much of it out of date. 2, Most of the data are confidential.
Exposure information for 250 chemicals–essentially plant-specific mass balance information [Types HP]	1. Kinds of chemicals studied are not primarily chemicals of common concern In hazardous wastes. 2 Virtually all data are confidential.
Health and safety data [Type H]	1. Many of the raw test data have not been evaluated. 2. Substances are chosen for review because of their use in products In commerce and manufacturing, not because of their presence as pollutants
Information on new toxic chemicals Includlng process information and estimates of environmental releases. Data on 6,000 new chemicals received [Types W,P,Tl	1, One-time only data; estimates of releases are not subsequently confirmed 2, Virtually all these data are confidential.
Census Bureau, Department of Commerce:	
Production information for all manufacturing operations [Type P]	1. Census Bureau is legally barred from disseminating this Information except on an aggregated, industry wide basis.
Bureau of Mines, Department of the interior:	
Production and use information on hazardous minerals (e.g , mercury, cadmium)	1 Data available on only a small number of substances (minerals rather than chemicals),[a] 2 Information confidential except in aggregated form.
Consumer Product Safety Commission:	
Rough percentage data on hazardous constituents in various consumer products [Type P&H]	1, Data are old (1974). 2. No estimates on total production are provided
Occupational Safety and Health Administration:	
Requires Material Safety Data Sheets listing hazardous constituents in chemicals sold [Type P]	1, No centralized database of this information, 2, Confidentiality can restrict information prowded,

Data collectd under individual programs can rarely be combined for one purpose because of different on methods—used

KEY Type W = Waste stream data
Type P Product Ion information
Type E Economtc (rrformatlon
Type T = Technology information
Type R = Regulatory information
Type H = Health and environmental effects tnformatton

SOURCE Office of Technology Assessment, 1986

and techniques are not the same among industry categories and among programs within EPA and are not the same over time.

- Most information concerns emissions that are dispersed into only one environmental medium.
- Very different amounts, kinds, and qualities of data have been collected for different hazardous substances depending on the kinds of regulatory actions that have been applied.
- Very little, if any, information exists for the many hazardous substances that are not regulated.
- Existing data are not very accessible, Most often they are in hard copy and very often are scattered through regional and State offices throughout the United States.

Federal Authority To Collect More Information

Congress has recognized the need to collect information on hazardous substances. Considcrable authority already exists under the Toxic Substances Control Act (TSCA) to collect information relevant to waste reduction should the Federal Government decide to pursue such an option, In addition, Congress has under consideration an expanded information-gathering program in the Comprehensive Environmental Response, Compensation, and Liabilities Act (CERCLA or Superfund) conference committee bill. If taxing provisions for Superfund are agreed to by the conference committee and both houses pass the full Superfund legislation, the government may have this new authority by the end of 1986.

Toxic Substances Control Act

Because TSCA is not a pollution cent rol statute but is aimed at control of production and distribution of toxic substances, it may be more relevant to waste reduction than any other statute. There are, however, several major problems with attempting to use TSCA for waste reduction purposes.

To support the ranking of chemicals for investigation and chemical risk assessments required under TSCA, the act's Section 8 gives the Federal Government broad powers to obtain information on the production, distribution, and use of toxic substances. This authority has been exercised with the promulgation of the Preliminary Assessment Information Rule (PAIR) which required plant-level mass balance and exposure information on 350 chemicals as of December 2, 1985.[8]

There are, however, a few limitations on TSCA reporting authorities which might reduce the ability to use Section 8 to obtain information for a hazardous waste reduction program, especially to gather mass balance data. First, Section 8 reporting authorities extend only to existing and "reasonably ascertainable" information, Reporting of hazardous waste reduction information that has not already been collected by a company and that is not "reasonably ascertainable" cannot be required under Section 8. However, the more cumbersome rule-making procedures of TSCA Section 4, which provide EPA with authority to require chemical testing, could be used to require the gathering and submission of previously unavailable information.

Second, because TSCA applies only to "chemical substances and mixtures, " it may be difficult to obtain information about operations that assemble or fabricate articles. In the case of the PAIR described above, reporting is required only for manufacturers of the designated chemicals. Thus, those using the designated chemicals to make other products and those generating the designated chemicals solely as wastes have been exempted from coverage.

Third, there is a small business exemption provision incorporated into Section 8. Thus, information collected under this section does not cover all plants. For example, in the case of the PAIR, most manufacturers or processors with total sales of less than $30 million per year or with total annual production of under 100,000 pounds of a chemical have been exempted from reporting.[9]

Finally, because much of the information submitted under TSCA is production, rather than waste, information, it is claimed as confidential business information. CBI cannot be shared with State governments, hence any information collected under TSCA Section 8 would not be adequate to support a hazardous waste reduction program that involved any significant State implementation, as do current pollution control programs.

Superfund Reauthorization[10]

Both the House and Senate bills to reauthorize Superfund proposed a new hazardous substances national inventory reporting system. A comparative summary of these provisions is given in table 4-3.

The Senate version was very similar to the New Jersey Industrial Chemical Survey (see discussion below). The Senate bill required certain firms to report to EPA and State governments every 3 years through 1993 (three reports in all) on a list of chemicals prepared by EPA or the hazardous substances listed in CERCLA. The information to be reported included plant-level raw material, product, and emissions data.

The House version was aimed at making information available to communities to support emergency response needs. It provided for annual reporting by companies using, producing,

[8]As proposed in February 1980, PAIR would have information on 2,226 chemicals. This number was reduced to 250 under the final rule issued in July 1982, in order to reduce the burden of reporting. Subsequent amendments to PAIR have raised the number to 350. According to the chief of the OTS Chemical Screening Branch, this reduction has limited the usefulness of the data. As it stands, PAIR provides data on too small a number of chemicals to allow ranking for Section 4 investigation, which was the purpose of collecting the data in the first place. [U.S. Congress, General Accounting Office, *CHEMICAL DATA: EPA's Data Collection Practices and Procedures on Chemicals,* RCED-86-63 (Gaithersburg, ML): February 1986), pp. 25-26.]

[9]Most chemicals produced in quantities greater than 100, OW3 pounds annually are made in continuous process operations. Batch process operations, which tend to be much more waste-intensive per pound of production than are continuous process operations, are therefore disproportionately excluded from reporting.

[10]As this report was going to press, Congress had finished its conference committee deliberations on new Superfund legislation, Complete details of the final bill, however, were not available in time to include them here.

Table 4-3.—Comparison of Proposed National Inventory Requirements in Superfund Reauthorization Legislation[a]

	Senate Bill	House Bill
Who must report	Manufacturers, processors (>200,000 lb/yr), users (>2,000 lb/yr) of listed substances; SICS 20 through 39	Companies producing, using, or storing listed substances
Hazardous substances list	EPA to prepare list following guidelines in bill; otherwise Superfund hazardous substances I ist effective	EPA's July 1985 Acute Hazards List or EPA determined list of those substances causing "imminent or substantial endangerment"
Reports due	1987, 1990, and 1993 only	Every year
Report content	Uses of chemical; estimated amounts	Chemical name (unless confidential)
Input data	Amount shipped to plant; amount consumed onslte	Amount present at plant
Output data	Amount leaving as product; amount shipped as wasteiby product	Total annual amount released to environment and amount in excess of that permitted under Federal pollution control laws
Discharge data	Amount of discharges to air, surface water, land, subsurface injection, POTWS, and amount discharged from onsite treatment facilities (and treatment method)	Discharges to any environmental medium in excess of a designated amount
Submitted to	State office designated by Governor and to EPA	Local emergency response committee
Other comments	EPA required to computerize information received; information to be publicly available	Health data (MSD sheets) also must be reported with above information

[a]According to limited details available before this OTA report went to press, *both* the Senate and House reporting systems are included in the Superfund conference bill; some aspects have been changed

SOURCE Office of Technology Assessment 1986

or storing listed substances to local emergency response committees. The data required included an inventory of the amount present at a plant site, annual environmental emissions, and material safety information on each chemical reported.

According to some information available on the conference committee bill, Congress has decided to require both types of reporting. The more extensive Senate version ("toxic chemical release forms") will not start until 1988 and will be an annual report until 1993, EPA then has the discretion to lessen the frequency of the reporting cycle. The threshold amounts that determine who must report were lowered for manufacturers and processors but substantially increased for users. Under the emergency response inventory, EPA has been given the discretion to set thresholds and the information submitted may be aggregated into health and physical hazard categories. Congress has retained the requirement that EPA set up a computerized database for management of the data collected on the toxic chemical release forms,

Later in this chapter is a discussion about appropriate ways to measure waste reduction. As that discussion shows, the above national inventory systems fall short of providing definitive waste reduction data (see also ch. 2). They could, however, supply some preliminary information that may be helpful for initial policy decisions and setting program priorities. The establishment of such systems could also pave the way for more appropriate waste reduction data collection.

State Chemical Inventories

Some States have already conducted plant-level chemical inventories; none have been conducted for waste reduction purposes or are particularly relevant for waste reduction. Surveys tend to be one time events so that no time series information on waste generation is *created,* and they collect annual inventory data rather than waste generation per production output. They can identify major sources of chemicals, and this information can be valuable for setting program priorities, New Jersey's Industrial Chemical Survey is one of the best known. It is probably the most comprehensive of these efforts and was the basis for the national inventory system provision in the Senate Superfund reauthorization bill.

New Jersey's Industrial Chemical Survey collected 1978 data on 155 chemicals from 7,000 plants representing a wide variety of manufacturers and users in the State, This one-time survey requested annual, plant-level mass balance data on the amount of each chemical purchased; the amount shipped as product; the maximum amount in inventory; and the amounts present in the air, water, and solid waste streams. The survey cost New Jersey approximately $200,000 to complete, and State officials have reported that few claims of confidentiality were made by firms.

In 1986 New Jersey began collecting new information under its right-to-know legislation; this survey will be repeated every 2 years. It covers firms that produce, use, or store any of 154 hazardous substances, Most firms only need complete Part I, giving a range of the maximum inventory of the chemicals on hand at any one time during the year. In Part II, estimated plant-level mass balances of the chemicals must be reported. In one section firms are asked if any methodologies are being employed to "achieve source reduction or waste avoidance of generated [RCRA] wastes, "[11] If the answer is yes, the respondent is given two lines in which to describe those methodologies, What is not clear is how New Jersey officials intend to use the responses to this question. As is the case with the Federal waste minimization reporting requirement, an endless variety of narratives may result for which no aggregation will be possible.

[11] New Jersey Environmental Survey, Part II, Question No. 14. The questionnaire defines source reduction and waste avoidance activities as those activities that OTA considers waste reduction. However, although the survey covers all media releases, this waste reduction question only applies to RCRA hazardous wastes.

Maryland has a Toxic Substances Registry that contains an inventory of specific chemicals and facilities that use, manufacture, or process them. Much of the information is considered confidential and is collected for and used primarily by State agencies for program development. For instance, one survey was conducted in 1985 on 300 chemicals of interest to the State air toxics program. Twelve hundred firms were surveyed (90 percent response rate) on their use, production, and handling of the listed chemicals; no emissions data was requested.

New York State has conducted an Industrial Chemical Survey to collect information on 142 chemicals used, stored, manufactured, or transported in the State to improve local emergency response procedures. The State Attorney General in assessing the information said that, while it is valuable, much is classified as trade secrets, is now outdated, and only covers larger firms in the State, [12]

[12] Robert Abrams, Attorney General, State of New York, "Toxic Chemical Accidents in New York State: The Risk of Another Bhopal, " Jan. 14, 1986.

WAYS TO MEASURE WASTE REDUCTION

Questions about how much waste is currently being generated and how that figure is being reduced (or increased) over time *should* be answerable with data on waste generation. However, as discussed earlier, true waste reduction may be disguised in waste generation trends by changes in production, changes in the amount of nonhazardous constituents in waste streams, regulatory changes, and cross-media shifts. Existing waste generation data are therefore not useful for answering waste reduction questions because: 1) they deal only with some fraction of hazardous wastes, often only with wastes regulated under a single statute (e. g., RCRA wastes); 2) they are mass or volume estimates only; and 3) they are in no way correlated to production.

Most hazardous wastes are complex mixtures of hazardous and nonhazardous constituents. Very often water is the largest component of raw waste streams that contain only small amounts of' hazardous substances. Thus, volume reduction measurements by themselves reveal nothing about the hazardous portion of any waste stream. Concentration of' hazardous substances alone is not waste reduction. Similarly, waste generation depends on production; trends in data not correlated to production may indicate a rise or f'all in waste generation attributable only to an increase or decrease in capacity utilization of a plant or operation, Finally, reduction in one waste stream does not necessarily mean that total emissions of a substance have been reduced; most operations have several points of emission for any given substance and discharge wastes into more than one environmental medium.

Theoretical Requirements for Measuring Waste Reduction

Simply charting trends in waste generation data as it is now collected is not an adequate measurement of waste reduction. But, what would be adequate? Theoretically, the only meaningful measure of waste reduction is the **total** amount of hazardous waste generated per unit of production. This is the only way to compensate for the production, volume, and multimedia limitations of existing data.

As outlined below, such a measurement would require a large amount of very detailed process- and substance-specific waste information collected periodically on a production output basis. There are many reasons why collecting this amount and type of data may be impractical, but understanding what data are theoretically required to assess waste reduction will illustrate some of the risks and uncertainties incurred by accepting imperfect and, perhaps, misleading data.

Measurement Criteria

To provide a complete and reliable measurement of waste reduction, waste generation (i at a collection methods would have to be changed to meet the following criteria.

Criterion 1: Waste Reduction Data Must Be Correlated to Production.—Because waste generation varies directly with capacity utilization (everything else remaining the same), it is important to know whether waste amounts are rising and failing because more or less product is being manufactured or because waste reduction measures are being implemented. *Waste generation figures not correlated to production can mask waste reduction successes as well as failures.* A company maybe implementing waste reduction as its business is growing. Waste volumes may appear to be going up while waste per unit product, the true measure of waste reduction, is actually going down.

Thus, it may be to the advantage of companies to measure waste generation on a per unit product basis. For example, Monsanto Co. found that in terms of absolute volume their waste generation decreased only 1.7 percent between 1982 and 1984. However, unit generation (pounds of waste/pounds of production) decreased by 19.7 percent over that period.[13] Similarly, the plating operation at Stanadyne, Inc. (Sanford, North Carolina), calculated that its waste sludge had decreased only 4 percent between 1983 and 1985, from 115,000 pounds to 110,000 pounds. But annual production hours had nearly doubled over this period from 2,380 to 4,55o, therefore waste generation dropped from 48,3 to 24.2 pounds per hour of production—almost a 50-percent decrease.[14]

Criterion 2: Waste Reduction Information Must Be Substance-Specific.—This is the only way to overcome the volume measurement problem and the media shifting problem. When waste streams are complex mixtures of hazardous and nonhazard-

[13] *Waste Reduction: The Untold Story*, proceedings of a League of Women Voters conference, Woods Hole, MA, June 1985.

[14] George McRae, Stanadyne, Inc., personal communication, Apr. 23, 1986.

ous substances, volume measurements do not give the amount of hazardous substances in the waste, much less the amount of any given hazardous substance. One might hope to gather this information by intensively monitoring waste streams for their hazardous constituents, however such a procedure would assume that all releases were known. Fugitive air emissions, leaks, and spills can contain substantial amounts of hazardous materials and would almost certainly not be accounted for in such a system.

In theory it is simple to calculate the amount of a specific substance appearing as waste in a process. One subtracts the amount of the substance in the product from the amount of the substance in the raw material; the difference is waste. A company would then know how much of that substance must be accounted for in all waste streams and emissions. Such a mass balance calculation for specific substances keeps nonhazardous constituents from diluting the usefulness of hazardous waste data. Also, by forcing an accounting of all emissions throughout the process, it finds previously unknown sources of waste which may aid in planning waste reduction.

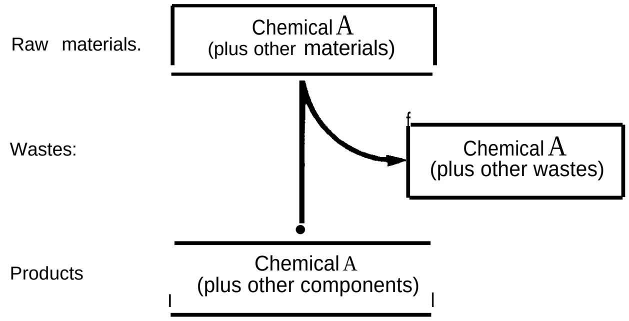
In practice, however, mass balance calculations are not always easy to conduct or reliable. There is always uncertainty in input and output measurements. When the inputs and outputs are large relative to the difference between them, the uncertainties may be larger than the amount of waste. Thus, these types of calculations may reveal little or nothing about small quantities of highly hazardous wastes.

Process chemistry can create additional practical difficulties in calculating mass balances. Figure 4-I illustrates three basic chemical scenarios which pose varying degrees of difficulty,

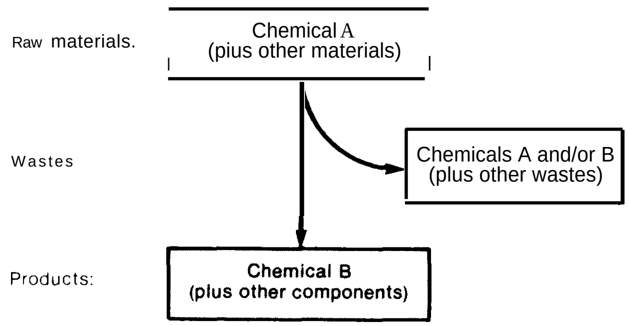
In Case 1, a hazardous Chemical A is used as a raw material that is incorporated into a product with some of it lost in the process. An example would be the use of cadmium metal in a cadmium plating operation, which generates cadmium m wastes i n the p recess.

Figure 4-1 .—Process Chemistry **Changes That May Affect Mass Balance Calculations**

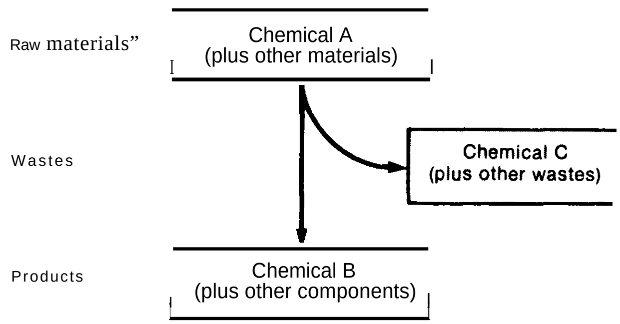
Case 1: Chemical A IS not changed In the production process (Chemical A IS a hazardous substance)



Case 2: Chemical A IS converted Into Chemical B In the production process (At least one of the two chemicals, A & B, IS hazardous



Case 3: Chemical A IS converted Into Chemical B, producing the unintended hazardous byproduct, Chemical C (Chemicals A & B may or may not be hazardous.)



SOURCE Off Ice of Technology Assessment

In Case 2, Chemical A is converted into Chemical B. At least one of these chemicals is hazardous, and some of that hazardous input or product finds its way’ into the waste stream.

For example, the process used in the 1970s to convert vinyl chloride gas, a known carcinogen, into polyvinyl chloride (PVC) plastic resin allowed the release of some of the vinyl chloride gas.

In Case 3, Chemical A is converted into Chemical B, producing the unwanted hazardous waste byproduct, Chemical C. An example of this is the generation of highly toxic 2,3,7,8 -tetrachlorodibenzo-p-dioxin (usually referred to as "dioxin") during the chlorination of a number of aromatic hydrocarbons, a process used in the manufacture of pesticides.

Even at this simple level, it is obvious that chemical alterations that occur in instances such as Case 2 and, particularly, Case 3 complicate the mass balance calculation. Calculating mass balances for complex industrial processes which involve many substances and many complex chemical reactions is a monumental task.

Criterion 3: Waste Reduction Data Must Be Process-Specific.—Conducting mass balance calculations at the plant level with a high degree of sensitivity and accuracy would be extraordinarily difficult. Processes, reactions, and transformations are usually so complex that good data cannot be collected except at the smallest production level—the process or unit operation. It might be possible in some cases to conduct a very rough mass balance on a hazardous substance at the plant level by figuring the difference between input and product output and assuming the rest is waste, without trying to track that waste. Doing this over time, one might get a rough sense of the amount of waste reduction, but the uncertainties in this calculation are almost always large and may not reveal much about small amounts of highly hazardous waste. Moreover, a plant-level mass balance would not normally provide any guide for waste reduction action because it tells little about where the substance appears as waste in the plant operations.

One illustration of the limitations of plant-level mass balances is the case of a leaking valve at USS Chemicals that was emitting 400,000 pounds of cumene worth $100,000 annually. The plant uses 700 million pounds of cumene annually and had conducted a cumene mass balance with an accuracy of plus or minus 1 percent. The valve loss, which accounted for only 0.06 percent of the raw material, could not be detected by this means.[15]

Criterion 4: Waste Reduction Data Must Be Collected Periodically.—This may sound obvious, but it is not always done. Without time series data on waste generation, waste reduction cannot be calculated. Government information collection efforts about wastes, in particular, are frequently one-time events or a series of events which cannot be compared.

Practical Constraints on Waste Reduction Measurements

There are several practical reasons why perfect waste reduction information can never be assembled by government. Some of these have already been alluded to. First, not all industrial operations lend themselves to measurement of waste on a production output basis because *units of production or output are often not easy to establish*. This is particularly true in service industry job shops such as autobody shops where significant amounts of solvents may be used but in a mix of applications which can not be easily correlated to sales, profits, or hours of operation, Similarly, in many batch processes, such as dye mixing and specialty chemical formulation where both product and waste vary in type and quantity, a meaningful measure of unit production may be difficult, but not impossible, to establish.

Second, *the amount of data theoretically needed to assess waste reduction is staggering.* Collecting process-level mass balance data on every single hazardous substance from every plant in the country is impossible.

Third, *many companies consider detailed data on their processes to be proprietary*. Companies may fear that, if made public, this information could be useful to their competitors

[15] David J. Sarokill, et al., *Cutting Chemical Wastes* (New York: INFORM, Inc., 1985).

and may therefore strongly resist reporting such data.

Fourth, even if industry had the resources to collect and report this kind of data, *government has not yet demonstrated its ability to efficiently and effectively manage the data on wastes that it currently requires from industry. A data deluge of this magnitude would be overwhelming.*

But, government does not necessarily need a huge amount of disaggregated process-level information, policy makers need a few crucial numbers to understand the crucial questions about waste reduction. Examination of current waste generation figures reveals uncertainties arising from nonhazardous constituents, cross-media shifting, and variations in production, However, once generation figures are substance- and process-specific and corrected for production volume they appear difficult to aggregate. The problem becomes one of how to combine:

- X metric tonnes of TCE waste/year of auto-body decreasing,
- Y metric tonnes TCE waste/meter of fabric scoured, and
- Z metric tonnes TCE waste/10,000 door-knobs cleaned to obtain plant-or company-level information.

PRACTICAL POSSIBILITIES FOR INFORMATION COLLECTION

Pooling Waste Reduction Data

One way for government to obtain waste reduction data without invading the proprietary domain of industry is for companies to pool their waste reduction data in the form of waste reduction *percentages*.

Pooling works as follows: a company calculates the absolute amount of a particular waste generated at the process level per unit production output per year[16] It then converts that figure into a percentage reduction (or increase) relative to the last year's generation. The percentages can be combined across different processes, plants, or industries by using weighted averages .17 An A percent reduction in a waste stream of X tonnes/year, a B percent reduction in a stream of Y tonnes/year and a C percent reduction in a waste stream of Z tonnes/year is a combined reduction of the total waste stream of X+Y+Z of:

A(X/X +Y+Z) + B(Y/X+Y+Z) + C(Z/'X +Y+Z) = ~e~~::::

Since the waste data is volume data, this approach does not necessarily reveal anything about the degree of hazard or environmental risks posed by the waste. However, when substance-specific data are available, this approach can make such determinations.

In this way, a company can pool its process-level reduction figures into one plant-level reduction figure for each waste. All the-plant level reduction figures can then be pooled into one company reduction figure. Similarly, company figures can be pooled into single reduction figures for States, industrial sectors, or the entire country, (See box 1-D in ch, 1,)

Government could choose whether it wanted companies to report at the plant or company

[16]A variety of ways to calculate waste reduction as related to production output have been used in industry. Some are simple variations on the method presented here. For example, measuring percentage waste reduction per unit production in any particular year against some standard baseline year (much the way economists measure in constant dollars) is perfectly valid. It differs from OTA's method only in that it presents sums of waste reduction percentages over all years since the baseline year, rather than reporting reduction as individual annual percentage changes. This method may be more useful for long-term trends but less revealing about activity in any given year. However, OTA considers some other methods currently used to be less accurate. For example, measuring percentage waste reduction as a function of revenues may not be reliable, because product changes and price changes prevent revenues from directly reflecting production.

[17]Without weighting reduction percentages to reflect the different sizes of waste streams reduced, the averages may be misleading. A large percentage reduction in a small waste stream could skew the average to give an overly positive picture of the average waste reduction, Similarly, the importance of a small percentage reduction in a large stream would not be adequately represented without proper weight ing of the percentages in the average.

level. In either case, pooled *percentages conceal information about company processes which can be of use to competitors, thereby alleviating industry's concerns about confidentiality*. The pooling system also greatly limits the amount of data the government will receive and will have to manage.

Screening for Changes in Degree of Hazard

The pooled figures correct] y measure the reduction in volume or mass of waste generated but they do not necessarily reveal anything about the amount of hazardous constituents in the waste or their degree of hazard. A waste reduction action may have little effect on the degree of hazard of a waste for two reasons. First, the concentration of the hazardous constituents in the waste may change. This is a problem of particular concern in measuring reduction in aqueous waste streams, which make up much of the national waste output. The great majority of wastewater streams are 90 percent or more water. With so much water, volume and mass measurements easily cloud waste reduction measurement. Reducing the amount of process water can significantly reduce the volume of an aqueous waste; the waste stream becomes more concentrated, with no reduction in hazardous content. Conversely, if the hazardous constituent in a dilute waste stream is significantly reduced, only a very small reduction would be measured when in fact significant waste reduction had occurred.

Second, the chemistry of the waste may change because of a waste reduction action and cloud substance-specific reduction measurements as well as mass or volume measurements. Data indicating that one particular hazardous constituent has been eliminated from a waste stream reveal nothing about any newly generated hazardous constituents. For example, TCE may be eliminated from a waste stream but if methyl chloroform has been substituted, the amount of hazardous wastes generated may not have been reduced. Similarly, if a waste reduction action involves substituting new raw materials that produce a smaller quantity of a more hazardous waste, true waste reduction has not occurred.

To understand and analyze reduction measurements involving changes in chemistry and concentration of wastes requires detailed data on the composition of the waste and the action(s) that brought about the change. In most cases this is likely to be cumbersome even for the industries directly involved, let alone for the government. However, it may be enough for government to screen out such data and not use them in its calculations of national waste reduction,

Limiting Data Collection/ Living With Imperfect Data

Clearly the data required for accurate waste reduction measurement are extremely difficult to obtain in practice. However, establishing a method for acquiring some useful data, even incomplete or imperfect data, would be an improvement over the current situation in which virtually *no* meaningful waste reduction data is available. Government has at least three *non-exclusive* options for drastically limiting the collection effort for waste reduction data and still learn something about waste reducing activities in American industry.

Option 1

Government could forego substance-specific data and require that simple waste volume (or mass) generation data be correlated to production output, as described above, and reported in terms of percent reduction. These data would suffer because they would treat water and other nonhazardous constituents as wastes, but they would at least incorporate economic activity into waste reduction figures. Such facts would also be relatively straightforward and inexpensive for industry to collect, and even this limited information would be an improvement over the current situation.

Option 2

Government could require substance-specific data correlated to production output on only a few substances of particular concern, perhaps gradually increasing this number over time. This option would be most useful if implemented in conjunction with Option 1. The two could be implemented concurrently (i.e., volume/production data on most wastes, with substance-specific data on a few substances) or sequentially (initiate volume/production collection, phasing in requirements for substance-specific data on substances of concern).

Option 3

Government could require simple waste volume (or mass) data correlated to production output but could screen these data for changes in degree of hazard. Government could require that for each reduction percentage reported, companies answer two questions: Has any change in concentration in the waste accompanied this reduction? Has any change in the chemistry of the waste accompanied this reduction? Government could then reject any data about which positive responses were given in calculating national waste reduction figures, because without further information the amount of true waste reduction in those instances cannot be verified. Alternatively, the government could require and analyze additional information to determine if true waste reduction had taken place. This, however, could become a very large task.

These options to reduce the quantity of data industry would be required to report to government could lift an enormous burden off both government and industry. The options may not, however, completely solve a number of the practical constraints on data collection cited earlier, such as analyzing the chemistry of a large number of waste streams and putting together an overall waste reduction picture from disaggregated data.

INFORMATION REQUIREMENTS AND OPTIONS FOR FEDERAL ACTION

The information the Federal Government might want in order to assess the need for waste reduction or act on this need will depend on the action contemplated. Table 4-4 lists several possibilities for Federal action and notes the information that might be needed to choose and/or implement them. It is clear from the table that the information requirements of some of the options are formidable.

Mandatory Reduction Levels

The amount of data and information that would be required both to set and to enforce mandatory waste reduction standards would quickly overwhelm the regulatory process as it now exists. The government might implement this option in the same way it has approached the setting and enforcing of Clean Water Act effluent limitations and standards, but it would be much harder for waste reduction. EPA would need, first, a vast amount of technology information on all industrial processes that release hazardous substances into the environment in order to determine what levels of waste reduction could reasonably be expected using best available technology (BAT) for each process. This assumes that industrial processes can easily be broken up into generic types that will be similar enough to be regulated under one BAT standard. Even if generic divisions could be established, industrial diversity and site-specific exceptions would be likely to force many companies to petition for variances, as has been the case under the Clean Water Act standards. Since BAT for waste reduction will have to be part of production technology, rather than an add-on treatment technology, one must assume that the diversity and variance requirements will be substantially larger. The continuous need to assess variances would inundate the government with further data and information to manage.

Second, standard-setting would be never-ending. As new industrial processes are developed and old ones are modified, new BAT standards would have to be set. In addition, as more is learned about waste reduction, BAT may change and new waste reducing techniques may be identified and need to be incorporated.

Table 4.4.—information Needs for Different Waste Reduction Actions by the Federal Goverment

Possible government action	Information needed	Type(s)
Assessing the waste reduction problem, setting priorities, and choosing an option for action:	Will vary depending on depth of analysis, but may include:	
	reliable national waste generation data, preferably on a substance-specific and production/output basis;	W,P
	. reliable data on national waste reduction (or increases) to date;	W,P
	• Information on the amount of further waste reduction that might be technically possible in different industries nationally,	TIP
	. cost and ease of various waste reduction measures both for industry and for government,	E, T,P,W
	• degree of hazard of different types of wastes to aid in targeting actions; and	H
	• already existing government programs that encourage waste reduction	R
No immediate action:	Updated assessment information (above) so that changes can be monitored and for changes which may require action.	
Nonregulatory options:		
Technical Assistance and Education Program	Waste reduction techniques and opportunities in a wide variety of Industries.	T
	Implementation and success rates of waste reduction In companies assisted so can evaluate program and justify continued funding.	W.E
Economic Incentives Program (tax breaks, grants, low-interest loans)	Costs of waste reduction activlties.	E
	Implementation and waste reduction success of companies assisted so can evaluate program and justify continued funding	W,E
Regulatory Incentives (extended permit lives, expedited delisting of certain wastes for companies demonstrating true waste reduction)	Current regulations and the current regulatory climate.	R
	Actual waste reduction achieved v. any sacrifices made so that trade-offs can be justified.	W,H
Regulatory options:		
Mandatory waste reduction levels:		
1 Targeting wastes of concern	Waste stream contents and amounts	W
2, Setting appropriate levels for each industry	Waste reduction potential in each industry	T, P,E,W
3. Enforcement	Continual updates on all of the above information.	T, P,E,W
Increased mandatory reporting of waste reduction activities, for example, requiring • More detailed reporting of waste reduction plans in place • Reporting of hard data on wastes reduced • Reporting of waste reduction data on a production output basis	None However, it is Important that government know why it is requiring this reporting. If purpose is simply to force industry to collect this data so industry WI I I be more alert to waste reduct!on possibilities, then government need do little, but if the Purpose is also to comile some useful data on indust activities, the government must have some way of managing an enormous quantity of Incoming data so that It is accessible Current management systems would not be adequate	

KEY Type W Waste stream data.
Type P Production Information
Type E - Economic Information
Type T Technology Information
Type R – Regulatory informatlon.
Type H Health and enwronmental effects information

SOURCE Off Ice of Technology Assessment, 1986

Third, EPA would have to enforce these standards. Presumably, companies would be required to report waste generation figures—perhaps by process and/or substance and/or unit output—at regular intervals. Those figures, even at the grossest level of total volume generated per plant for most industrial plants in the country, would quickly swamp EPA. A massive inflow of information of this kind could not even begin to be managed with existing resources since EPA does not have the resources to manage the data it already receives and current compliance with regulatory programs of this type is low.

Mandatory Increased Information Collection

A milder regulatory option open to the Federal Government would be to increase mandatory reporting of waste reduction information, including, perhaps, more detailed waste reduction plans, but to set no enforceable standards or waste reduction targets for industries. This eliminates the need for standard-setting and enforcement but is still likely to produce a flood of information which government currently cannot manage. It is therefore important that before choosing this option, policy makers decide why they want more information and what they plan to do with it. The purpose may simply be to stimulate industry to be more alert to waste reduction possibilities. If so, government need not be very concerned about analyzing or using the information. Government may even decide not to require reporting but to require that industry have the information available for in-house scrutiny by EPA or State officials. (This is similar to the current waste minimization reporting requirements under RCRA.) If, on the other hand, government wishes to compile waste reduction information for its own use, government must create advanced new systems to collect and manage incoming data.

Nonregulatory Options

Nonregulatory options generally require much less information and make fewer demands on data management systems. The primary requirements are for data for planning and priority setting among these options, The government would probably want some information on significant obstacles to waste reduction and would want to know where companies most need assistance in reducing their waste before deciding what program(s) would be most effective. Similarly, government would probably also require information on the effectiveness of these programs after they are instituted in order to justify continued funding, As a practical matter, it is not necessary that either type of information be provided in great detail; government has made many decisions to authorize and continue funding programs based on limited data as to their effectiveness.

No New Major Action

In order to make a considered decision that government should take no major action, some amount of the planning and priority-setting information necessary for all other options would be needed.

CASE STUDIES: INFORMATION AVAILABLE ON TWO HAZARDOUS SUBSTANCES

To illustrate the information currently being collected on hazardous substances and its lack of usefulness for waste reduction efforts, OTA reviewed the information gathered on two hazardous substances—cadmium and trichloroethylene (TCE), Neither of these substances is representative of the universe of hazardous substances. Both were recognized decades ago as having potentially hazardous properties, and each has an extensive history of scrutiny under a wide variety of regulatory statutes. Much more information has therefore been generated about cadmium and TCE than about most other hazardous substances in industrial use today.

Cadmium and TCE were chosen, not only because there was a great deal of information about them, but also because they represent very different classes of hazardous substances with different lifecycles and industrial uses. Trichloroethylene is a liquid synthetic organic chemical used widely as a solvent. TCE is typical of synthetic organic chemicals: it is manufactured, it is used by the chemical industry to make other chemicals, it is widely used in other industries, and it can be destroyed by a variety of waste treatment processes or allowed to degrade in the environment.

In contrast, cadmium is an elemental metal. As such, it cannot be destroyed. Once dug up from the ground, typically as a component of zinc or copper ore, 100 percent of it must be disposed of in the environment. In addition to appearing in its pure metal form, cadmium is found as a component of hundreds of different chemicals, most of which share its toxic properties. Thus, when one refers to cadmium as a substance of environmental concern, usually both metallic cadmium and its compounds are being discussed, Cadmium and its compounds are generally easier to detect and quantify in waste streams and the environment than are most organic compounds, such as TCE.

For cadmium and TCE, the case studies examined the quantity and quality of information available to the Federal Government about:

1. public health and environmental hazards;
2. industrial uses that result in waste generation and possible waste-reducing approaches (e.g., substitutions);
3. extent of generation as a waste nationally and at individual industrial plants [including all types of emissions, releases, and discharges into the environment); and
4. regulation and the ways in which regulatory activities have affected its waste generation nationally.

Cadmium Case Study

Summary

Cadmium is an elemental metal long known to cause serious kidney, respiratory and cardiovascular effects. More recent evi ience from animal studies suggests that cadmium may also cause cancer.

Cadmium is mined only as a byproduct of other metals, usually zinc, but also copper and lead. It must be separated from these ores during processing; the total cadmium supply is heavily dependent on the production of these other materials. Because the supply of cadmium is determined by the demand for zinc, the price of cadmium is dependent only on its demand and can fluctuate widely. Ultimately, because an element cannot be destroyed, all cadmium mined eventually becomes waste: during mining and extraction, during manufacturing and industrial use, or after the disposal of cadmium-containing products.

Despite massive efforts, the national materials balance of cadmium is unknown because of the highly complex dispersion paths of the metal through the economy and into the environment. Different studies ascribe the major industrial sources of cadmium in the environment to: 1) mineral processing and use in various industrial applications (e. g., electroplating, battery manufacture); or 2) the burning of coal and other fuels containing traces of the metal.

Extremely imprecise estimates project that about half of cadmium wastes initially go to the air, about a quarter go directly to land, and another quarter are discharged into waste water streams, *6 Whatever the nature of the original discharge, cadmium rapidly binds to soils and sediments and then concentrates in biological materials, particularly leafy vegetables grown on contaminated soils. As a result, foods are the largest source of human exposure to cadmium.

Cadmium has a long history of regulation, but it is not clear what effect regulations hate had on the amount of cadmium used in industry and whether regulations have prompted cadmium waste reduction by industries. The opportunities for cadmium waste reduction are complicated by the fact that the total supply is so dependent on the production of other materials and that all of that supply must eventually become waste, Major cadmium legislation and regulations are presented in table 4-5.

Industrial Use of Cadmium[19]

Cadmium coatings are particularly useful in the electrical, electronic, automotive, and aerospace industries. Cadmium is also important in a number of other capacities. It is used in the negative plates of batteries. Cadmium pigments offer high-temperature stability, brilliant colors and high opacity, resistance to chemical attack and degradation by light, and good dispersion characteristics in plastics and paints. Cadmium compounds are also used as stabilizers in both flexible and rigid types of polyvinyl chloride to retard the degradation process caused by heat and light,

[18] JRB Associates, Inc., "Level 11 Materials Balance: Cadmium," draft contractor report prepared for EPA's Office of Pesticides and Toxic Substances, Survey and Analysis Division, Mar. 21, 1980.

[19] U.S. Department of the Interior, Bureau of Mines, *Mineral Facts and Problems,* 1985 edition.

Table 4-5.–Major Legislation and Regulations Pertaining to Cadmium (Cd)

Statute: Action(s) taken
Clean Air Act:
Intent to list Cd as a hazardous air pollutant published Nov. 16, 1985, based in part on EPA's conclusion that Cd is a probable human carcinogen. Decision to list will rely on pollution control techniques for Cd and further public health risk analysis.
Safe Drinking Water Act:
National Interim Primary Drinking Water Standards (N IPDWS) of 0.01 milligrams/liter set December 1975 was intended to include a fourfold safety factor to reduce the earliest manifestations of chronic Cd poisoning.
Clean Water Act:
Water quality criterion for Cd to protect human health is identical to NIPDWS, 0.01 mg/l; set Mar, 15, 1979.
Ocean dumping banned for all but trace amount of Cd (proposed Jan. 11, 1977, finalized Jan. 6, 1978),
"Reportable quantities" of cadmium acetate, cadmium bromide, cadmium chloride set at 100 lb in 1979. Discharge of more than the reportable quantity into navigable waters within a 24-hour period must be reported to National Response Center.
Cd and Cd compounds were specifically designated in list of 65 priority toxic pollutants or pollutant categories. Cd and Cd compounds are regulated for specified industrial point sources.
Applicants for NPDES permits in certain primary industrial categories with processes which discharge Cd or Cd compounds must report quantitative data on Cd discharge at each outfall.
Resource Consewation and Recovery Act (RCRA):
Solid waste classified as toxic hazardous waste, if passes toxicity test.
Wastewater treatment sludges from electroplating operations are designated as hazardous in part because of their Cd content.
Emission control dust/sludge from the primary production of steel in electric furnaces and from secondary lead smelting are regulated as hazardous in part because of their Cd content.
All of these designated hazardous wastes are subject to the "cradle-to-grave" manifest system that covers generators, transportation, storage, and disposal of such wastes.
Groundwater cannot be contaminated beyond the facility boundary at Cd levels in excess of 0.01 mg/1.
Oil containing more than 2 ppm Cd is restricted for burning.
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA):
Tax of $4.45/ton on manufacturers, producers, and importers of Cd.
Tax on receipt of waste containing Cd of $2.13/dry weight ton.
Reportable quantity of 1 lb for Cd and 100 lb for Cd acetate, Cd bromide, and Cd chloride released into the environment. Cd particles need not be reported if larger than 100 micrometers.
Occupational Safety and Health Act:
Average exposure limit of 0.1 mg/m^3 of Cd fume and 0.2 mg/m^3 of Cd dust; maximum exposures: 0.3 mg/m^3 and 0.6 mg/m^3 respectively.
Mine Safety and Health Act:
Maximum air concentrations of Cd established for different types of mining operations.
Federal Food, Drug, and Cosmetic Act:
Same standards as NIPDWS—O.01 mg/1.
Hazardous Materials Transportation Act:
Has established rules governing transport of cadmium acetate, cadmium bromide, and cadmium chloride.

SOURCE Office of Technology Assessment, 1986.

Substitutes for Cadmium*"

There are a number of possible substitutes for cadmium. For electroplating, zinc can be substituted for cadmium except for applications in alkaline environments or when the plate must be exceptionally thin. Aluminum platings have also been successfully substituted for cadmium platings in recent years. The best substitutes for cadmium in paints and pigments are other inorganic compounds, but they are often less brilliant in color and lack cadmium's stability, which is especially important in high-temperature molding of plastics.

Organotin compounds are the most efficient stabilizers known for polyvinyl chloride, but they are much more expensive than cadmium. Lead stabilizers are relatively cheap and effective, but they are also toxic. The lead-acid battery is the lowest cost substitute for cadmium batteries. They are easily recharged and have

[20]Ibid.

more capacity but are less dependable and have a shorter life than cadmium batteries.

Transport and Transformation in the Environment

There is less information on the environmental movements of cadmium waste than there is on its health effects. Because cadmium is a stable element and does not have a half-life for destruction, the amount of cadmium in the surface environment can only increase.

The metal and its compounds move through the environment in a variety of ways. Cadmium is first introduced into the surface environment during mining. The volatility of the metal allows release of cadmium vapors during thermal processes, such as ore roasting and smelting, as well as during incineration of wastes and combustion of fossil fuels. Cadmium vapor reacts with carbon dioxide, oxygen, or water vapor in the air to form cadmium carbonate, cadmium oxide, or cadmium hydroxide salts,[21] Atmospheric releases of cadmium eventually settle on lands and surface waters where they bind to soils and sediments.

In a recent report, EPA's Office of Water Regulations and Standards (OWRS) suggested that deposition through dispersion of atmospheric emissions can affect essentially all cropland, although the intensity of deposition is very low.[22] By contrast, since cadmium is known to accumulate in sewer sludge, land spreading of sludge can cause intense cadmium contamination in very small areas. OWRS estimates that as much as 400 metric tons per year (mt/yr) of cadmium may reach cropland topsoil via phosphate fertilizer,[23] as much as 140 mt/yr via emissions deposition, and as much as 70 mt/yr from sludge land spreading. Cadmium can also be eroded from crop topsoil and transported to streams and stream sediments; figures on quantities transported in this manner are presented by OWRS with some caution.

Data Used for Legislation and Regulations

In general, each regulation is supported by some amount of: 1) health effects data; 2) exposure data, often in the form of environmental release data; and 3] health risk assessment data, which is based on the first two.

One instructive example is EPA's notice of intent to list cadmium as a hazardous air pollutant under Section 112 of the Clean Air Act.[24] Although this action is only a notice of intent to regulate and thus can be based on less information than required for a full regulation, the type and amount of data on which this action is based is of interest because: 1] it is one of EPA's most recent actions involving cadmium and thus is based on the most current data; and 2) it is probably similar to the type, amount, and quality of data currently available to Congress or EPA if either were to take action on waste reduction for cadmium.

EPA makes clear in its intent to list notice that data on sources and levels of cadmium emissions are problematic:

> The present estimates of cadmium emissions are subject to several sources of uncertainty. These include a general lack of source-specific information that requires the use of simplifying assumptions (e. g., the use of average values for the cadmium content of fossil fuels, municipal waste, and sewage sludge). A second source of uncertainty concerns the levels and effectiveness of current emission controls. The EPA is aware that a number of the identified source categories are already reducing emissions of cadmium through equipment installed to control total suspended particulate matter and lead. There are questions concerning whether the control efficiency}' for cadmium emissions are equivalent/similar to the control efficiency for total particulate emissions.[25]

[21] U.S. Environmental Protection Agency, *Intermedia Priority Pollutant Guidance Document: Cadmium*, July 1982.

[22] U.S. Environmental Protection Agency, *Cadmium Contamination of the Environment: An Assessment of Nationwide Risk*, EPA-440/4-85-023 (Washington, DC: Office of Water Regulations and Standards, February 1985).

[23] Phosphate fertilizer is contaminated with cadmium because cadmium has a natural association with phosphate minerals. The degree to which phosphate rock is contaminated with cadmium depends on the origin of the phosphate, [U.S. Environmental Protection Agency, *Cadmium Contamination of the Environment: An Assessment of Nationwide Risk*, op cit, p. 25.

[24] 50 Federal Register 4200, Oct. 16, 1985. Specific documents relied on are listed in the Notice.

[25] 50 Federal Register 4200, Oct. 16, 1985.

EPA also noted that current source information is based on engineering estimates only. Before making a decision to list, EPA plans to improve its information by requesting data directly from source owners and making plant visits and source tests,

EPA also plans to request additional health effects data. EPA's 1981 Health Assesmient Document emphasized the long-recognized kidney dysfunction problems as cadmium's principal health effect, and ingestion, rather than inhalation, as the principal path of cadmium exposure.[26] Recent studies suggesting cadmium's potential carcinogenicity prompted EPA to review and revise this document and classify cadmium as a probable human carcinogen.

Public exposure information was based on dispersion modeling, which may affect the quality of the data. EPA's Human Exposure Model estimates the cancer risk from cadmium exposure by using location and emission characteristics of actual or representative sources, combined with census and meteorological data to estimate the magnitude and distribution of population exposure. EPA notes that there are a number of assumptions underlying these estimates that can yield either over or under estimates of the risk posed by cadmium. These include estimating the carcinogenic potency of a substance through the use of a mathematical model for extrapolating high-dose worker or animal studies to the much lower concentrations present in the ambient air. EPA plans to improve these estimates before proceeding further with its listing procedures.

Despite the fact that EPA relied mostly on 1985 or updated data in its deliberations about whether to list cadmium as a hazardous air pollutant, it is clear from this brief overview that:

EPA concluded that in most areas it had insufficient data, especially concerning sources of cadmium emissions, to promulgate a regulation at this time.

- Most of the data EPA uses and plans to collect to support this regulation are on health effects and public exposure, both of which are only peripherally related to waste reduction. The emissions data component of the exposure information, the most relevant to waste reduction because it is plant-specific, is the area in which EPA's data was the weakest.
- Much of the information EPA plans to collect will be sampling data to support modeling of exposure and dispersion. Such information will be only marginally relevant to waste reduction.

National Materials Balance

Several attempts have been made to conduct a national materials balance for cadmium. The most extensive effort, conducted in 1980,[27] shows as much about the difficulties involved in this massive effort as it shows about the amounts of cadmium and its movements through the country.

The study was ambitious, It took a year, cost $225,000, and attempted a Level II materials balance, which involves searching the published literature thoroughly and contacting trade associations, other agencies, and industry for unpublished information. A Level I materials balance would have entailed only a survey of readily available information, with many assumptions to account for gaps in information. A Level III balance would have collected new data from site visits and monitoring to fill in gaps in the Level 11 balance so that its results be would statistically valid,

The report has never progressed beyond draft form, in part because EPA's Office of Toxic Substances decided not to pursue regulation of cadmium, eliminating the reason for the materials balance, Further, EPA had strong reservations about some of the assumptions and estimates.[28] One reason for commissioning a Level II mass balance was that EPA hoped to

[26] U. S. Environmental protection Agency, *Health Assessment Document for Cadmium*, EPA-600/81 -023, May 1981.

[27] JRB Associates, Inc., op. cit.

[28] Mike Callahan, Acting Director, Exposure Assessment Group, Office of Research and Development, U.S. Environmental Protection Agency, personal communication, June 10, 1986.

eliminate some of the significant uncertainties in Level I mass balance calculations. Unfortunately, the dispersion pathways for cadmium are so complex that the contractor could do little but guess at estimates of cadmium quantities in particular sinks and at how imprecise their estimates might be. EPA's concern was that these estimates, although probably as reliable as the others, were not of Level II certainty.[29]

A study on cadmium in 1985[30] points to fossil fuel emissions as a much larger source of cadmium air emissions than ore refining which was identified in the earlier study as the major source. Another study supports the importance of fossil fuels as sources of atmospheric cadmium.[31] Discrepancies among the various materials balances are large, often by orders of magnitude, and often sources of release which appear to be significant in one study are not even listed in another. These areas of disagreement cast doubt on the accuracy of these materials balance studies and call into question the possibility of conducting a reliable national materials balance on cadmium,

One problem encountered in all cadmium materials balances is that cadmium dispersal is highly complex, both in relation to production and to use. Cadmium, a minor constituent in zinc, copper, and lead ore, is not entirely removed by refining, Thus, some cadmium is carried with its companion metals through their lifecycles. A significant fractions of cadmium in use is associated with galvanized zinc, in which it is found as an impurity. Similarly, about a quarter of all cadmium sent to waste disposal facilities comes from phosphorus production, where cadmium is an impurity in the phosphorous mineral. Thus, data on the lifecycles of these other substances may be necessary for a complete understanding of the cadmium materials balance.

[29] This is not to say that a Level I I materials balance is impossihle. JRB also did a Level II materials balance for benzene which EPA considers to be more reliable. [Callahan, op.c t.]

[30] U.S. Environmental Protection Agency, *Cadmium Conta17?i-nation of the Environment: An Assesment of Nationwide Risk*, op. c it,

[31] GCA Corp., *Survey of Cadmium Emission Sources*, EPA-450/3-81-01 3, contractor report prepared for EPA's office of Air Quality Planning and Standards, September 1981.

[32] Between 25 and 33 percent, according to the JRB study.

Another difficult y is the variation in cadmium content of fossil fuels, which account for a significant fraction of air emissions. The cadmium content of coal or petroleum products varies from reserve to reserve, from seam to seam, and even within seams.

Plant, Company, and Industry-Level Information

OTA attempted to find sample plant-level information on cadmium wastes, input, or product outputs but was unsuccessful. EPA's document, Sources *of Atmospheric Cadmium*, which did not examine plants but instead relied on references and models, concluded that: "very little information could be found about individual plants which manufacture products containing cadmium,[33]

Trichloroethylene Case Study

Summary

Trichloroethylene (TCE) is a volatile organic compound (VOC) known for decades to be toxic to the liver and nervous system. More recently there has been evidence suggesting its carcinogenicity.

Trichloroethylene is an inexpensive but effective solvent commonly used in decreasing operations of many kinds, particularly for metals, plastics, and textiles, It is also used as a stabilizer in the manufacture of polyvinyl chloride. TCE is produced at only two plants in the United States and is used as a chemical intermediary at about a dozen other plants. However, over 90 percent of all emissions into the environment are estimated to come from the tens of thousands of different industrial decreasing operations all around the country. Only a few tenths of 1 percent of ail emissions are emitted during TCE production,

Because of its volatility, most TCE eventually finds its way into the air, Even TCE initially discharged into water or land will, in large part, volatilize. Estimates are that more than 85 percent of TCE is discharged into the atmosphere, where it is expected to degrade with a

[33] U.S. Environmental Protection" Agency, *Sources of Atmospheric Cadmium*, EPA-45015-79-006, August 1979.

half-life of between 24 and 48 hours. Inhalation is by far the most common form of human exposure.

Trichloroethylene has a long history of regulation which may, in part, account for its rapidly declining use in industry. While this decline has obviously been accompanied by a decline in TCE wastes generated, the overall result may not be a decline in the amount of hazardous waste, since the principal substitutes for TCE have been other hazardous materials—methyl chloroform for metal decreasing and methyl chloroform and perchloroethylene for textile scouring. While these substitute materials are considered under current regulations to pose less risk to workers, when discharged into the environment they are known to be hazardous, although their effects are not well understood.

One interesting feature of TCE regulation is that it has been focused largely on TCE discharges into water, which are estimated to account for only 12 percent of TCE wastes. EPA is only now beginning to undertake regulation of TCE air emissions, which account for approximately 85 percent of TCE wastes. Major TCE legislation and regulations are presented in table 4-6.

Hazardous Characteristics and Health Effects[34]

TCE has been known since the early part of this century to have a wide variety of effects on the human nervous system including: headache, dizziness, vertigo, tremors, nausea, sleepiness, fatigue, lightheadedness, unconsciousness, and in some cases, death. Death related to TCE exposure is believed to result from cardiac arrest.

Recently TCE has been the subject of an active debate over its carcinogenic potential. After reviewing the evidence, EPA has concluded that sufficient evidence exists to warrant classifying TCE as a probable human carcinogen.

Industrial Use of TCE

Trichloroethylene is one of the most versatile and least expensive solvents used for degreasing—primarily for metals but also for plastic, glass, and textiles.ss

In addition to being a solvent, TCE is used in the production of polyvinyl chloride, fungicides, adhesives, and cleaning fluids.[36]

Substitutes for TCE

Market factors, such as increased replacement of metals with plastics, as well as environmental and health concerns, have prompted substitution of methyl chloroform (l,l,l-trichloroethane) and other solvents for TCE, As a result, production and use of TCE have decreased since production peaked in 1970 at 277,000 metric tons per year (ret/y r). Production has been estimated at 146,000 mt/yr for 1978, 81,000 mt/yr for 1982, and 65,700 mt/yr for 1983.[37] A Level I Materials Balance for TCE, published in 1980, reported that TCE had already been widely replaced by methyl chloroform in the metal cleaning industry and by methyl chloroform and perchloroethylene in the textiles industry.[38]

Transport and Transformation in the Environment

There is less information on the environmental characteristics of this chemical than on its health effects. Most of the information must be pieced together from very disparate sources, and models tend to be used heavily where data is absent,

Volatilization is the major process by which TCE is removed from surface water. The half-

[34]J. Doull, C.D. Klaasen, and M.O. Amdur, *Casarett and Doull's Toxicology* (New York: MacMillan Publishing Co., Inc., 1980). Also, U.S. Environmental Protection Agency, *Health Assessment Document for Trichloroethylene*, EPA/600 /8-82 /006F, July 1985. Also, Chemical Effects Information Task Force, Oak Ridge National Laboratory, *Trichloroethylene Health Effects*, Sept. 26, 1985.

[35]Arthur D. Little, Inc., and Acruex Corp., "An Exposure and Risk Assessment for Trichloroethylene, " final draft, March 1981, revised October 1981, p. 3-16.

"31 bid., p. 3-24.

[37]J.J. Vandenberg, *Trichloroethylene Exposure and Cancer Risk Analysis*, Oct. 11, 1985.

[38]JRB Associates, Inc., "Level I Materials Balance: Trichloroethylene," draft interim contractor report prepared for EPA's Office of Pesticides and Toxic Substances, Survey and Analysis Division, April 1980.

Table 4.6.–Major Legislation and Regulations Pertaining to Trichloroethylene (TCE)

Statute:	Action(s) taken
Clean Air Act:	Intent to list TCE as a hazardous air pollutant published Dec. 23, 1985, based in part on EPA's conclusion that TCE is a probable human carcinogen. Decision to list will rely on possibilities for pollution control techniques and further public health risk analysis.
	Standards of Performance, promulgated Oct. 18, 1983, for new stationary sources covers producers of TCE as an intermediate or final product.
	Required reporting of TCE emissions, emission levels, emission control techniques, production volumes, sales and purchase data for 15 plants known to produce (directly or as a byproduct) or use TCE under Section 114 for EPA's recent report, '(Survey of Trichloroethylene Emission Sources. "
Safe Drinking Water Act:	EPA promulgated a Recommended Maximum Containment Level (RMCL) for TCE of zero (Nov. 13, 1985) because of the Agency's conclusion that TCE is a probable human carcinogen. RMCLS are nonenforceable. At the same time EPA proposed a Maximum Containment Level (M CL) of 0.005 mg/1 for TCE in drinking water. MCLS are enforceable and are set as close to RMCLS as feasible, given technologies and costs.
	TCE is regulated as a hazardous waste under the Underground Injection Control Program.
Clean Water Act:	"Reportable quantity" of TCE set at 1,000 Ibs in 1979. Any discharge into navigable waters in excess of the reportable quantity in a 24-hour period must be reported to the National Response Center.
	NPDES permit applicants in specific industrial categories must provide quantitative data on TCE discharge from each outfall and must meet the standards set under the various industrial point source categories.
	TCE was specifically designated as 1 of 65 priority toxic pollutants or pollutant categories. TCE is therefore regulated for a number of specified industrial point source categories.
Resource Conservation and Recovery Act (RCRA):	RCRA specifies that any solid waste containing TCE is a hazardous waste. In addition, TCE is considered hazardous under RCRA as spent halogenated solvent (FOO1, FO02).
	Hazardous wastes under RCRA are subject to the "cradle-to-grave" manifest system that covers generators, transportation, storage, and disposal of such wastes.
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA):	Reportable quantity of 1,000 Ibs (same as Clean Water) constitutes a hazardous spill.
Occupational Safety and Health Act:	Average exposure limit, set June 27, 1974, is 100 ppm, with an acceptable maximum of 200 ppm.
Federal Food, Drug, and Cosmetic Act:	Establishes tolerances for residues of TCE in certain foods as a result of its use as a solvent in their manufacture.
Hazardous Materials Transportation Act:	Has established rules governing transportation of hazardous materials, including TCE.

SOURCE Off Ice of Technology Assessment, 1986

life of TCE in surface water is estimated to be a few hours to a few days, depending on the characteristics of the body of water, TCE is also known to volatilize from soil; rate estimates are imprecise but suggest that volatilization from soil occurs at about an order of magnitude than volatilization from water at a similar depth.[39] The fate of TCE is usually destruction by photo-oxidation following direct emission to air or volatilization from water or soil. The half-life for this process is estimated to be 24 to 48 hours.

Although TCE was not thought to undergo any other significant breakdown reactions, it is now thought that TCE trapped in groundwater does degrade, with a half-life of about a year. EPA recently concluded that available data supports the hypothesis that the major source of groundwater contamination by vinyl chloride, 1,2-dichloroethylene, and 1,l-dichloroethylene is the decomposition of TCE and tetrachloroethylene.[40] Since TCE is widely released in the environment, EPA also expects its degradation products to have a wide occurrence. TCE is the most common hazardous substance at Superfund sites.[41]

[39] Arthur D. Little, Inc., and Acruex Corp., op. cit.

[40] 50 Federal Register *46880*, Nov. 13, *1985*.

[41] U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, "Supporting Analysis for CERCLA Section 301(a)(1)(c) Study," draft report, Task No. 7, EPA contract 68-01-6872, July 1984, Exhibit 1, p. 3-5.

Data Used for Legislation and Regulations

In general, regulatory action is supported by some amount of: 1) health effects data; 2) exposure data, often in the form of environmental release data; and 3) health risk assessment data, which is based on the first two.

EPA's most recent action regarding TCE was its notice of intent to list it as a hazardous air pollutant under Section 112 of the Clean Air Act.[42] Although this action can be based on less information than that required for a full regulation, the type and amount of data on which this action is based is of interest because: 1) it is one of EPA's most recent actions involving TCE and thus is based on the most current data; and 2) it is probably similar to the type, amount, and quality of data currently available to Congress or EPA if either were to take action on waste reduction for TCE.

Most of the data used by EPA were health effects data, however, the notice makes it clear that EPA felt much of the information about carcinogenic effects of TCE on humans was unreliable. It considered only two studies with animals to be sufficiently valid to provide a basis for classifying TCE as a probable human carcinogen,

EPA's TCE exposure and cancer risk analysis used EPA's Human Exposure model to estimate public exposure to TCE from TCE source categories described in EPA's Survey *of Trichloroethylene Emissions Sources.* However, EPA admits that the source and environmental release information used in the risk estimates is very rough and plans to improve these data before proceeding further with the listing procedures.

Despite the fact that EPA relied on very recent data in its deliberations about whether to list TCE as a hazardous air pollutant, it is clear from this brief overview that:

- EPA concluded that in most areas it had insufficient data to promulgate a regulation at this time.
- Most of the data EPA uses and plans to collect to support this regulation are health effects and public exposure data, both of which are only peripherally related to waste reduction.
- Much of the information EPA plans to collect will be sampling data to support modeling of exposure and dispersion. Such information will be only marginally relevant to waste reduction.

National Materials Balance

There were two early separate attempts at a materials balance for TC E[43] Both of these are rather old now; they used 1977-78 data. The Level I materials balance draws on a wide variety of readily available public documents and personal communications with producers and users of TCE.[44] More recent data (1983-84) have been collected in other studies, but these are less comprehensive and do not specifically attempt a materials balance.

One of the most useful sources of information compiled about TCE is EPA's *Survey of Trichloroethylene Emissions Sources* (STES) .45 To supplement background information available in public documents and other published literature, EPA used its authority under Section 114 of the Clean Air Act to request data on TCE sources, production/sales, emissions, and emissions control techniques from the two identified producers of TCE and 13 of the 16 identified producers or users of TCE as a byproduct in operations.

There are a number of limitations on these data. First, companies were asked only to provide *estimates* of these figures, not to measure emissions. Emissions from equipment leaks and storage tanks, for example, were calculated using modeling equations. Second, and more

[42] 50 Federal Register 52422, Dec. *23,* 1985, amended at 51 Federal Register 7714, Mar. 5, 1986. Specific documents relied on are listed in the Notice.

[43] JRB Associates, Inc., "Level I Materials Balance: Trichloroethylene, " op. cit. Also, JRB Associates, Inc., "Materials Balance—Task #14: Chlorinated Solvents, " final draft contractor report prepared for EPA's Office of Pesticides and Toxic Substances, Survey and Analysis Division, July 11, 1980.

[44] Compare this with the Level II materials balance attempted for cadmium which was much more ambitious in scope.

[45] U.S. Environmental protection Agency, *Survey of Trichloroethylene Emissions Sources, EPA-450/3-85-021* (Washington, DC: Office of Air Quality Planning and Standards, July 1985).

important, the 15 plants from which EPA was able to gather plant-specific data only' account for approximately 128 metric tons of the estimated 57,600 metric tons of TC E emitted in 1983.48 EPA was unable to gather data from specific sites for metal decreasing operations for the STES report. These are estimated to account for 85 percent of TCE use and about 91 percent of' total TCE emissions. An attempt was made to compensate for this enormous gap using gross estimates of the amount of TCE emitted in five industries that use TCE in decreasing operations [47] These estimates were obtained by applying emissions factors generated from available literature to 1983 consumption data for each of the fiv'e industries.[48]

EPA has published estimates of the distribution of TCE emissions in environmental media shown in table 4-7. Although TCE emissions can be controlled through carbon traps and/or condensers, almost all TCE in use is eventually emitted into the air because recycled solvent is reused and landfilled still bottoms lose residual TCE \'ia volatilization.

[46]See table 4-7, below

[47]These five industries are: furniture and fixtures, fabricated metal products, electrical and electronic equipment, transportation equipment, and miscellaneous manufacturing industries.

[48]EPA estimated that for every kilogram of fresh TCE used in degreasing, 94 percent is directly volatilized during the degreasing process.

Table 4-7.— Release of TCE Into the Environment (metric tons per year for 1978)

Source	Alr	Land	Water
Production ., .,	300-		40
Metal decreasing	92,400	12,800	2,200
Other solvent uses	11,400	*1,600*	270
PVC chain terminator.	130	—	—
Total	104.230	14.400	2.510
Percent of total .	(86%)	(12°/0)	' (20/0)

SOURCE U S Environ mental Protect Ion Agency *IntermediaPriority Pollutant Guidance Document Chlorinated Solvents* July 1962 revised October 1984

Plant, Company, and Industry-Level Information

OTA was able to find some small amount of plant level data on TCE for the 15 producers and users surveyed by EPA under Section 114 (see above), although the production/sales data for these plants were confidential. In addition, a materials balance for TCE in the electronics industry has been done, But less than 1 percent of the total use of TCE is accounted for in the electronics industry' which has now' turned to TCE substitutes in most cases for occupational safety reasons.[49]

[49]PEI Associates, Inc., "Occupational Exposure and Environmental Release Assessment of Four Chlorinated Solvents When Used in the Electronics Industry," draft contractor report prepared for the U.S. Environmental Protection Agency, Jan. 10, 1985.