Nonnuclear Industrial Hazardous Waste: Classifying for Hazard Management

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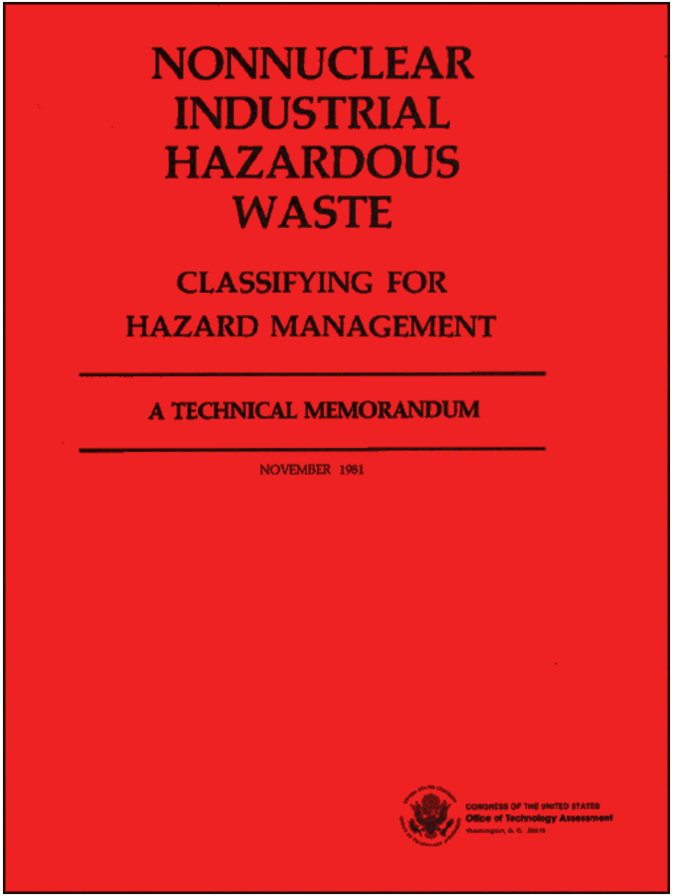

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Preface

The Office of Technology Assessment is currently conducting an assessment on nonnuclear industrial hazardous waste at the request of the House Committee on Energy and Commerce. Its Chairman, Rep. John D. Dingell, asked OTA for a preliminary report on hazard classification because this critical issue, one of several being studied in the OTA project, will likely be addressed this fall.

This technical memorandum addresses the following topics:

- basic issues surrounding a degree-of-hazard classification approach;
- the potential for incorporating a degree-of-hazard concept through classification in current regulations of the Resource Conservation and Recovery Act (RCRA);
- various ‘methods for applying a degree-of-hazard classification system; and
- some questions to be addressed in making the decision whether or not to select and incorporate a degree-of-hazard classification system at the Federal and State level.

OTA’s analysis to date finds that a well-designed degree-of-hazard classification system might provide a strategy for cost-effective management of nonnuclear industrial hazardous waste, However, it would be important to choose several degrees of hazardousness and not to exclude types of waste, such as those generated in relatively small quantities and some chemicals with known chronic (long-term) toxicity, without making assessments of the levels of hazard they pose to the public.

While a regulatory system based on degree-of-hazard classification may appear reasonable and cost effective, it should not be regarded as a panacea for the critical national problem posed by industrial waste. Moreover, it is not necessarily a radical departure from existing regulations. No change in RCRA would be needed, and a quantitative hazard classification scheme could be incorporated incrementally into various segments of the current program. Hazard classification, based on scientific data for waste, management technologies and sites, should be viewed as an evolutionary rather than revolutionary development for industrial waste management and regulation.

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Summary

The management, or in some cases mismanagement, of industrial waste present various levels of hazard to the public. Nonnuclear industrial waste range from being relatively harmless to being so extremely hazardous that the waste must be totally isolated from humans and the environment, destroyed or permanently detoxified. In developing regulations to implement the Resource Conservation and Recovery Act of 1976 (RCRA), the Environmental protection Agency (EPA) chose not to classify waste beyond a designation of hazardous or nonhazardous. Moreover, EPA has excluded types of waste, such as those generated in relatively small quantities and some chemicals with known chronic (long-term) toxicity, without making assessments of the levels of hazard they present to the public. The Office of Technology Assessment finds that a well-designed degree-of-hazard classification system might provide a strategy for cost-effective management of nonnuclear industrial waste. A quantitative classification system incorporating the degree-of-hazard concept is possible because the following two conditions are met:

- particular waste, management programs, and sites have important shared characteristics; and
- scientific criteria and data that describe hazards are either available or can be, in principle, obtained.

Alternatively, a qualitative degree-of-hazard approach without specific categories requires less effort to develop criteria and data, and its apparent simplicity may be attractive from a programmatic perspective. In the long term, such an approach could prove to be inefficient, since scientific information appropriate for classification may be needed in the future. In addition, much of the information obtained in a qualitative approach on a case-by-case basis often is not fully used, may be unnecessary, and often is not appropriate for classification.

The present state of knowledge, however, does not lead to an easy endorsement or condemnation of the use of a hazard classification system for implementing the mandates of RCRA. While a system based on degree of hazard may appear reasonable and cost effective, degree-of-hazard classification should not be regarded as a panacea for the national problem posed by disposal of nonnuclear industrial hazardous waste. Moreover, it is not necessarily a radical departure from existing regulations. Classification by hazard could be incorporated incrementally into various segments of the current program. Hazard classification should be viewed as an evolutionary rather than revolutionary development for industrial waste management.

The objectives of a classification system are twofold:

- to identify with greater certainty industrial waste that pose the most severe threats to human health and environment; and
- to allow development of management strategies that reflect the differences in potential hazards of industrial waste.

Waste classification methods include technical criteria based on waste characteristics, rank-ordering based on results of specified tests, grouping by particularly important characteristics (multiple discriminatory factors), and ordering the potential of facilities to contain or destroy the waste. Because of incomplete information and data about industrial waste streams, none of these methods can be implemented without first developing scientifically based criteria that reflect both real world exposures and intrinsic properties of waste. Although much of the preliminary investigative effort required to develop a degree-of-hazard classification system has been initiated in compliance with other environmental regulations, further evaluation of all schemes is needed.

The benefits of using degree-of-hazard classification in regulating industrial waste include concentration of regulatory action on waste that pose the greatest hazards; a more effective allocation of the resources of generators, disposers, and government; a means to establish

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priorities for reduction of the waste stream by changing manufacturing processes, end product substitution or recycling of waste; a means to increase the public's knowledge about the variation in hazard posed by industrial waste; and finally a means to assure that the intent of RCRA is achieved.

A number of questions, however, require examination. There is concern about the costs to EPA for developing a classification system, and also the cost to society for time that might be lost during a transitional period in implementation of RCRA. Uncertainties surround availability of appropriate data, the ability to establish scientifically based criteria, and increased complexity of regulations. Finally, the costs that result both from developing a degree-of-hazard system and from not designing a classification approach need to be determined.

Background

The concept of degree of hazard is receiving increased attention as discussion of the current system for regulating nonnuclear industrial hazardous waste (NIHW) continues. For example, it has been reported that the Executive Office of Management and Budget has requested the Environmental Protection Agency (EPA) to conduct a review of the Resource Conservation and Recovery Act (RCRA) regulations; this review may include a study of the potential for incorporating references to the degree of hazard of various waste. (1) Moreover, the House Committee on Science and Technology has identified classification of hazardous waste as a major issue.(2)

> There appears to be no question among those who deal with the issue that there are differing degrees of hazard and that different means of handling treatment disposal are warranted. The problem is in applying degrees of hazard to specific wastes. Both economically and from an environmental and health standpoint, the issue is legitimate,

Because of the complexity of industrial waste, it does not seem appropriate, however, to reference or consider degree of hazard without understanding the meaning of the concept, the necessity of establishing technical criteria for classifying waste, and the problems surrounding implementation of a classification system in Federal and subsequent State hazardous waste regulations. A discussion of each area is presented in this document.

As part of a comprehensive, ongoing assessment of nonnuclear industrial waste, OTA is studying the potential application of a degree-of-*hazard* concept to regulatory policies. For the purposes of this report, degree of hazard reflects the relative level of particular characteristics selected by EPA for defining a hazardous waste (i.e., toxicity, ignitability, corrosivity, and reactivity). Risk *assessment*, in contrast, estimates the probability of adverse impacts resulting from a hazard during particular exposure conditions. Risk *analysis* estimates the social and economic costs that would result from a particular level of risk. This document is limited to a discussion of a degree-of-hazard system as a means to reduce risks posed by management of NIHW.

The first phase of the OTA study is a review of the methodology that might be adapted for use in classifying and managing industrial waste. Subsequent phases will explore unresolved questions that have been raised at this stage of the assessment and will analyze further the feasibility of implementing a degree-of-hazard concept within the current regulatory structure. As a means of providing a basis for understanding the concept and potential benefits as well as anticipated problems, this paper discusses the following:

- basic issues surrounding a degree-of-hazard classification approach;
- the potential for incorporating a degree-of-hazard concept through classification in current regulations;
- various methods for applying a degree-of-hazard classification system; and
- some questions to be addressed before the decision whether or not to select and incorporate a degree-of-hazard classification system at the Federal and State level can be made.

RCRA was enacted, in part, to regulate the management of hazardous waste.(3) Regulation of NIHW, however, is a complex problem. The types of waste that must be regulated consist of discarded byproducts from industrial production processes and residues created by commercial use of industrial compounds. These include, for example, wastewater sludges from a variety of processes, organic chemical residues, spent-plating bath solutions from electroplating processes, and emission-control dust/sludges from secondary lead smelting, The chemical, physical, and toxicological properties of these NIHW are quite diverse and produce effects on human health and the environment that vary in character and severity. Because industrial waste generally comprise mixtures of compounds, often there is uncertainty surrounding the specificity of cause and effect relationships between the presence of a hazardous waste and a perceived adverse impact. This diversity (in types of waste, their properties and effects) and lack of certainty present a challenge for designers and enforcers of Federal environmental policies to find a regulatory structure that is cost effective, capable of being implemented on a national level, and compatible with the variety of NIHW being generated as well as the diversity of environmental conditions.

The legislative history of RCRA suggests that Congress was aware of the complex nature of NIHW and was concerned with appropriate ways to identify waste that present the most hazard to human health and the environment. Preliminary discussions centered on such issues as volumes of the waste being considered and the certainty, or lack thereof, of identifying adverse effects. For example, the following observation was made in a congressional committee report .(4)

> The Committee anticipates the identification of two basic types of substances: those which are hazardous in their elemental and most common form, regardless of concentration, and those which when present in sufficient concentration or when mixed with other substances constitute hazardous waste. The criteria for identification of these substances should make such a distinction based on the danger to human health and the environment. The listing of any substances not found to be hazardous per se should be accompanied by an explanation as to when such waste are considered hazardous.

Some members of Congress suggested that the act should make reference to regulating NIHW according to the extent to which waste pose a health or environmental threat. In subsequent discussions on amendments to the act however, Sen. Jennings Randolph, one of the key sponsors of RCRA, maintained:

> . . . that flexibility can be accomplished within the current agency consideration of the proposed regulations and the comments received in a manner consistent with the statute.(5)

The final act neither requires nor precludes the development of a regulatory system based on classifying NIHW by the potential to cause harm if managed improperly.(6)

In developing regulations to implement the RCRA mandate, EPA chose not to classify waste beyond a designation of hazardous or nonhazardous. The Agency's position was taken for two reasons.(6)

> The Agency does not believe that any of the degree-of-hazard systems suggested by commentors (or any the Agency could itself conceive) are capable of actually distinquishing different degrees of hazard among the myriad hazardous wastes and also reasonably relating management standards to these degrees in a technically and legally defensible way. . . (and) believes that the final regulations already achieve the objectives of a degree-of-hazard system; thus such a potentially complex and challengeable system is unnecessary.

Comments received by EPA on the December 1978 publication of the first set of proposed regulations, however, suggest that regulating NIHW according to degrees of hazard could be a cost-effective strategy.(7) Several arguments for this type of system have been presented.(8) First, the use of a degree-of-hazard approach concentrates regulatory action on waste that exhibit a high level of hazard and have the greatest probability for exposure to humans and other organisms. A degree-of-hazard system could prevent excessive regulation of waste shown to present either a low hazard potential or a low probability of exposure. Moreover, although there is general recognition of the need to reduce waste generation at the source, through such measures as process or end-product change, without some classification of waste it is difficult to establish appropriate priorities and goals for waste reduction.

Second, the volume of waste to be handled by procedures outlined in the regulations is anticipated to be quite large; EPA estimated that NIHW generated in 1980 could range from 28 million to 56 million metric tons with annual increases of 3.5 percent expected .(9,10) A system of classifying waste by degree of hazard could facilitate effective management programs by concentrating limited resources of generators, disposers, and government on those materials of greatest concern. For example, there are a limited number of appropriate sites where waste can be disposed safely in land (i. e., with minimal contamination of surface or ground water). Given this limited availability, it is suggested that a management policy should be developed whereby the most hazardous waste are destroyed, detoxified, or as a last option sent to the most secure land disposal sites, and the less hazardous materials are assigned to sites requiring fewer controls and lower management costs. Analyses and forecasts of landfill capacities on a National, State, or regional basis are likely to be made more accurate and useful if hazard classification becomes used.

Finally, a degree-of-hazard approach to waste management could be used to direct educational efforts toward increasing the public's understanding of those properties of waste and environmental conditions that contribute to contamination problems. While the public has become increasingly aware of dangers associated with disposal of NIHW, this awareness has been accompanied by misunderstandings about the diversity of hazards posed by different types of materials. This lack of understanding is due in part to limited access by the public to the available information about the expected threats to health or the environment. As the public becomes more knowledgeable about differences in hazard posed by the variety of NIHW, greater acceptance of waste treatment or disposal sites might result for low-hazard waste sites and for high-hazard waste sites that reflect the most appropriate and safe management. It can be argued, however, that as the public learns more about specific waste and dangers they pose, developing a necessary consensus on siting could be delayed.

More recently, some concern has been expressed that the current regulations of EPA could eventually undermine the intent of RCRA by allowing some potentially hazardous waste to escape regulation.(n) For example, it has been suggested that the listing mechanism for identifying hazardous waste reduces the efficacy of the act. The current EPA list is considered by some to be deficient with initial exclusions of many hazardous materials and the potential to remove identified hazardous waste from the list. Because of a failure to establish clear criteria, certain types of exclusions in current regulations could reduce the effectiveness of RCRA, particularly in the long term. These exclusions include small generator exemptions, materials covered under other environmental regulations (e. g., Clean Water Act), specific exemptions of materials through the delisting-petition process, and the potential to designate a hazardous materiaI for recycling purposes and therefore removing it from regulatory control.

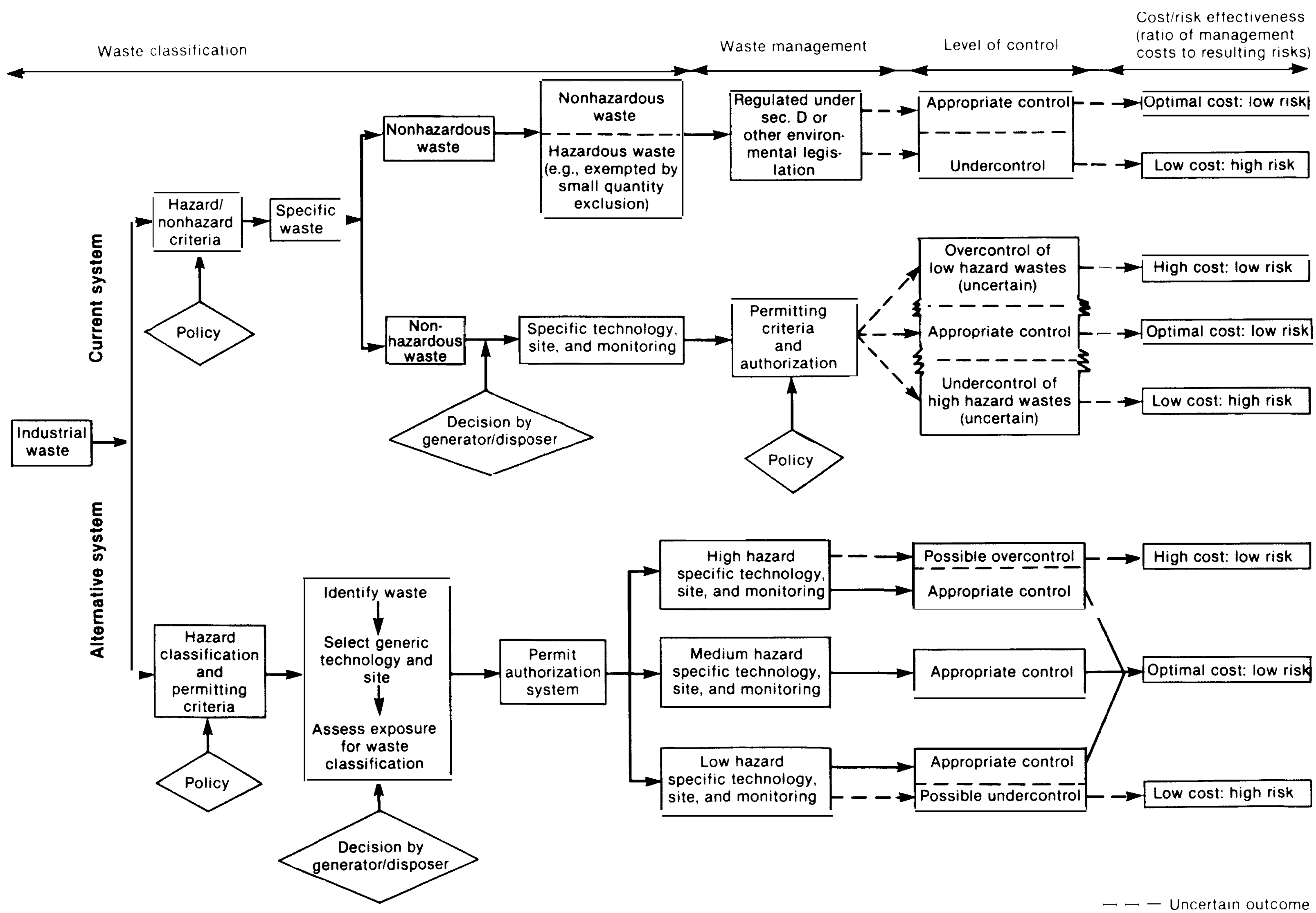
Arguments can be made that it would be more prudent to provide an all-inclusive regulatory policy with established criteria rather than one which allows a variety of exclusions. For example, the policy might be to classify all industrial waste and not to exclude any from some level of regulation (i. e., using permit by rule for less or nonhazardous waste). An aura of uncertainty is created when the potential exists at some future time to relist waste currently exempted and delist waste currently included. A degree-of-hazard approach based on classifying and regulating all industrial waste could facilitate private sector investment decisions for waste management facilities by providing a more certain regulatory environment and could shift the current regulatory emphasis from the legal to more technological arenas.

The format for applying a degree-of-hazard classification system, however, would have to be designed carefully. A very complex system might be unworkable and unmanageable. A system using three to four broad classes of hazard (e.g. high, medium, low, and nonhazardous) with specific criteria for each could provide a reasonable regulatory framework. Such a system could include the disposition of all industrial waste including small quantities, specific less-hazardous waste with their related liability needs, material covered under other regulations, and waste designated for recycle or reuse.

Included in the comments on the 1978 proposed regulations were several proposals for classifying both waste and management facilities by the degree of hazard posed to human health or the environment. After review of these systems, EPA determined that a satisfactory classification scheme could not be readily developed nor implemented within the time period mandated by Congress. EPA was under a court-ordered schedule to develop Federal regulations. EPA was already late in meeting the schedule and pressed to develop a program quickly. EPA felt that the objectives of a classification system could be met just as efficiently through a phased approach in promulgating regulations. For example, the initial list of NIHW included those which EPA considered to pose the highest risk and for which the most information on health and environmental impacts was available. EPA intended to add other waste to the list over time. In addition, the first set of proposed regulations included exclusion levels for small quantities of waste, a variance procedure allowing disposers to demonstrate that the level of required insurance was not consistent with the degree of risks associated with their facility, and pe itioning procedures for requesting lower levels of insurance. Also, in this first phase of regu a tory development, EPA stated the intent to tailor management requirements reflecting differences in potential hazards of NIHW as well as differences in environmental conditions surrounding the facility site.

A comparison of the current regulatory system with a proposed degree-of-hazard alternative approach is illustrated in figure 1. The current system could lead to a situation of some over-regulation of low-hazard waste and some under-regulation of highly hazardous waste, i.e., if the final management standards do not reflect stringent controls. This could result in an imbalance in the ratio of management costs and the level of risk that results from the management choice. Instead of optimal management costs and potentially low levels of resulting risk, the consequences are uncertain (dotted lines) and could be either high management cost for low-risk waste or low management costs with potentially high levels of risk resulting from the management choice. Assuming that classification criteria can be developed that will correctly distinguish degrees of hazard (such an assumption cannot yet be made with certainty), the alternative approach has the potential for reducing uncertainty and providing a more appropriate balance between management costs and the expected level of risk resulting from the management choice.

Figure 1.—Information and Decision Flow for Current and Alternative Waste Management



SOURCE: Office of T Assessment.

Concept of Degree of Hazard

As part of the decision process of whether to incorporate a degree-of-hazard concept into Federal regulations, it is appropriate to examine the technical basis of the concept, its application in a classification system, objectives and purpose, economic effectiveness, and uncertainties that surround implementing the concept for management purposes.

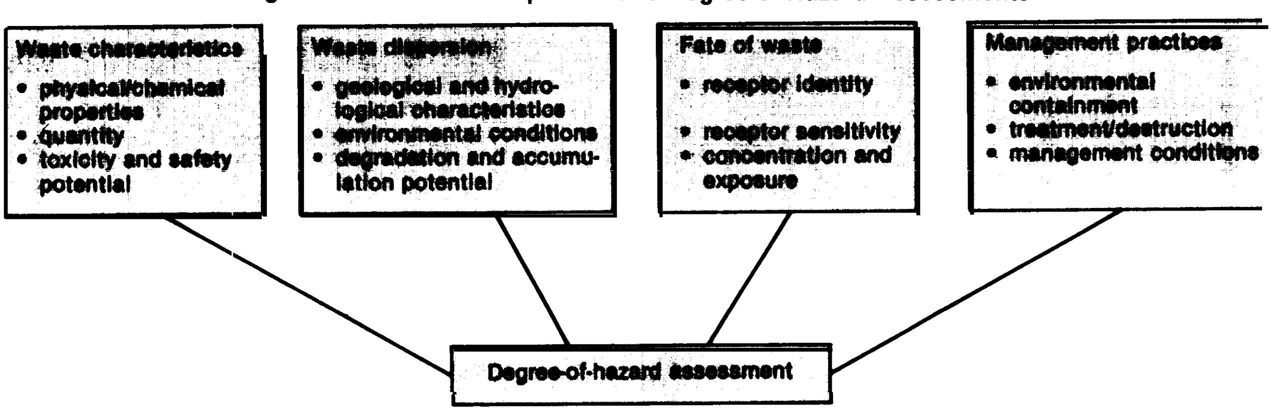
TECHNICAL BASIS

The degree to which accumulation and dispersion of nonnuclear industrial hazardous waste (NIHW) could pose a hazard to human health and the environment depends on many factors as illustrated in figure 2: characteristics of the waste contributing to its toxicity and the need for safe handling (e. g., ignitability, corrosivity, and reactivity); concentration and duration of the exposure; properties that determine its movement in the surrounding environment, the potential for degradation and accumulation in living organisms; the sensitivity of exposed organisms to the waste; and site-specific environmental and management conditions that enhance or inhibit movement of the waste to a point for potential exposure. Because of the potential for both acute and chronic toxicity, this factor has received the most attention when developing degree-of-hazard criteria for classification systems.

The toxicity of NIHW is a function of the inherent capacity of waste constituents to produce adverse effects. The major determinants of the magnitude of these effects are the characteristics of waste (e. g., chemical, physical, and toxicological properties), the quantity of the waste constituent to which humans and other organisms are exposed for a specific period (e. g., the dose, which equals the concentration available for some hours, months, or years), and the sensitivity of organisms being exposed (e. g., oxygen is highly toxic to anerobic bacteria but not to humans, and herbicides directly kill plants but not animals). Of these factors, toxicity and dose are of prime importance when assessing the potential hazard of NIHW.

For any chemical there is a dose level that will produce adverse effects in *any* organism; likewise there is a concentration sufficiently low that no adverse effect can be observed (i. e., the response observed in the test population cannot be distinguished from normal background incidences). Chemical and physical properties of the particular chemical and the sensitivity of an affected organism are factors that influence amounts required to cause harm. Thus, the dose

Figure 2.—Factors of Importance to Degree-of-Hazard Assessments



SOURCE: Office of Technology Assessment.

of one chemical required to produce death in one species (e. g., rat) will be different from the lethal dose of another chemical for that same species; the lethal dose for one chemical also will vary among species (e. g., monkey, dog, and human). In addition, not all animals or humans respond to the same concentration or exposure route in a similar fashion. For example, nitrates in water can be ingested by an adult human with no adverse effect, but these nitrates at certain concentrations are toxic to infants. Finally, some compounds are toxic if inhaled, but do not present a risk if ingested or if applied to the skin (e.g. silica sand).

Differences in concentrations that can lead to a hazardous effect are particularly significant when considering constituents of NIHW. Examples of these differences for acute toxicity are presented in table 1. All of the compounds presented in this table have been designated **as** hazardous constituents by EPA based on results from scientific studies of toxicity, carcinogenicity, mutagenicity, or teratogenicity. (13) The amount of each substance listed in the table that is required to produce the same result (i. e., death in 50 percent of the test population) varies greatly and ranges from 3 mg/kg for cyanide to 5,000 mg/kg for toluene. (14) (It is interesting to note that the lethal dose for a commonly used product—table salt—is equal to 3,000 mg/kg, an amount less than that for toluene. Because of the lack of evidence that salt is carcinogenic, mutagenic, or teratogenic, it has not been designated a hazardous constituent for waste. As table 1 suggests, not all constituents of NIHW are equally toxic; the level of toxicity depends

Table 1 .—Toxic Doses for Selected Hazardous Waste Constituents

Compound	LD_{50}a
Cyanide	3
Phenylmercuric acetate	30
Dieldrin	46
Pentachlorophenol	50
DDT	113
Naphthalene	1,780
Toluene	5,000

aAmount (mg/kg body weight) that is lethal for 50 percent of the test population, in these examples following oral administration to rats.

SOURCE: Examples of compounds are taken from EPA regulations, sec. 261.33 and app. VIII (13). LD_{50} concentrations are taken from *Registry of Toxic Effects of Chemical Substances,* 1980 *edition* (14).

on properties of the waste constituents, amounts (dose) available for uptake by plants and animals, and concentrations accumulating in surface and ground water.

The quality of an adverse effect (i.e., immediate death, reversible or irreversible illness) is also influenced by the exposure period. A large quantity of any compound given in a single dose can produce death in organisms (humans included). For some types of substances deleterious consequences may not be observed or may be much less serious when the same dose is encountered over a long time period. For example, although table salt can produce severe effects at extremely high doses, small amounts ingested during prolonged use do not often present health problems, except for particularly sensitive individuals. The importance of concentration and exposure period in determining potential risk is the basis for setting standards that describe permissible levels of some compounds present in our food, water, and air.

Chemical and physical properties of NIHW and interactions among constituents determine the potential for degradation and accumulation in organisms, as well as their movement in the environment. Some classes of compounds can be degraded easily by micro-organisms or through physical processes such as photolysis and hydrolysis. Other compounds are extremely stable and can accumulate to dangerously high levels in the environment or organisms. Concentrations and interactions of waste constituents also influence rates of degradation and accumulation. Likewise, interactions among waste constituents can result in products with solubilities different from the original compounds, thus affecting their movement among environmental media.

The actual exposure of humans and other biota to waste constituents depends not only on chemical and physical properties of the waste but also on characteristics of the storage, treatment, or disposal system. Rates of movement of NIHW in the environment to points of potential exposure are influenced by such factors as type of soil, climatic conditions at the site, hydrogeological factors (e. g., the presence of underlying bedrock or aquifers), and “steady-state”

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conditions can be disrupted by natural disasters, such as floods or earthquakes. Some chemicals may migrate rapidly through the environment that surrounds the management site and may accumulate in surface or ground water; others may bind with soil particles and remain isolated from vegetation or water. Thus an analysis of the potential risk that NIHW will pose to human health or the environment must include a consideration of not only the hazard potential of constituents but also the fate of constituents or their degradation products should they move from the disposal storage, or treatment site.

The degree to which the presence of a specific waste produces a hazard requires assessment of certain critical information:

- toxicological data including limits of confidence (hazards associated with exposures of specific organisms to specific chemicals at specific concentrations for specific durations);
- safety evaluations (hazards associated with ignitability, corrosivity, and reactivity);
- waste loads (chemicals and quantities to be stored, treated, or disposed at a site);
- environmental fate (factors influencing the movement of waste at a site); and
- exposure (estimates of the chemical concentration and residence time at the point of exposure by organisms, e.g., in ground water).

DEGREE= OF= HAZARD CONCEPT V. HAZARD CLASSIFICATION

Degree of hazard is a concept which acknowledges that various waste managed or mismanaged in various ways at different sites pose different degrees of hazard to the public. The practical application of this concept, however, requires some means of using data and information to carry out a specific task, such as permitting a facility for waste management. In other words, there must be some measure of different degrees of hazard if the concept is to be applied.

A formal classification system of some type could be used to apply the degree-of-hazard concept because the following two conditions are satisfied:

- particular waste, management strategies, and sites have important shared characteristics; and
- scientific criteria and data that describe hazards are either available or can be, in principle, obtained to make classification an objective and quantitative system.

An alternative is to apply the degree-of-hazard concept in a qualitative manner, i.e., some type of “go/no-go” system in which waste, or combinations of waste and management systems, are labeled as hazardous or not hazardous, or perhaps as low or high priority. Such qualitative approaches, however, usually use a minimal amount of technical data and scientific information. There is little effort to apply established criteria either on a case-by-case basis or to broader applications. Moreover, such qualitative approaches make it extremely difficult to analyze resulting decisions.

The primary advantage of a classification approach based on a degree-of-hazard concept is that a systematic, technical framework for dealing with complex cases is provided. This approach can be both reactive and anticipatory. Because a qualitative approach requires less effort to develop criteria and data, its apparent simplicity may be attractive from a programmatic perspective. However, it has little value for long-term organization of information and understanding of unifying principles. Moreover, information obtained in a qualitative approach, usually on a case-by-case basis, is not appropriate for quantitative analysis.

Objective and Purpose of a Classification System

The objective of classifying NIHW by degree of hazard is twofold:

- to identify waste that pose the most severe threats to human health and environmental deterioration, and
- to allow development of cost-effective management strategies for each level of hazard within the classification scheme. (Although transportation is an important aspect of a management strategy, the OTA assessment of NIHW does not include transportation of materials from generator to disposer.)

The basic premise of any system for categorizing NIHW, however, is that the waste and/or constituents of the waste stream can be grouped according to those properties that define quantifiable effects and determine exposure under specific conditions. Because waste streams often can contain more than one hazardous constituent, it is unlikely whether enough information on these types of properties is currently available for actual waste streams. Information on individual constituents (once identified within the waste stream) is relevant, and would permit a possible minimal estimate of degree of hazard by compiling the combined results, ignoring synergistic and antagonistic interactions among constituents. As pointed out in a report by the Surgeon General, the necessary information, however, is not yet available for many of the waste constituents.

> A review . . . suggests that toxicologic information is deficient or missing. . . Many of the chemicals are not commercial products but are their precursors or process intermediates. A major toxicologic problem is that humans are likely to be exposed to a combination of mixtures of chemicals. There are virtually no data on or experience in testing mixtures of chemicals for potential health effects.

Drawing upon specific technical information, a classification system could rank waste and waste streams by degree of hazard. Different categories could be established according to specified ranges of the probability of injury to human health or the environment that might result if the waste or waste constituents were to escape from the management site. In addition, management options could be matched to each class of waste to assure that NIHW are handled in the most cost-effective manner possible. This match may not always be easy to accomplish. Conceivably some waste could be difficult to manage effectively, regardless of the identified level of hazard, An example is the PCB-contaminated sediment proposed for dredging from the Hudson River, Because of the relative concentrations of PCBs within the volume of sediment removed, incineration is impractical and landfilling is considered by many to be undesirable.

The development of a classification system, however, has four requirements:

1. establishment of standard criteria and methods, which are widely available and generally accepted by the scientific community;
2. identification of widely accepted indicators of the relationships of real-world exposure to potential toxicity;
3. definition of acceptable levels of hazard for each category in the classification system; and
4. an equitable and inexpensive mechanism to administer the program.

Fulfillment of these requirements will not be simple, as there currently is debate about the best testing scheme (#I); and choice of indicator species (#2); particularly when evaluating chemical effects on the environment. (16,17)

Classification of waste by degree of hazard could serve several purposes:

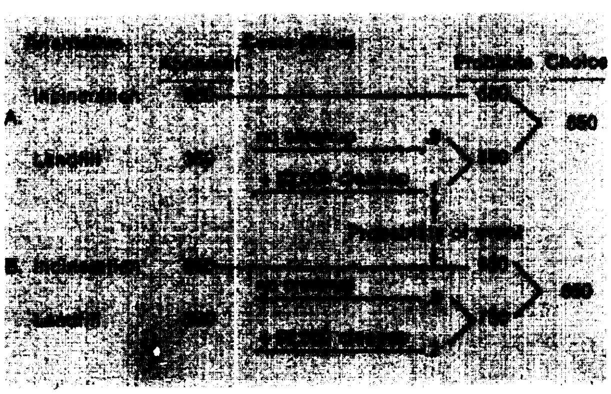
- it could facilitate establishing priorities of NIHW for inclusion in Federal or State regulations;
- it could indicate the level of emergency measures required in the event of an accidental or deliberate spill;
- it could set priorities in use of scarce high-security landfill facilities or more costly technologies for treatment or disposal;
- it could influence general management policies that determine the stringency of regulation, liability coverage, or the required level of monitoring; and
- it could provide a scale by which cost factors are included in determining the choice of management procedures.

Economic Effectiveness

Compared to present Resource Conservation and Recovery Act (RCRA) regulations, the use of a hazard classification system could change dramatically the way in which many hazardous waste are disposed. Many facilities treat all waste similarly and costs to users are generally high; with a hazard classification system it may be possible to reduce costs for the disposal of some less hazardous waste. Because of the high hazard posed by some waste now being handled in a least costly (but legal) manner, the disposal method may have to be changed to a more expensive practice. The basis for requiring such a change in disposal practices is that the more costly management alternative would be more effective in detoxifying or destroying waste classified as extremely hazardous.

In order to illustrate the potential economic effectiveness and logic of applying a degree-of-hazard classification system, decision analysis can be made by using proxy disposal alternatives, as illustrated in figure 3. This comparison assumes that landfill disposal corresponds to current RCRA regulations without use of a degree-of-hazard classification. Using this type of classification, extremely hazardous waste would be incinerated in this example to assure their complete destruction. Although landfills have a

Figure 3.— Decision Analysis Illustrating the Impact of Degree of Hazard on the Choice of Management Practice



SOURCE Off Ice of Technology Assessment

lower cost per ton of waste, there is some probability of failure. Failure is defined as the creation of a hazard for people or the environment at some future time, even using currently accepted best available technology and engineering judgment. The costs used in this figure are based on present technology and practices; the cost of cleanup represents an average number based on documented remedial activities. These figures, however, should not be considered precise, and are used only for illustration.

The purpose of using a decision analysis is to illustrate that although incineration may appear, in the short term, to be substantially more expensive than landfills, when the probability of future damage (the critical probability in this example is 15 percent) and cleanup costs ($2,000/ton) are relatively high, the decision to choose incineration is logical and economical. For this illustration, it is assumed that cleanup costs are borne (directly or indirectly, such as through insurance costs) by the decisionmaker, who is considering alternatives. In other words, when a waste is considered to present a high enough hazard and major risks are taken into account (internalized into the economic decisionmaking), using a management strategy with higher initial costs than other alternatives can be appropriate. If the perceived or estimated probability of landfill failure is 20 percent (as in example B in fig. 2), then incineration costs are $100 less per ton than landfill costs. When the probability is reduced to 10 percent (e. g., a value associated with a lower degree of hazard for a different waste or a different site), however, landfill becomes the most cost-effective alternative, assuming that monitoring is 100-percent effective and cleanup takes place before damage occurs to human health or the environment.

UNCERTAINTIES IN IMPLEMENTATION

No matter which degree-of-hazard classification system is considered for use with NIHW management, uncertainties regarding potential hazards will always exist due to limited data on waste, health and environmental effects, and sites. If the uncertainties are identified and acknowledged, a workable system might still be developed. The major requirement in formulating a classification system is the assurance that both objectives of a degree-of-hazard approach are met, It is not sufficient to only identify those NIHW of priority concern; if a degree-of-hazard system is to be effective, management strategies that reflect differences among categories of hazard also are needed. Design of treatment and disposal facilities needs to focus on the capability to minimize off site migration of waste constituents; while this focus is necessary, it could make permitting a more difficult task as prediction of offsite migration is often difficult. The impact of this type of system on large and small industries is also unknown.

Implementing the mandate of RCRA through a regulatory approach based on degree of hazard requires development of a realistic, yet uncomplicated, system. This point was emphasized in a recent report by the Conservation Foundation on developing a classification system for management of low-level radioactive waste.

> A workable and enforceable system must be devised that takes account of limited financial, institutional, and physical resources. When ill-conceived rules exist, the public and participants in the waste management system will disobey not only the senseless rules but also the significant, well-drafted ones. Compliance is especially important with rules directed towards defining and classifying wastes, since ignoring safeguards at this initial step will hinder the effectiveness of subsequent stages of waste disposal.(18)

Degree of Hazard in the Current Regulatory Approach

Those regulations aimed at defining which waste are hazardous are not currently based on a strictly interpreted degree-of-hazard concept: the established criteria identify waste only as hazardous or nonhazardous. If a waste stream is to be considered hazardous and therefore within the jurisdiction of the Resource Conservation and Recovery Act (RCRA) regulations, it must first meet one of three criteria, and then it is evaluated by the Environmental Protection Agency (EPA) to determine whether listing is required. EPA has chosen in some instances to use considerable discretion in applying the second and third criteria when designating a waste stream as hazardous, and in others to apply appendix VIII of EPA's regulation in an indiscriminate manner. The three criteria are:

- The waste exhibits any of the characteristics (i.e., toxic, ignitable, corrosive, or reactive) identified in subpart C, *Characteristics of Hazardous Waste*, of the regulations. (It is the responsibility of industry to determine if a waste meets this criterion.)
- The waste is fatal to humans in low doses; or studies indicate the following acute toxicity levels: oral LD_{50} in rats—less than 50 mg/kg, inhalation LC_{50} in rodents—less than 2 mg/l, dermal LD_{50} in rabbits—less than 200 mg/kg; or ". . . is otherwise capable of causing or significantly contributing to an increase in serious irreversible, or incapacitating reversible, illnesses.''
- The waste contains any constituents listed in appendix VIII, *Hazardous Constituents*, of the regulations, unless after evaluating several factors, ". . . the Administrator concludes that the waste is not capable of posing a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed. . ." (13)

Based on these criteria, EPA has prepared lists of designated hazardous waste from nonspecific sources, specific sources, and discarded products listed as acute hazard or toxic waste. EPA can, and probably will, make additions to these four lists as well as to appendix VIII and could develop other lists of waste classes that it considers to be hazardous and therefore subject to regulation.

Development of a regulatory framework for managing NIHW has just begun; thus an evaluation of the effectiveness of current regulatory approach is premature. Although a degree-of-hazard scheme based on specific criteria has not been explicitly applied by EPA, incorporation of the concept that different hazards exist is implied or used in some sections of EPA proposed regulations, With reference to the degree-of-hazard concept, and the use of phrases such as "substantial threat, " "hazard posed, " and "extent necessary to protect human health and environment, " an opportunity is provided for judgments to be made, probably in the courts, without technical basis. To date, no scientifically based criteria have been established by EPA that can be used to make decisions about threats or hazards posed or the extent to which humans and the environment are protected. Put another way, many generators and disposers of waste as well as third parties such as insurance companies face an "unbounded" situation (e.g, in setting liability limits), with no programs being developed for adding substantive meaning to the qualitative language frequently used in proposed regulations.

Table 2 illustrates selected sections of the proposed regulations where degree of hazard may be considered by the permitting authority, either in identifying NIHW or in the management of NIHW storage, treatment, or disposal. For example, EPA has excluded from federally permitted disposal sites those waste in amounts that are less than 1,000 kg/month (for administrative convenience) and is considering a further change to reflect tighter restrictions (less than 100 kg/month) suggesting that these are

Table 2.—Selected Examples of a Degree-of-Hazard Interpretation in Current RCRA Regulations

Identification of NIHW

Small quantity generators.—Waste from a small quantity generator are not subject to regulation under parts 262-267 and 122-124 and are not subject to the notification requirements of 3010 of RCRA. A small quantity generator is one who generates less than 1,000 kg of waste per month, or less than 1 kg of acutely hazardous waste.

Criteria for listing hazardous waste.—One condition for listing a solid waste as a hazardous waste is if the waste contain any of the constituents listed in app. VIll unless after considering any of the factors listed (e.g., nature of toxicity, persistence, bioaccumulation potential and migration potential of the constituents, and quantities of waste generated) the Administrator concludes that the waste is not capable of posing a substantial threat to human health or the environment.

Transportation

Pretransport requirements. -Packaging required in accordance with DOT regulations, which are based on hazard classes.

Labeling required in accordance with DOT regulations, which are based on hazard class.

Marking required in accordance with DOT regulations, which are based on hazard class.

Placarding required in accordance with DOT regulations, which are based on hazard class.

Spills. —Use DOT spill-reporting system, which is based on severity of spill.

Emergency

Preparedness and prevention.—

- Facility design and operation.—Design, construct, maintain, and operate facility to minimize fire, explosion, or release of hazardous waste, which would threaten human health and the environment; includes use of performance standards.
- Emergency equipment.— Emergency equipment required only if the waste handled pose a hazard, which requires specific kinds of equipment.
- Arrangements with authorities.—Arrangements required as appropriate for the type of waste handled and the potential need for such services.

Contingency plan and emergency procedures.—Plan must be designed to minimize hazards to human health and the environment from fires, explosions, or release of waste.

Facilities

Security.— Prevent unknowing entry and minimize possibility of unauthorized entry, *unless* contact with the waste will not injure unauthorized persons or livestock and if unauthorized entry will not result in inability to comply with standards.

Environmental performance standard for new land disposal facilities.—Prevent ion of adverse affects to ground water, surface water, air quality, and subsurface environment through consideration of parameters including the volume, physical and chemical characteristics of the waste in the facility, the potential for human health risks caused by exposure to waste constituents, the potential damage to wildlife, crops vegetation, and physical structures caused by exposure to waste constituents, and the persistence and permanence of the potential adverse effects.

Regional Administrator may waive any of the design, operation, closure and postclosure requirements to achieve treatment of a waste provided the environmental performance standard is met.

Regional Administrator may specify additional requirements where necessary to comply with the environmental performance standard.

Closure: plan and fund.—Closure must result in control, minimization, or elimination of postclosure releases to the extent necessary to protect human health and the environment. Fund required to meet cost of closure.

Insurance: sudden and nonsudden.—Minimum liability amounts specified may be increased or decreased depending on hazards posed. Premiums charged reflect degree and duration of risk.

Technology

Underground injection.—An injection well must be designed to assure compliance with the environmental performance standard.

An injection well must be operated in a manner that will comply with the environmental performance standard.

Methods for operating an injection well must reflect a consideration of the volume and physical and chemical characteristics of the waste injected in the well.

Incineration.—Regional Administrator selects principle organic hydrocarbons (POHCs) based on hazard posed considering incinerability, concentration and quantity.

Performance standard requiring 99.99 percent destruction of selected POHCs.

Range of acceptable operating limits determined for each waste feed.

SOURCE Consideration of Hazard In the Regulations unpublished document from Environmental Protection Agency, Off Ice of Solid Waste

not sufficient quantities to pose a threat to health or the environment. (These exclusion amounts do not consider the potential toxicity of these waste, however; a very toxic waste produced in small quantities could be hazardous to humans or other organisms.) The pretransport requirements are based on regulations of the Department of Transportation that, in turn, are based on classes of hazard. The regulations governing spills are based on the ‘severity’ of the spill. (No definition of severity is provided and the March 1981 craft of the National Contingency Plan defines quality of a spill according to the size of the discharge.) The proposed facility standards are based on performance rather than specific design, but do not provide criteria for assessing performance; if the type of waste or the environmental conditions surrounding the site are such that little or no migration of constituents were possible from the site to potential sources for exposure of humans or other living organisms, application of performance standards could permit less stringent control measures to be used. (20)

As the regulations are currently designed the stringency of control for any facility whether onsite or off site is apparently determined by the permitting authority within each State or region. While this may provide the opportunity to regulate NIHW disposal by degree of hazard, uniform application of this type of approach is not assured, particularly in the absence of specified criteria for evaluating predicted performance of facilities. EPA's approach does permit site- and waste-specific flexibility in permitting facilities. Left to the interpretation of individual permitting authorities, confusion and unequal enforcement could result. Some of the confusion and inconsistency might be avoided through public participation (i. e., through concern about siting new facilities) in the permitting process and through the use of litigation to prevent authorization of those facilities that are perceived as not being safe. It is uncertain, however, if these are the most appropriate ways to achieve effective management and enforcement of EPA regulations.

Because RCRA regulations are in the interim final stage, it is possible to apply the concept of degree of hazard within the current structure. For example, specific criteria based on degree of hazard for the waste to be handled could be developed for assessing the performance of storage, treatment, or disposal facilities. In addition, a degree-of-hazard classification and management system could be incorporated into the regulations incrementally, thus reducing transitional uncertainties that would arise if the entire program were changed radically and suddenly from its present design. As table 2 suggests, EPA is moving toward application of a degree-of-hazard concept in a qualitative manner. The major uncertainty is whether a rigorous classification scheme with scientific criteria can be and should be implemented fully within the regulations.

Methods for Classifying Waste and Facilities by Degree of Hazard

There are several ways to develop a system of classifying both NIHW and management facilities by degree of hazard: grouping by technical criteria, rank order by test results for specific characteristics, the use of multiple discriminatory factors for categorization that concentrates on important exposure and effects data, or classifying by environmental containment, Of these various methods, only the first has received much attention. The other schemes have been applied in narrowly focused tasks and are very speculative options for adaption in management of nonnuclear industrial hazardous waste (NIHW). The systems presented in the following discussion serve only as examples of these various types of classification methodology. The omission of any specific design does not reflect a judgment as to the appropriateness of the omitted example. Because of the variety of potential designs, the intent is to indicate the diversity of methods, rather than to discuss all potential approaches.

CLASSIFICATION USING TECHNICAL CRITERIA

As States begin formulating their own regulations for management of NIHW, the majority are using a scheme based on technical criteria to identify waste as hazardous. At present, however, definitions of the term hazardous vary widely among the States. For example, a recent survey indicated that 45 States use general or qualitative definitions of hazardous, but the term is not uniformly applied in all State laws. (21) Among these 45, 34 States include characteristics such as flammability, corrosiveness, and toxicity to narrow their definition of hazardous waste, but only eight of these States specify test protocols and acceptable ranges for test results. Thirteen States followed the lead of the Environmental Protection Agency (EPA) and developed lists of NIHW. Of the total 45 States in this survey, only five considered measures of volume or specific chemical, physical, and toxicological characteristics to distinguish between more than one class of NIHW; these include California, Illinois, Maryland, Pennsylvania, and Washington. Four States—California, Rhode Island, Texas, and Washington—proposed detailed programs using different technical criteria of toxicity to classify NIHW in response to the 1978 proposed regulations. Recently other States, including Kentucky, Ohio, and Michigan, have developed some form of a degree-of-hazard program for managing NIHW. The programs discussed below are presented only as illustrations of this type of classification methodology.

California.—California has a two-tier system for classifying hazardous waste, *hazardous* and extremely *hazardous.* Criteria based on toxicity, flammability, pressure-generating reactivity, corrosivity, irritancy, and sensitizing properties are used to describe each category, The major determining factor that distinguishes between the two groups seems to be the level of toxicity. To designate a waste as hazardous, certain toxicity measurements are required: acute toxicity (i.e., short-term response), carcinogenicity, chronic toxicity, and estimates of degradability and bioaccumulation (see table **3).** The category designated as *hazardous* has acute toxicity test results in a range of 51 to 2,000 mg/kg, contains substances that are known or suspected to be carcinogens, are considered nondegradable, accumulate in tissue, and can contribute to chronic health problems. The extremely *hazardous* category includes those materials that are shown to have high levels of acute toxicity (equal to or less than **sO** mg/kg), that are defined by California law as carcinogens, or that have been tested in the laboratory and results indicate that they are

'Table 3.—Toxicity Criteria in the California System of Degree-of-Hazard Classification

	Limits[a]	
	Extremely hazardous	Hazardous
Mammals		
Oral administration	⩽ 50 mg/kg[b]	⩽2000 mg/kg
Exposure to skin	⩽200 mg/kg	⩽1200 mg/kg
Inhaled	⩽200 mg/l	⩽4000 mg/l
Aquatic animals	—	⩽ 500 mg/l
Carcinogenicity	Defined as carcinogen by California law	Defined as carcinogen by California law or suspected carcinogen by NIOSH listing
Tests in animals indicate . .	Carcinogenicity, high chronic toxicity, persistence, or bio-accumulative properties	Chronic toxicity, persistence or bioaccumulative properties

[a]Amounts that result in mortality for 50 percent of the test population. The lower the concentration the more toxic the material is to test organisms. LD_{50} for mammals and LC_{50} for aquatic animals.
[b]Mg of material/kg body weight of Organism

SOURCE. Sterling Hobe Corp. (12).

potential carcinogens, cause chronic toxicity, are nondegradable, and accumulate in tissue. Except for differences between the moderate and high levels of acute toxicity and the State definition of some carcinogens, no quantifiable measures have been provided to distinguish the other toxicity criteria between categories, except for threshold limits of certain compounds that have been specified in the California legislation. Limited technical justifications for minimal differences between criteria for classifying waste as *hazardous* or *extremely hazardous* have been provided,

Although the California proposal places NIHW in different classifications, management practices do not vary between the two categories. The waste (i.e., hazardous or extremely hazardous) are sent to the same type of facility and treated in a similar manner. Transportation and admninistrative procedures for handling NIHW (e.g., recordkeeping) are maintained separately for each category. The utility of the proposed classification without differences in management practices is dubious.

A further classification system exists in this State under the authority of the Water Quality Control Board and is independent of the above system. Waste are put into one of three groups based on the probability of ground water contamination. These waste are directed to match facility sites that have specific geological structural standards related to each group of waste.

Rhode Island.—The State of Rhode Island has developed and implemented a system that attempts to rank the materials using several characteristics of hazard, e.g., levels of toxicity, reactivity, flammability, and irritancy. Distinctions such as high, moderate, and slight are designated for each characteristic. Qualitative and quantitative definitions of each level (e.g., moderate flammability) are provided. Responsibility for determining correct classifications of the waste lies with the generator. The transport manifest includes a description of waste constituents and the designated classification. State officials use this information to verify that an appropriate classification has been made. If a disagreement about the assigned class results between generator and State officials, conflicts are resolved through further testing.

Industry representatives have worked closely with State officials in formulating criteria for each degree-of-hazard category. Although this scheme is comprehensive and detailed, it is currently being used only in recordkeeping and for limiting routes of transportation. The State has developed criteria for land disposal; however, all waste are currently sent to out-of-State disposal facilities.

Texas.–Prior to development of the EPA proposed regulations, the Texas Department of Water Resources proposed using a classification system based on differences in the potential for adverse effects on human health or the environment.(23) The definitions and specific measurements were derived to identify potential impacts resulting only through land disposal of industrial solid waste. The system included both a list of hazardous substances and criteria for designating new waste as hazardous. Table 4 illustrates the type of measures proposed for classifying materials. The basic difference between Class II and Class III in this scheme was that the latter represents inert materials, e.g., essentially insoluble and not readily decomposable materials including rock, brick, glass, dirt, certain plastics, and rubber. Placement of a NIHW within a particular class was to be based on analysis performed by the appropriate State agency.

Some important characteristics of potentially hazardous waste (e.g., chronic toxicity, genetic impairment, and persistence) were not included in the Texas system. Also, criteria were designed solely for use in land disposal and little indication of the applicability of the scheme for other management practices was provided. The Texas definition of Class I materials corresponded to EPA's current definition of hazardous waste, as both of the other classes identify relatively nonhazardous materials. If the plan were to be implemented under EPA regulations, State officials would manage waste from Classes II and III on a waste- and site-specific basis. Management practices for waste classed as hazardous (Class I) would closely follow the regulations by EPA. (23) Therefore, as presently designed this proposed system does not really provide a degree-of-hazard approach.

Table 4.—Criteria for the Texas System of Degree-of-Hazard Classification

	Class I	Class II	Class III[a]
Hazard index[b]	⩽50	>50	>50
LD_{50} measures[c] . . .	⩽500 mg/kg	>500 mg/kg	>500 mg/kg
pH[d] . . . . , ...	<2.5, > 12	2.5 –12	2.5 – 12
Corrosion rate[e] . . .	<0.25 in/yr	>0.25 in/yr	>0.25 in/yr
Flash point[f]	⩽140° F	>140° F	>140° F

[a]See text for compositional differences between Class II and Class III.
[b]Represents the potential hazard to the environment if improperly disposed, based on measures of toxicity and solubility of the substance.
[c]Median lethal dose; dose required to kill 50 percent Of a population exposed to the chemical of concern.
[d]Measure of acidity or alkalinity; pH 7 indicates neutral solution; <pH 7 indicates acidic solution; >pH 7 Indicates alkaline or basic solution.
[e]Corrosion rate on steel (SAE 1020) at a test temperature of 130"F as determined by NACE.
f Determined by a Pensky-Martens Closed Cup Tester using ASTM Std. D-93-73.

SOURCE Sterling Hobe Corp. (12)

One major drawback to these three systems (i.e., California, Rhode Island, and Texas) is that there is no consideration of actual or potential concentrations at the source of exposure. As discussed previously, it is the concentration at the time of exposure that has the greatest influence on the severity of any adverse effect. Any system that does not consider dose level cannot be consistently effective in providing relevant protection either for human health or for maintaining a clean environment. Another important problem with these systems is that criteria for listing new waste as hazardous are not comprehensive enough to adequately "catch" all potential NIHW. Primary measures of toxicity, either in the hazard index or LD_{50} criterion, depend only on acute toxicity. No consideration is given to waste that may result in chronic health problems or long-term, low-level deterioration of the environment. Thus a number of chronically hazardous waste could pass the tests provided in these systems, but could still pose hazards to humans and other organisms.

Washington.—The Department of Ecology for the State of Washington has developed a classification system that includes some consideration of concentration and potential exposure, This system has two classes designated as *extremely hazardous* and *dangerous.* The distinguishing criteria among the two classes include characteristics of persistence, concentrations in the waste stream, potential to cause genetic effects, level of toxicity, and concentrations of specific classes of known toxic chemicals (e.g., polycyclic aromatics). Table 5 illustrates these distinctions. Extremely hazardous waste are further ranked into two categories: 1) hazard resulting from toxic effects on humans and wildlife; 2) hazard attributed to the persistence of the material. Specific criteria for extremely *hazardous* waste include complex combinations of different measures of acute toxicity and percent volume of specific waste constituents. An important aspect of this system is that the method-

Table 5.—Criteria for the Washington System of Degree-of-Hazard Classification

	Extremely hazardous	Dangerous
Oral, rat, LD_{50}[a]	<500 mg/kg	<5,000 mg/kg
Aquatic fish, LC_{50}	<100 mg/l	<1,000 mg/l
Halogenated hydrocarbons	>1%	>0.01%
Polycyclic aromatics	>1%	None
Concentration of heavy metals in EPA leach test	10,000 x DWS[b]	100 x DWS
Nonbioaccumulative carcinogens	—	IARC[c] human or animal: positive or suspected
Corrosivity, reactivity, ignitability	—	EPA definition

[a]For pure compounds or simple mixtures book designation using the NIOSH Register and the designation diagram are possible. see appendix.
[b]DWS = drinking water standard.
[c]IARC = International Agency for Cancer Research. This group weighs published studies on suspected cancer causing agents and issues findings.

SOURCE: Provided by E. W. Tower, Solid Waste Management Division, Off Ice of Land Programs, Department of Ecology, State of Washington, Olympia, Wash.

ology has been developed for classifying waste mixtures and permits an evaluation of potential hazard at the point of exposure. (24) (see also appendix.) Any nontoxic waste in amounts exceeding 100 lb/week that is considered corrosive, explosive, or flammable is classified as *dangerous waste.* Disposal of this class of materials is regulated less stringently than *extremely hazardous,*

In this system, the generator is responsible for determining the correct classification of a waste. If toxic constituents are known, classification can be made without testing; if waste components are not known with any degree of certainty, either qualitatively or quantitatively, analytical tests must be conducted to identify constituents and determine their degree of hazard. The State has developed standardized rat and fish bioassays to be used as biological indicators of toxicity in the degree-of-hazard assessments. Tests must be performed to ascertain flammability and corrosivity of *dangerous waste.* A prose test (narrative description) is applied to determine explosive potential.

The degree-of-hazard approach has also been applied to facility standards. Washington State law requires that *extremely hazardous* waste must be disposed at the Hanford site where the climate and topography of the eastern section of the State is best suited to contain these more hazardous wastes. *Dangerous* waste can be disposed of at any other permitted site, which follows the criteria established by EPA. State officials consider that these restrictions address the exposure potential of NIHW to humans or other biota.

The Washington State system has been in operation since 1978 and as yet no major problems have emerged. This approach for classifying and managing NIHW appears more stringent than the EPA regulations. Therefore, problems could develop for interstate transportation and the acceptance of out-of-State waste by Washington State disposers.

Other Schemes.—In reponse to the December 1978 publication of regulations proposed for implementing RCRA, 12 classification schemes using a degree-of-hazard approach were proposed to EPA in addition to the State systems. Most of the 12 schemes formulated technical criteria using qualitative or quantitative measures of toxicity, safety hazards, environmental fate, and management practices. Many of the proposals lacked detail on technical criteria and served only to suggest how a classification system might be developed. Three of these proposals did provide some detail about the type of criteria to be applied in each category. Table 6 illustrates these characteristics.

All of the proposed schemes, including those of the four States, have major disadvantages. Table 7 provides a comparison with respect to the type of technical criteria required. Those characteristics that may be considered to be of prime importance for identifying NIHW include estimates of potential genetic impairments (e. g., carcinogenicity, mutagenicity, teratogenicity), measures of acute and chronic toxicity, degree of persistence and bioaccumulation, estimates of potential concentrations in waste, indications of

Table 6.—Proposed Technical Criteria for Classifying Nonnuclear Industrial Hazardous Wastes

	System 1	System **2**	System 3
Class I	Genetic impairment and persistence; or high-level acute toxicity; or moderate acute toxicity and persistent; exceeds 1,000 X drinking water standards.	High acute toxicity and concentration exceeding 100-mg/kg waste; or reaction at normal temperature and pressure; or or forbidden explosive (by law).	Moderate to high acute toxicity; or genetic impairment, persistent or bioaccumulates; or reactive or infectious.
Class II	Genetic impairment and not persistent; or moderate acute toxicity and bioaccumulates or persistent; or 300 to 1,000 X drinking water standards.	Flash point <100°F, considered hazard during management; or flammable compressed gas; or pH <2 or >13; or corrodes steel; or highly reactive; or exceeds 100 X drinking water standards.	Low acute toxicity; or ignitable, corrosive or reactive; or low in feetibility.
Class III	Low acute toxicity and bioaccumulates or persistent; or 100 to 300 X drinking water standards.	Flash point 100° - 200° F; or hazard during burning; pH 3-12; or less than 100 X drinking water standards.	

SOURCE Sterling Hobe Corp (12)

Table 7.—Comparison of Proposed Degree-of-Hazard Classification Systems

	Hazardous characteristics											
	Genetic impairments	Acute toxicity	Chronic toxicity	Persistence	Concentration	Bioaccumulation	Exposure potential	Sensitive biota	Ignitability	Corrosivity	Reactivity	Remarks
California	+	+	+	+	-	+	-	-	+	+	+	System does not include distinctions for disposal facilities or disposal requirements.
Texas	-	+	-	-	-	-	-	-	+	+	+	Distinctions among facilities are proposed for land-disposal only; class I materials are equivalent to EPA hazardous materials; class II and III are nonhazardous materials.
Rhode Island	+	+	-	+	+	+	-	-	+	+	+	Concentrations of materials considered only for the highly toxic classification; criteria for land-disposal facilities have been developed to reflect degree-of-hazard system, but currently the State does not have in-State disposal.
Washington	+	+	*	+	+	+	*	*	+	+	+	Dangerous waste class is equal to EPA hazardous waste; criteria are being proposed for management activities that are related to waste classifications.
System #1	+	+	-	+	+	+	-	-	+	+	+	Primary distinctions are based on toxicity measures; classification for facilities also proposed.
System #2	-	+	-	-	-	-	-	-	+	+	+	Provides for small quantity exemptions for each class; no distinctions in management activities.
System #3	+	+	-	+	-	+	-	-	+	+	+	Very simple system; does not consider classification of disposal facilities.

+ Characteristic included in proposed scheme.
- *Characteristic not addressed.*
* Characteristic indirectly addressed in regulations.

SOURCE: Office of Technology Assessment.

the potential for exposure to sensitive biota or to humans, and measures of ignitability, corrosivity, and reactivity. Except for the Washington State system, concentrations of the waste-stream constituents have not been considered. In most of these systems, chronic toxicity is not a criterion, nor is there any assessment of the potential for movement from the waste site. Some of the proposed systems rely on previously set standards, when such standards (e. g., water quality criteria standards) exist for only a few compounds. This approach could permit some extremely hazardous waste constituents to remain unregulated. Finally, none of the systems to date has management strategies or facility criteria that relate to the different identification categories in a relevant way.

RANK-ORDER CLASSIFICATIONS

With passage of the Toxic Substances Control Act (TSCA) the need for mechanisms by which chemicals could be given priority for further toxicity testing received much attention. Several models have been developed that combine test scores for a variety of toxicity tests: LD_{50} or LC_{50} ranges, carcinogenicity potency, chronic health effects, teratogenicity potential, etc. In rank-order schemes the compound of concern receives a "score" that is based on a particular combination of results from several types of tests. Those results or tests considered to be most important for the assessment (i. e., carcinogenicity) can be weighted to reflect this relative importance. Once the composite score is calculated, chemicals can be ranked by their scores and priorities established for further action.

Although the rank-order type of approach has not been applied directly to industrial waste, there is some potential for its usefulness in NIHW management. For example, table 8 illustrates a rank-ordered system developed by the State of Michigan. The State uses this method to identify compounds for its Critical Materials Register. A system such as that illustrated in table 8 could be adapted and used as a means to classify waste or waste constituents according to degree of hazard. Particular test results could have a greater influence on a hazard designation and thus receive more weight in a classification scheme. For example, scores for properties such as persistence or bioaccumulation could be multiplied by a factor of two, giving these characteristics greater weight in the ranking. Hazard categories then could be designated by the total expected scores, for example:

	Combined score
Extremely hazardous	46
Moderately hazardous. .,	25-45
Slightly hazardous,	24

This range of categories is given only as an example of how the system might operate. Before limits for each group could be defined and justified, careful consideration of all criteria is needed. Development of such criteria would require extensive research efforts.

Several schemes similar to rank-order assessments have been proposed as methodology for performing hazard assessment, (28,29) Table 9 illustrates the types of factors included in assessments of potential biological impact and dispersion of NIHW. Recently, ranked classifications based on the statistical technique of discriminant analysis were proposed. This type of analysis was used to classify waste streams from selected smelting and refining industries. This particular approach was suggested as being appropriate for rank-order classification of management practices or facility sites.

Recently this type of classification has received some criticism. (31) These criticisms focus on the following points:

- combining scores of different effects into one index for ranking purposes entails making a value judgment; and
- there is no logical basis for assigning weights to specific factors due to the diver-

Table 8.—Michigan's System for Rank-Order Assessment of Critical Materials

I. Acute toxicity

Score	Oral LD_{50} mg/kg	Dermal LD_{50} mg/kg	Aquatic 96 hour LC_{50} mg/l
7	<5	<5	<1
3	5-50	5-200	1-10
2	>50-500	>200-500	>10-100
1	>500-5000	>500-5000	>100-1000
0	>5000	>5000	>1000
•	Insufficient information		

II. Carcinogenicity

Score	Category
7	Human positive; human suspect; animal positive
3	Animal suspect
2	Carcinogenic by a route other than oral or dermal; strong potential carcinogen by accepted mutagenicity screening tests or accepted cell transformation studies
1	Potential carcinogen by accepted mutagenicity screening tests or accepted cell transformation studies
0	Not carcinogenic
•	Insufficient information

III, Hereditary mutagenicity

Score	Category
7	Confirmed
4	Suspect - multicellular organisms
2	Suspect - micro-organisms
0	Not a hereditary mutagen
•	Insufficient Information

IV. Teratogenicity

Score	Category
7	Confirmed
3	Suspect
0	Not teratogenic
•	Insufficient information

V. Persistence

Score	Category
4	Very persistent
3	Persistent
2	Slowly degradable
1	Moderately degradable
0	Readily degradable
•	Insufficient Information

VI. Bioaccumulation

Score	Bioaccumulation	Log P
7	>4000	>6.00
3	1000-3999	5.00-5.99
2	700-999	4.50-4.99
1	300-699	4.00-4.49
9	<300	<4.00
•	Insufficient information	

VII, Esthetics

Score	Fish tainting/taste and odor (threshold level in water - mg/l)	Foaming, floating film, and/or major *color* change
3	0.0001-0.001	
2	>0.001-0.01	
1	>0.01 -0.1	Yes
0	>0.1	No

VIII. Chronic adverse effects

Score	Category
4	Irreversible effects
2	Reversible effects
1	Adverse effects by route other than oral, dermal or aquatic
0	No detectable adverse effects
•	Insufficient information

SOURCE Michigan Department of Natural Resources (27)

Table 9.—Suggested Effect and Exposure Factors

Exposure	Effects
Bioaccumulation	Genetic impairment
Persistence	Reproductive changes
Mobility	Acute toxicity
Environmental concentrations	Chronic toxicity
Geographic dispersion	Ecosystem changes
Population factors	Dose factors

SOURCE Modified from TSCA-interagency Testing Committee, subgroup S (31)

sity and composition of the various test parameters.

It has been argued that this method of setting priorities eliminates the necessary indications of the relative importance of any individual factor. For example, the fact that a chemical may be persistent and produce chronic effects could be very important, but might be overshadowed if no other adverse effects were measured. Much developmental work will be required before such rank-order approaches can be applied to the wide range of waste-management problems that currently exist.

MULTIPLE DISCRIMINATORS

A new concept based on multiple discriminatory factors, commonly termed *red-flag*, is being considered as an appropriate way to rank chemicals under TSCA jurisdiction. In this approach a chemical receives scores based on specific test results, similar to those presented in table 8. Within each test category, however, a minimum score termed a discriminatory factor (e.g., a score greater than 2 for persistence or greater than 3 for bioaccumulation) is identified that serves to "flag" the chemical for further attention.

A classification system for NIHW could be developed using the red-flag approach and combining exposure and effect factors (see table 9). The discriminatory factors could be combined in a logical manner within each class. For example, a chemical might be classed as extremely hazardous if it received high scores (and therefore red flags) in areas of carcinogenic effects, chronic effects, bioaccumulation, persistence, and mobility. Another example includes classifications based on a hazard index that is developed by combining certain discriminatory factors; for example, by combining quantity discharge, bioaccumulation, and persistence into one index value or by using a combination of environmental concentration, bioaccumulation, and persistence. This type of analysis represents a new approach in identifying priority compounds and can be considered only as a speculative option for use in classifying NIHW. Before acceptance or rejection of the concept, however, careful study is needed to determine if this approach is appropriate for identifying as well as managing the treatment and disposal of NIHW.

CLASSIFICATION BY ENVIRONMENTAL CONTAINMENT

Another speculative type of classification system categorizes facilities by the ability to minimize escape of potentially harmful substances. Here the emphasis is on management rather than identification. Classification schemes for sites are available, but these have focused primarily on identifying the hazard potential of abandoned dumps .(33,34) With some modification these schemes could be applied to landfill, incineration, or treatment facilities as well. Although there are serious technical concerns over the rating levels presented in table 10, this system illustrates the types of variables that appear to be appropriate. These include the distance to nearest population and drinking wells, critical environments, distance to nearest surface water, depth from facility to ground water, amount of precipitation, soil permeability, bedrock permeability, and depth to bedrock. Once facilities are classified, the waste streams could be grouped according to those chemical and physical properties that are major factors contributing to the potential movement of NIHW constituents from the facility to the surrounding environment. Appropriate classes of waste could be matched to management at the appropriate site. Such a classification has been suggested previously .(35) For example, NIHW with a high potential to escape from the facility (i.e., readily soluble in water) and not easily environmentally degraded might be put into those sites that could minimize exposure to humans and other biota. A system very similar to this concept has been considered for defining and classifying low-level radioactive waste. (18) It has been suggested that management facilities for low-level waste could be designed and classed according to a specific containment time;

Table IO.—Suggested Environmental Parameters for Classifying Facility Sites

Rating factors	Rating scale levels 0	1	2	3
Population within 1,000 ft	0	1 to 25	26 to 100	Greater than 100
Distance to nearest drinking-water well	Greater than 3 miles	1 to 3 miles	3,001 ft to 1 mile	0 to 3,000 ft
Distance to nearest off site building	Greater than 2 miles	1 to 2 miles	1,001 ft to 1 mile	0 to 1,000 ft
Land use/zoning	Completely remote (zoning not applicable)	Agricultural	Commercial or industrial	Residential
Critical environments	Not a critical environment	Pristine natural areas	Wetlands, flood-plains, and preserved areas	Major habitat of endangered or threatened species
Distance to nearest surface water	Greater than 5 miles	1 to 5 miles	1,001 ft to 1 mile	0 to 1,000 ft
Depth to ground water	Greater than 100 ft	51 to 100 ft	21 to 50 ft	0 to 20 ft
Net precipitation	Less than 10 inches	– 10 to + 5 inches	+ 5 to + 20 inches	Greater than +20 inches
Soil permeability	Greater than 50 percent clay	30 to 50 percent clay	15 to 30 percent clay	O to 15 percent clay
Bedrock permeability	Impermeable	Relatively impermeable	Relatively permeable	Very permeable
Depth to bedrock	Greater than 60 feet	31 to 60 ft	11 to 30 ft	0 to 10 ft

SOURCE: Modified from JRB Associates (33)

this containment potential is related to the half-life of radioactive waste. The report stresses, however, that "no one factor would control the assessment of risks, and . . . other screens must be considered. Screens for classifying waste . . . should include: toxicity, concentration, chemical and physical form, compounds that waste may decay to or become during storage, volume, and possibility of release and mobility. " The report continues . . , "Since all waste do not require the same degree of containment or care, various types of disposal techniques should be used; this would more efficiently allocate limited resources. It should be possible to save space and money while preserving or enhancing administrative simplicity. " Although these statements were made for management of radioactive waste, they are applicable to management of industrial hazardous waste as well.

Table 11 illustrates a potential scheme for classifying facilities based on the need to minimize escape of hazardous components. Materials could be classed according to the environmental mobility and degradable characteristics and assigned for treatment or disposal in the appropriate facility class. In such a system a facility would not be limited to handling waste within its permit class but could receive waste within lower classifications (e. g., a Class A facility could receive all classes of waste; Class B facility could receive Class B, C, and D waste but not Class A). Although the prohibition of landfills in the Class A designation may appear to be a radical action, restricted use of landfills for certain high-priority hazardous waste had been considered by the New York State legislature. (36)

The California Office of Appropriate Technology (OAT) has completed a comprehensive study of hazardous waste disposal in California. (37) Using currently available data, OAT identified six classes of high priority waste and concluded that these waste were unsuited for land disposal. The study reviewed alternative management options for these classes of waste and made the following recommendation for use of the most secure landfills (Class I):

> The State should abandon the concept of Class I landfills as repositories for almost all types of hazardous waste by restricting land dis-

Table 11.—Potential Classification Scheme Based on Containment and Destruction

	Landfills	Incineration or treatment facilities
Class A		
— Permitting requires specific operational criteria, detailed environmental evaluation, and stringent monitoring; facility used for waste requiring special handling.	Restricted unless special authorization provided by EPA.	Designed to destroy (incinerate or biodegrade) or detoxify (biologically or chemically) NIHW that pose extreme hazard to human health or the environment; some potential for generating toxic residues.
***Class* B**		
— Permit corresponds to currently proposed facility standards.	Permitted, if in compliance with technical standards based on ability to contain NIHW.	Designed to detoxify (naturally or induced) NIHW within finite containment period and in compliance with technical standards.
Class C		
— Permit by rule for recycling or routine treatment or detoxification process.	Permitted for large volume specialty waste (e.g., utility waste, oil-drilling waste).	Designed to handle readily degradable, or totally recycled NIHW, or waste that are incinerated without producing toxic byproducts.
Class D		
— Permitted to dispose of nonhazardous waste.	Sanitary landfills.	Municipal waste treatment and disposal.

SOURCE: Based on material provided by B. L, Simonsen, IT Corp., Wilmington, Calif.

posal to those waste which have been specifically identified as safe for this method of disposal.

It appears likely that this recommendation will be accepted by the State legislature.

The basis for this is type of scheme is the ability of a facility to properly contain the NIHW for a specified time period and to match this time period with the duration for degradation or mobility potential of the waste. Thus, those facilities that are shown to be able to contain the waste for a specified time or are capable of completely destroying the waste (e.g., incineration) could be used to handle NIHW that are shown to be highly persistent and nondegradable. If it is known that controlled release is likely or that there is potential for surface or ground water contamination at some time in the future then these sites could be used to handle waste with degradation potentials that match the expected time of escape from the facility. As mentioned above, this is a highly speculative approach. Before implementation at any level of operation (i.e., National or State) is possible, full investigation is needed to determine the proper facility-environment parameters, including facilities other than landfills, and to decide whether suitable parameters can be measured for NIHW. A thorough review of the application of this scheme to disposal of radioactive wastes could provide some insight into which factors are most important.

Unresolved Questions

Because of the current lack of information and data, none of the schemes discussed in the previous section could be immediately implemented in a regulatory policy. Each approach has advantages and disadvantages that require substantial further evaluation. The systems that propose to classify on the basis of specific technical criteria do not consider all of the characteristics that are important for hazard assessments. The more complete systems, California, Washington, and System #1 (see table 7) do include the majority of hazard characteristics: potential to cause genetic impairment, acute toxicity, chronic toxicity, persistence, concentration (to a limited degree), bioaccumulation, and characteristics of safety evaluation. These approaches, however, do not consider directly such factors as dose, exposure potential, environmental mobility, and sensitive environments or populations. (The Washington system addresses these points indirectly.) Approaches using rank order or multiple discriminators (e. g., the Michigan system illustrated in table 8) generally rely primarily on effects data without much attention being given as yet to exposure data. The multiple discriminator system, proposed for setting priority chemicals under the Toxic Substances Control Act (TSCA), does include some environmental or exposure parameters and thus could have greater promise for application in managing nonnuclear industrial hazardous waste (NIHW). The advantage of classifying facility and waste according to containment or destruction ability is apparent, but there is uncertainty with this approach also. Verification is needed to assure that waste can be characterized in a way that reliably quantifies the potential for degradation and environmental mobility. If it could be assumed that those persistent and relatively immobile chemicals are also those with the highest level of hazard, then the lack of toxicity criteria in the last approach would not be disadvantageous; however, *conclusive evidence* that supports this assumption is not yet available.

Although no perfect system exists at the present time, further consideration of the appropriate use of a degree-of-hazard concept in regulating NIHW is warranted, given the increased attention this concept has received domestically and internationally. A recent report of the North Atlantic Treaty Organization (NATO) indicates that definition and classification of hazardous waste is a task that requires attention by member countries. The NATO countries have followed three approaches:

- describing hazardous waste in qualitative terms,
- defining hazardous waste using criteria based on standard testing procedures, and
- defining hazardous waste by the quantity of harmful constituents.

The end-result for each country has been an industrial waste list that varies in detail and in the number of hazardous categories.

Before applying a full-scale effort toward designing an appropriate classification system, important questions require resolution:

- Is there is a need to change or modify the current regulatory approach?
- Can appropriate criteria for a degree-of-hazard classification be established?
- Can the analytical burden imposed on industry be efficiently reduced by a degree-of-hazard classification system?

1. Is there a need to change the current Federal approach?

Now that the Environmental Protection Agency (EPA) has begun formulating the regulatory structure for managing NIHW, an evaluation of the advantages and disadvantages of a degree-of-hazard concept is appropriate before decisions can be made to implement this type of approach. Consideration of what can be gained by changing or modifying the current structure is needed. Serious questions concerning the degree-of-hazard approach include:

- What are the costs required of EPA for additional research and development efforts aimed toward the design of an appropriate scheme? What are the costs in time lost for regulating and enforcing proper management of NIHW while a scheme is being developed? Any benefits derived from using a classifying system based on degree of hazard must be greater or at least equal to these development and opportunity costs.

- What evidence exists to support the contention that use of a degree-of-hazard concept in managing NIHW would be more cost effective than the current program? To date quantitative evidence does not exist. An in-depth analysis of this point is needed before encouragement or condemnation of the concept can be made.
- Is it necessary to change the current regulatory structure in a drastic way? It may not be necessary to apply a degree-of-hazard system as a replacement for the current regulatory approach. The EPA program is relatively new and opportunities exist whereby this type of system can be integrated in an evolutionary manner in the current program. Incorporating a degree-of-hazard scheme as a component of the current program would reduce transitional uncertainties that are sure to arise if the entire regulatory system were to be changed abruptly.
- Are there sufficient data currently available to apply an appropriate degree-of-hazard classification system? In which areas will it be necessary to do basic or targeted research before such a system can be developed? Are there substantial problems related to testing techniques, available standards for measurements, and variability of data? These questions are now being examined by OTA.
- What is the most appropriate group for expeditiously designing this type of management system: EPA, private or Government research groups (e. g., National Bureau of Standards), or organizations that represent several interested parties (e. g., consumers, producers, regulators)?

While advocates of a degree-of-hazard classification and management system agree that these questions are important, they argue that the current program is inadequate, and suggest that a degree-of-hazard scheme could be developed and effectively implemented. The California Office of Appropriate Technology (OAT) study indicates that categorization of industrial waste is possible and recommends that Department of Health Services should develop a "categorization scheme for hazardous waste as a means of linking waste with preferred methods of treatment and disposal . . ."(37) A recent cost-benefit analysis finds:(39)

> . . . that more stringent (and therefore more costly standards) should be set on the more hazardous waste and less stringent standards for those waste that pose smaller health risks. If one set of standards is imposed on all types of health risks, a serious misallocation of resources will result with some risks being overregulated, in the sense that dollars spent elsewhere would provide greater reduction in health risks and perhaps, some hazardous waste risks not being regulated strictly enough.

Thus the current EPA attitude, supporters suggest, should be to encourage rather than discourage investigation of the concept.

Critics of EPA's regulations have made the following statements:

- The waste are not categorized by intrinsic properties that could lead to a hazardous situation.
- The criteria for listing waste rely primarily on measures of genetic impairment and acute toxicity; measures related to mobility, degradability, and long-term exposure are needed also.
- Performance standards, as currently proposed, do not provide adequate guidelines for the uniform application of the permitting process.
- The current approach leads to extensive regulation of high-volume, low-hazard waste and inadequate regulation for very low-volume, but extremely high-hazard waste.
- The current regulations do not encourage a cost-effective means to control NIHW nor to recover components from it, and because of its exclusive rather than inclusive orientation may actually encourage increased activity to remove large quantities of hazardous waste from regulatory control.

2. **Can appropriate criteria** for hazard classes be established?

Although specific criteria are proposed for all the classification methods, the justification for selected criteria has not been provided or thoroughly investigated. Given the paucity of information about the cause-effect relationship between some compounds and environmental or health hazard plus the uncertainties surrounding the extrapolation of data from one species to estimates of risk for another, skeptics have suggested that scientific justifications cannot be developed for a standardized classification system. The specificity of hazardous conditions and the extreme diversity of NIHW prevents the development of realistic guidelines or standards related to a degree-of-hazard approach. In the current climate of decreasing resources, development of a degree-of-hazard system may produce an unwarranted burden for data-collection. The current program is not yet complete and there is little justification at this date to discount the effectiveness of EPA's approach.

With increasing emphasis on cost-benefit analyses by EPA and the current administration, supporters of a degree-of-hazard concept maintain that technical justifications and scientifically based criteria can and must be developed if the current program is to operate effectively. Moreover, establishing boundaries for a classification system would be no different from setting standards (e. g., EPA standards established for permissible levels of regulated substances). The task is not easy, however; it could take several years to develop a workable system, one that improves existing systems. (The current regulatory program also will take time before it is fully implemented, e.g., EPA has suggested it could be up to 6 years before facilities receive permits.) The variety of preparatory efforts that are necessary include a review of those data currently available (e. g., chemical, physical, and toxicological) and those data needed to establish the system; evaluations of interrelatedness of data for classes of compounds; directed research to justify certain boundaries or criteria for classes of compounds; and development of models of environmental fate and projected health impacts to suit degree-of-hazard evaluations.

The concept of degree of hazard is not new. Assessments of the potential hazard to human health and the environment created by many types of materials are required in other environmental regulations (e. g., Clean Air Act; Clean Water Act; Federal Insecticide, Fungicide, and Rodenticide Act; TSCA; and Superfund) and much of the preparatory work discussed above has been initiated already. In fact, EPA has explored the possibility of developing a screening mechanism for compliance with TSCA that groups new chemical notifications by categories of high, medium, and low risk. (40) Drawing upon the information and data required by these other regulations, the increased understanding of the principles for human and ecosystem toxicology, and elements of currently proposed classification systems, supporters suggest that scientifically justified criteria could be established for a degree-of-hazard classification scheme. These criteria could include the level of toxicity, safety characteristics, environmental fate, potential for movement once released to the environment, and concentrations released from the disposal facility; the establishment of these criteria at the national level would reduce much of the current uncertainties within the EPA program and could provide continuity among the State programs.

3. **Can the analytical burden** inherent **in** NIHW management be reduced by a degree-of-hazard approach?

Once any regulatory system is fully implemented, generators and disposers will be required to conduct some analytical tests on waste streams for use in leachate-monitoring activities. These tests include screening tests for chemical and toxicological properties for a wide range of compounds. Skeptics of a degree-of-hazard system contend that it is unclear whether the analytical and financial capability currently exists to accomplish the large-scale testing effort that a classification system could demand, particularly for small companies. While it is true that extensive testing could be required initially to facilitate classifying particular waste material, supporters of the concept argue that subsequent analysis required of industry is routine and minor by comparison. Extensive retesting is necessary only if and when the industrial process generating the waste has been changed or in those industries using batch processes. Also the development of adequate analytical capabilities is necessary even under the current regulatory system; the analytical burden imposed on industry for delisting a material now judged hazardous by EPA is currently substantial (even though EPA may not have provided a comparable analytical justification for listing the waste); thus supporters maintain that a degree-of-hazard concept would net add substantially to the analytical burden. This position, however, is controversial.

If a degree-of-hazard system is developed, it will be necessary to establish analytical criteria (chemical and toxicological) with some care. It is conceivable that the cost of meeting these criteria could be greater than actual disposal costs for small volume or one-time waste generators (i. e., waste generated through cleanup of a process unit or through accidental upset in the system; waste resulting from batch rather than continuous processes where the waste composition varies from job to job). Care will be needed to develop analytical criteria and methodologies which are economically and technically applicable to these situations as well as to large-scale waste generation.

Federal and industry efforts to validate data-gathering activities for multiple evaluation of similar waste and similar facilities could reduce some of the costs and eliminate duplication of effort. Considerable effort will be needed to establish accredited laboratories where required tests can be performed. Establishing a network of laboratories could reduce the economic burden for small and large industries alike. Some effort in developing test methodology will be needed. Although test protocols may already be available for analysis in one medium (e. g., water) they generally are not easily transferable to other media (e. g., air or soil).

Conclusion

In its ongoing assessment of nonnuclear industrial waste disposal, OTA will continue its investigation of the advantages and disadvantages of degree-of-hazard classification and the potential for incorporating it into a regulatory policy framework. Further evaluation is needed to answer the questions raised here and to identify, if not resolve, the uncertainties that can emerge when developing a classification and management system based on degree-of-hazard, rather than some qualitative use of the concept only. Of particular importance is an assessment of how to implement such a scheme — no t necessarily as a replacement, but as a growing component of the current program. For example, it may be appropriate to maintain the national framework as it currently exists and to incorporate degree-of-hazard classification in areas dealing with permitting or liability requirements. Another alternative is to allow the States, as ultimate managers of the nonnuclear industrial hazardous waste (NIHW) problem, to develop degree-of-hazard classification and management systems within their programs. If this were a practical outcome of an implementation analysis, then efforts to develop uniform criteria within the Environmental Protection Agency (EPA) regulations would be desirable. Full implementation of such a system requires developing a set of technological criteria and treatment/disposal alternatives for managing the various classes of waste. The availability of these alternatives is another area of some uncertainty that requires further investigation.

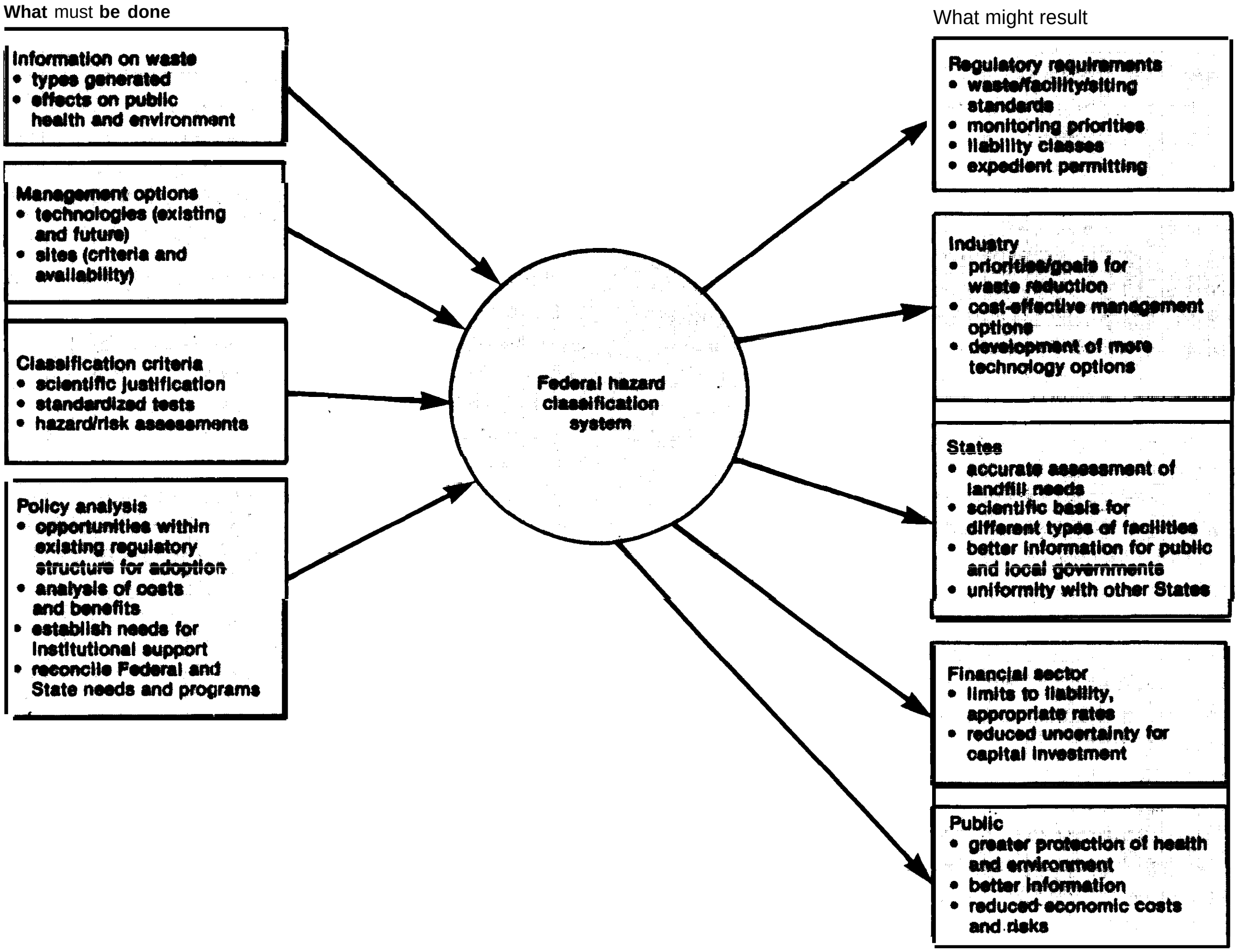
Figure 4 summarizes those areas that require further research, development, and analysis, and the possible benefits of implementing a Federal hazard classification system for management of industrial waste. Before a Federal system can be designed and implemented it will be necessary to develop information about waste generation, management needs and options, classification criteria, and policy opportunities, and the costs of obtaining these, Without addressing these information needs and the uncertainties surrounding them, the optimistic results indicated in figure 4 may not occur or classification could have negative impacts on a national waste management effort. If properly developed, however, a hazard classification system might provide a cost-effective means of handling the hazards posed by management of industrial waste. However, an analysis of the current approach and a degree-of-hazard approach is needed.

The problems and uncertainties of developing and applying a degree-of-hazard classification and management system to NIHW might be resolved by combining the interests of the public for health protection, the needs of industry, the initiative of State programs, and the efforts of the scientific community, The anticipation of a greater potential for protecting human health and the environment and long-term economic benefits provides an important incentive for reconsidering this concept as a potentially cost-effective way to manage NIHW.

Development of an efficient management system, whether it follows a classification approach or not, requires that certain factors be taken into account. The system must be designed to maximize compliance and must be enforceable; therefore, it is necessary to consider ultimate ease of administration and capability for institutional compliance. If the system undergoes frequent and unrealistic changes, tremendous problems can result, as was emphasized by the Conservation Foundation's report on low-level radioactive waste disposal. **(18)**

> The proper role of the scientist in defining and classifying . . . waste, now often unclear, frustrating and constantly changing, is also a key element in establishing an administratively workable system. Scientists initially develop the information used in promulgating standards and then are required to comply with and implement classification systems that have emerged from the political process. However, the rules that emerge from the standards-setting process may not reflect the actual capability or practice of those who must comply with them.

Figure 4.—Research, Development, and Analysis Requirements and Possible Benefits of Implementation of a Hazard Classification System



SOURCE: Off Ice of Technology Assessment.

Finally, resource constraints must be assessed realistically. A well-designed, cost-effective management system will make certain that the limited resources–whether economic or man-power—are directed toward waste that pose the greatest risks for both the short and long terms for human health or the environment.

Appendix: Dangerous Waste Criteria for the State of Washington

The following description illustrates the categorization of one class of waste and suggests methods for applying the scheme to waste mixtures. This information was provided by the Department of Ecology, State of Washington.

WAC 173=303=100 Dangerous Waste Criteria

(I) The Dangerous Waste Criteria consist of:

(a) The "Dangerous Waste Characteristics, WAC 173-303-090;

(b) Toxic Dangerous Waste, WAC 173-303-101

(c) Persistent Dangerous Waste, WAC 173-303-102; and

(d) Carcinogenic Dangerous Waste, WAC 173-303-103.

(2) Applicability. Any person who has established that his waste meets any of the Dangerous Waste Criteria is a dangerous waste generator, and shall comply with the requirements set forth in this chapter for generators.

(3) Relation to Lists. The Dangerous Waste Criteria shall be the primary means used by the department to modify the Dangerous Waste Lists set forth under WAC 173-303-080.

WAC 173=303=101 Toxic Dangerous Waste

(1) Purpose. This section describes methods for determining the toxicity of a waste and the criteria by which a toxic waste shall be designated as a dangerous or extremely hazardous waste.

(2) Categorization. Table A-1 establishes categories (X, A, B, C, or D) for particular toxicity levels. The X category is the most toxic, and the D category is least toxic. Substances which have toxicity levels below the D category are generally considered to be nontoxic.

Table A-1 .—Toxic Category

Category	Aquatic (fish) LD_{50} - (ppm)	'Oral (rat) LD_{50} (mg/kg)	Inhalation (rat) LC_{50} (mg/L)	Dermal (rabbit) LD_{50} (mg/kg)
x -	< 0 1	< 0 5 -	<002	-<-2
A	0 1 - 1	055	002-02	2-20
B	1 10	5 - 5 0	0 2 - 2	20-200
c	10- 100	50-500	2 . 2 0	200-2000
D	100- 1 000	500-5000	20-200	200-20,000

(3) Establishing Waste Toxicity. A person shall establish the toxicity of his waste or waste constituents by applying his knowledge about his waste, and/or by using the following information sources and testing methods:

(a) The National Institute for Occupational Safety and Health (NIOSH) document "Registry of Toxic Effects of Chemical Substances" (Registry);

(b) The U.S. EPA's regulation 40 CFR table 117.3 (Spill Table); and

(c) The bioassay testing methods adopted under WAC 173-303-110 (3).

(4) Book Designation Procedure.

(a) A person may use the Book Designation Procedure described in this paragraph only if:

(i) He knows the toxicity categories (as set forth in paragraph (2), above) for the significant toxic constituents in his waste;

(ii) He knows the concentrations of the significant toxic constituents in his waste; and

(iii) He can demonstrate to the department beyond a reasonable doubt that any waste constituents about which he has limited or no knowledge do not significantly affect the toxicity of his waste.

(b) Equivalent Concentration (E. C.). A person who is book designating his waste shall determine the equivalent concentration (in percent) of the toxic constituents in his waste by using the following formula:

$$E.C.\ (\%) = X\% + \frac{A\%}{10} + \frac{B\%}{100} + \frac{C\%}{1,000} + \frac{D\%}{10,000}$$

where (X, A, B, C, or D) 70 is the sum of all the concentration percentages for a particular toxic category.

Example 1. A person's waste contains: Aldrin (X category)-O.Ol%; Diuron (B category)-1%; Benzene (C category)-4%; Phenol (C category)-2 %; Cyclohexane (C category)-5 70; Water (nontoxic)— **87%.** His equivalent concentration (E. C.) would be:

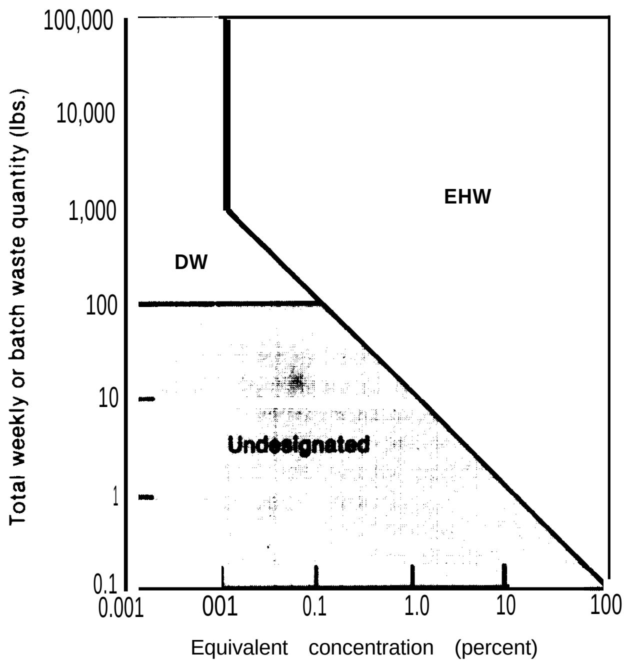
$$E.C.\ (\%) = 0.01\% + \frac{0\%}{10} + \frac{1\ \%}{100} + \frac{(4\% + 2\% + 5\%)}{1{,}000} + \frac{0\%}{10{,}000}$$

$$= 0.01\% + 0\% + 0.0170 + 0.01170 + 0\% = 0.03170$$

So his equivalent concentration equals 0.031%.

(c) Toxic Dangerous Waste Graph. To book designate his waste, a person-shall use the Toxic Dangerous Waste Mixtures Graph below (fig. A-1) by finding the equivalent concentration percentage for his waste along the absicissa, finding his total waste quantity along the ordinate, and plotting the point on the graph where the horizontal line drawn from his total waste quantity intersects the vertical line drawn from his waste mixture's equivalent concentration. If the plotted point is in the area marked dangerous waste (DW), he shall designate his waste as a dangerous waste; if the plotted point is in the area marked extremely hazardous waste (EHW), he shall designate his waste as an extremely hazardous waste.

Figure A-1 .—Toxic Dangerous Waste Mixtures



DW = dangerous waste
EHW = extremely hazardous waste

SOURCE: E. W. Tower, Solid Waste Management Division, Off Ice of Land Programs, Department of Ecology, State of Washington, Olympia, Wash

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