AD-A139 213 COMBUSTION TECHNOLOGY FOR INCINERATING WASTES FROM AIR FORCE INDUSTRIAL PROCESSES(U) NATIONAL BUREAU OF STANDARDS WASHINGTON DC W M SHAUB ET AL. FEB 84 1/2

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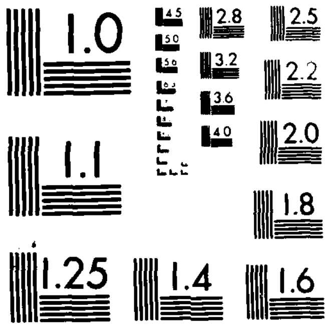

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COMBUSTION TECHNOLOGY FOR INCINERATING WASTES FROM AIR FORCE INDUSTRIAL PROCESSES

W.M. SHAUB, WING TSANG

NATIONAL BUREAU OF STANDARDS
WASHINGTON D.C. 20234

FEBRUARY 1984

FINAL REPORT
JUNE 1981 - JUNE 1983

AFESC

ENGINEERING AND SERVICES LABORATORY
AIR FORCE ENGINEERING AND SERVICES CENTER
TYNDALL AIR FORCE BASE, FLORIDA 32403

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ESL TR-83-14	2. GOVT ACCESSION NO. AD-A139 313	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) COMBUSTION TECHNOLOGY FOR INCINERATING WASTES FROM AIR FORCE INDUSTRIAL PROCESSES		5. TYPE OF REPORT & PERIOD COVERED Final Report Jun 81 - Jun 83
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Walter M. Shaub Wing Tsang		8. CONTRACT OR GRANT NUMBER(s) MIPR N 8146
9. PERFORMING ORGANIZATION NAME AND ADDRESS National Bureau of Standards Washington D.C. 20234		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS PE 63723F JON 21037012
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Engineering and Services Center Tyndall Air Force Base, Florida 32403		12. REPORT DATE February 1984
		13. NUMBER OF PAGES 113
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution Unlimited: Approved for Public Release.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Availability of this report is specified on reverse of front cover.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Incineration	Energy Recovery
Hazardous Wastes	Pollution Control
Combustion Technology	Incinerability Index
Resource Recovery	Destruction and Removal Efficiencies
Solid Waste Management	Thermal Processing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Air Force bases, particularly Air Logistics Centers, generate significant amounts of process wastes from a variety of industrial operations. Some of these wastes are classified hazardous under the Resource Conservation and Recovery Act and are properly disposed at cost to the Air Force. Onsite incineration with heat recovery is being considered as a disposal option, to reduce the overall disposal costs. Since relatively small amounts of single wastes are generated at any one base, an incineration system must be flexible to handle a wide variety of materials.

(Continued)

- Results indicate a technical basis for using Air Force industrial wastes as supplemental fuels. Suggestions made in this report should enable Air Force personnel to design and execute programs to destroy such wastes, recover energy, and show empirically that applicable environmental laws and regulations have been properly taken into account. Furthermore, a technique to allow decision makers to select least-cost options to use the suggestions made in this report exists, i.e., a modified form of the resource recovery planning model (RRPLAN) developed at the National Bureau of Standards.

PREFACE

This report was prepared by personnel of the National Bureau of Standards, Washington, DC 20234, under MIPR N 8146 for the Air Force Engineering and Services Center, Engineering and Services Laboratory (AFESC/RDVW), Tyndall Air Force Base, Florida 32403. The report describes work performed between June 1981 and June 1983.

The AFESC/RD Project Officer was Captain Randy L. Gross.

Results indicate that there is a technical basis for using Air Force industrial wastes as supplemental fuels. Suggestions made in this Report should enable Air Force personnel to design and execute programs to destroy such wastes, recover energy, and show empirically that applicable environmental laws and regulations have been properly taken into account. Furthermore, a technique to allow decision makers to select least-cost options to use the suggestions made in this report exists, i.e., a modified form of the resource recovery planning model (RRPLAN) developed at the National Bureau of Standards.

This report has been reviewed by the Public Affairs Office (PA) and is releasable to the National Technical Information Services (NTIS). At NTIS it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication.

RANDY L. GROSS, Capt, USAF, BSC
Project Officer

ROBERT E. BOYER, Col, USAF
Director, Engineering and Services Laboratory

JIMMY N. FULFORD, Lt Col, USAF
Chief, Environics Division

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SECTION I

INTRODUCTION

Air Force personnel responsible for assuring that the USAF meets all requirements of existing laws and Executive Orders pertaining to treatment, storage and disposal of industrial process wastes have concluded that:

- Air Force bases, particularly Air Logistics Centers, generate significant amounts of process wastes from operations such as paint removal, electroplating, industrial waste treatment, carbon removal and cleaning. Some of these wastes are classified as hazardous under the Resource Conservation and Recovery Act, and all are handled and disposed of appropriately at Air Force expense.

- Over the long term, thermal processing (including pyrolytic and excess air incineration) may be a suitable alternative for reducing waste volume, mass and toxicity. Recovery of the heat released during thermal processing could reduce the costs of waste incineration.

- Normally, relatively small amounts of individual wastes are generated at a given location, presenting strong economic limitations to incineration systems designed for a single material. Some potential exists for developing a single thermal processing technology with the flexibility to be used individually on a variety of wastes. Such a system could make feasible the reduction or elimination of a variety of process wastes in an environmentally compatible, energy-efficient and cost-effective manner.

- Before such a system can be implemented, considerable developmental work is required to chemically characterize the waste materials generated, estimate their performance in a field-scale thermal processing system, determine the expected pollutant emissions (ash, residue, gases), and derive a quantitatively based design concept for a prototype system, subject to follow-on test and evaluation.

The implications of these conclusions were discussed by personnel of the Air Force Engineering and Services Center (AFESC), Tyndall Air Force Base and the National Bureau of Standards (NBS). As a result of these discussions, AFESC contracted for NBS to perform the developmental work required to characterize the wastes and to suggest means to deal with them in an environmentally and economically sound manner. The specific tasks assigned to NBS were as follows:

Task 1: Literature Review. Conduct a literature review dealing with the chemical analysis, chemical composition, combustion parameters and characteristics, environmental aspects, corrosion potential and incineration of industrial process wastes, including: paint chips, chlorinated solvents, oil and grease sludges, oil skimmings, waste hydraulic fluids, carbon removal baths, highly concentrated phenolic solutions, general industrial waste sludges and waste nonrecyclable petroleum oils and lubricants.

Task 2: Chemical Characterization. Advise and carry out research on procedures for the characterization of industrial process wastes.

Task 3: Combustion Analysis. Determine and quantify the essential combustion parameters of industrial process wastes with respect to heat-recovery thermal processing system design.

Task 4: Environmental Analysis. Estimate the potential environmental problems associated with unabated combustion (pyrolytic and excess air) of industrial process wastes.

Task 5: Corrosion Potential. Advise and carry out necessary research on the corrosion potential associated with a facility capable of using all waste materials separately.

Task 6: Heat-Recovery Potential. Quantify the heat-recovery potential associated with industrial process wastes.

Task 7: System Concept. Provide a recommended system concept for a facility capable of heat-recovery thermal processing of industrial process wastes.

In addition, NBS was to obtain samples of the wastes listed above at various Air Force bases. However, because of the wide variability of the wastes on each base, representative samples could not be provided. As a result, some aspects of Tasks 2, 3, 5, and 6 could not be performed.

This Final Report includes the following major categories:

1. A careful search and evaluation of existing data pertaining to energy recovery from incineration of potentially hazardous wastes,

2. Detailed strategies which would enable the Air Force to establish a program for incinerating various wastes in a manner which would allow compliance with enviromental requirements at lowest cost to the Air Force (i.e., economic and hazard assessments taken into account),

3. A consideration of the physical basis of hazardous wastes incineration in order to suggest incinerability scales, and

4. A brief listing of current legislative and regulatory activities which might affect Air Force incineration actions.

With this report, the Air Force can evaluate the suitability of existing equipment to incinerate Air Force wastes in an environmentally acceptable, efficient process.

SECTION II

LITERATURE REVIEW

Examination of published data and conclusions concerning incineration of hazardous wastes allowed a critical evaluation of these results to determine what is and is not known about all aspects of energy recovery from industrial wastes used as fuels. Appendix I lists a selected group of publications (many more were reviewed) which provide a suitable cross section of data and results for making the "know" or "do not know" decisions.

Based on our review of the existing literature, NBS concluded that the following issues can be resolved without further Air Force research:

1. Corrosion problems; the boiler manufacturer can design to minimize these difficulties. Certainly, the corrosive nature of wastes used as supplemental fuels cannot be ignored, but given present knowledge, such characteristics can be taken into account,

2. Heat recovery methods; waste heat boilers are commercially available,

3. Economic evaluation of various systems for waste destruction combined with heat recovery,

4. Control of atmospheric emissions by particulates, HCl, Cl, and other common pollutants arising from combustion processes,

5. Staff training requirements.

On the other hand, NBS concluded that the following issues are unknown or highly uncertain:

1. Origins of unwanted organic emissions, e.g., possible formation of dioxins during combustion,

2. Control and/or prevention of organic emissions from energy-recovery unit process modifications that can result in meeting environmental requirements at lowest cost and risk,

3. Existence of means and methods to verify successful control and/or prevention of organic emissions from energy-recovery units,

4. Methods to assess hazards to humans and ecosystems as a result of incineration of industrial process wastes in various combustion chambers,

5. Systems analysis methods to correctly compare economic aspects of options to recover energy, reuse, recycle, market, treat, or

dispose of various wastes created in variable quantities over wide geographic areas, and

6. Possible impact of pending legislation, regulations, and judicial interpretations of existing laws and regulations.

Accordingly, NBS has chosen to deal with these "unknowns" as individual entities. What follows is meant to provide a detailed strategy for dealing with the first five issues on the foregoing list as well as an "awareness" statement concerning the last item.

SECTION III

UNKNOWN (1): ORIGINS OF UNWANTED ORGANIC EMISSIONS, E.G., POSSIBLE FORMATION OF DIOXINS DURING COMBUSTION

GOAL

- Identify physical and chemical processes which control the formation of dioxins during combustion to delineate operations which will minimize dioxin emissions from municipal incinerators or Energy-Recovery Units (ERUs).

OBJECTIVES

- Use existing literature to establish a basis for constructing models for gas- and non-gas-phase dioxin formation during combustion, then construct the models.

- Compare dioxin emission levels predicted by the models with reported dioxin emission levels from municipal incinerators and ERUs.

- Suggest possible engineering operations to control dioxin emissions from municipal incinerators and ERUs.

BACKGROUND KNOWLEDGE OF DIOXIN FORMATION AND DESTRUCTION IN THERMAL ENVIRONMENTS

Field Measurements

- There is great variability in the levels of particle-bound and gas-phase dioxin emissions from thermal processing units.

- Other chloroorganics are observed to be emitted when dioxins are emitted, e.g., chlorodibenzofurans, chlorophenols, and chlorobenzenes. Chlorophenols and chlorobenzenes are usually more predominant than dioxins and furans.

- There is partioning of dioxins between the gas and fly ash in emissions. This partitioning is variable, but generally, there appears to be as many or more dioxins in the gas phase in the postflame combustion zone than in the solid phase. This apportionment may reverse on exit from the stack of an incinerator or ERUs.

- In emissions, isomer distributions are often skewed towards increasingly chlorinated species.

Laboratory Measurements

- Dioxins can be formed from chlorobenzenes and chlorophenols when these are heated in quartz ampoules with oxygen at elevated temperatures.
- Chlorodibenzofurans are preferentially formed from PCBs in similar experiments.
- There are many catalysts and pathways for the synthesis of dioxins.
- Dioxins can be formed by heating coal in the presence of HCl or Cl_2. Dioxin formation from heating coal in the presence of NaCl is much less.
- Dioxins can be readily destroyed at elevated temperatures.
- Dioxins can be formed as secondary products from various reactions under various conditions.
- Comparisons between some laboratory and field measurements show similarities in isomer distribution patterns.
- Dioxins can be formed by heating wood in the presence of air saturated with HCl.

Theoretical Analyses

- There are no thermodynamic equilibrium barriers to dioxin destruction at elevated temperatures.
- Dioxin formation and destruction is controlled by kinetic processes and mass transport effects in municipal incinerators and ERUs.
- Catalytic processes are probably operative in some laboratory experiments. Other non-gas-phase processes are also likely.
- Many hypothetical chemical pathways have been proposed.
- An increasing degree of chlorination of dioxins makes them more resistant to oxidative bimolecular attack.
- A statistically representative analysis of the chloroorganic compounds in the input waste feedstreams of municipal incinerators or ERUs may not be a practical possibility.

General Observation

- The above information has been selectively chosen to highlight what is known about dioxin formation and destruction in thermal environments. More information is available than has been outlined above.

PROBLEMS

Field Measurements

- Consensus sampling and analytical methods for dioxin emissions have not yet been established.
- There is uncertainty as to what measurements would be useful.
- The quality, completeness, and utility of reported measurement results are variable.

Laboratory Measurements

- In experiments, concentrations of reactants and reaction conditions are often not representative of those found in municipal incinerators or ERUs.
- Details of experiments and results should often be more completely reported to interpret results.
- In situ, noninterfering diagnostic methods for monitoring dioxin formation and destruction in thermal environments have not been developed and applied.

THEORY

- Currently proposed mechanisms for dioxin formation and destruction: (1) are not adequately delineated according to gas- and non-gas-phase contributions, and (2) have not been made quantitative.
- Kinetic data for individual chemical reaction steps in proposed mechanisms have not been obtained.
- ...butions of physical processes to dioxin formation and ...ion are not well characterized.

General

- Conse... us statistical methods for validating data in terms of the precision and accuracy of measurements, particularly with respect to the probability of false positives and false negatives, have not been applied.

PROGRAM

Thesis

- The construction of theoretical models for gas- and non-gas-phase dioxin formation and destruction processes is possible. These models can be used to provide insight about dioxin emissions from municipal incinerators and ERUs, which is consistent with stated goals and objectives.

Gas-Phase Modeling

Action

- Develop and apply a model to assess the likelihood that gas-phase processes contribute to the formation of dioxins in municipal incinerators and ERUs.

Approach

- Identify a likely precursor (chlorophenol) for dioxins to form from.

- Construct a "worst-case" model (beyond what is reasonably likely to occur) for gas-phase dioxin formation from the precursor.

- Test the model using input parameters, e.g., residence time, temperature, gas-phase species concentrations, which are typical of the thermal environment of a municipal incinerator or ERUs.

Non-gas-Phase Modeling

Action

- Develop and apply a model to assess the likelihood that non-gas-phase processes may be important contributors of dioxin emissions from municipal incinerators and ERUs.

Approach

- As an example, assume that a gas-solid catalysis process contributes to dioxin formation in municipal incinerators and ERUs.

- Construct a model for dioxin formation consistent with a gas-fly ash catalysis mechanism.

- Test the model using input parameters, e.g., residence time, temperature, gas-phase and fly ash surface species concentrations, which are typical of the thermal environment of a municipal incinerator or ERUs.

- Force the model to predict dioxin emission levels consistent with typical reported emission levels from municipal incinerators and ERUs.

- Determine if the kinetic parameters required to force the model predictions to agree with reported results are consistent with kinetic parameters characteristic of catalytic surface reactions and desorption processes.

Conclusions

1. Gas-phase dioxin formation processes alone cannot account for reported dioxin emissions from municipal incinerators and ERUs.

2. Catalytic and other non-gas-phase processes need to be considered in order to account for reported dioxin emissions from municipal incinerators and ERUs (References 1-3). Predicted rate parameters from modeling are consistent with expectations based on prior experience among chemical kineticists.

Predictions

1. Additional experiments can be designed that would provide further insight consistent with the stated goals and objectives of this section.

2. The goal of identifying process modifications for minimizing dioxin emissions from municipal incinerators and ERUs appears reasonable, based on research which has been performed to date. As brought out in several reports developed at the National Bureau of Standards (References 1-3), some potential operations for minimizing dioxin emissions from municipal incinerators and ERUs are recommended to the engineering community for further investigation. It is premature to speculate on the utility of the suggested approaches without an extensive program of carefully designed tests.

SECTION IV

UNKNOWN (2): CONTROL AND/OR PREVENTION OF ORGANIC EMISSIONS FROM ENERGY RECOVERY UNITS: PROCESS MODIFICATIONS THAT CAN RESULT IN MEETING ENVIRONMENTAL REQUIREMENTS AT LOWEST COST AND RISK

GOAL (BOILERS WILL BE CONSIDERED AS AN EXAMPLE OF AN ENERGY RECOVERY UNIT.)

- Delineate significant decisions concerning emission control methods for hazardous waste incineration in boilers.

OBJECTIVES

- Identify technical problems associated with hazardous waste incineration in boilers which may cause pollutant emissions.
- Identify engineering options which may reduce emissions produced from hazardous waste incineration in boilers.
- Develop a schematic diagram which suggests relationships between the technical problems and the engineering options.

BACKGROUND

- Boilers which incinerate hazardous waste mixtures may emit pollutants such as organic chemical compounds, particulates and HCl.
- Current federal regulations, as promulgated under RCRA, regulate permissible emission levels for many organic compounds when they are destroyed in incinerators. Those organic compounds which are regulated are called Principal Organic Hazardous Consitituents, or POHCs.
- In the future, these regulations may apply when incinerating hazardous waste mixtures in boilers. In that event, engineering options may be necessary to control pollutant emission levels from boilers.
- Engineering options may be determined by the technical problems associated with hazardous waste incineration in boilers.

PROBLEM

- It is difficult to determine engineering options which may be applied to control pollutant emissions produced by hazardous waste incineration in boilers.
- This difficulty is particularly pronounced when selecting engineering options for controlling POHCs emissions from boilers.

PROGRAM

Thesis

- A schematic diagram can be constructed to suggest how potential engineering options may be applied to control pollutant emissions resulting from the incineration of hazardous wastes in boilers.

Action

- Identify technical problems associated with the incineration of hazardous wastes in boilers which may result in pollutant emissions. Determine the relationships between the technical problems and possible remedial engineering options to control these problems. Use schematic diagrams to illustrate the potential problem-control option relationships.

Approach

- Examine the existing literature to determine if technical problems and potential control options have been reported.

- If the information obtained from the literature is incomplete, analyze technical uncertainties associated with pollutant emission and control in boilers by: (1) establishing theories which suggest the underlying physical and chemical nature of presently uncertain aspects of pollutant emissions, and (2) examining the implications for control options that these theoretical investigations may suggest.

- Determine relationships between technical problems and control options.

- Hierarchically order the technical problems and control options with respect to the sequence of events which, together, describe the incineration-energy recovery process in boilers. This sequence includes: (1) waste feed preparation, (2) waste injection into the boiler, (3) combustion of the waste, (4) postcombustion of the waste, (5) heat recovery, and (6) air pollution control.

- Construct a diagram (Figure 1) which: (1) suggests the relationships between technical problems and control options, and (2) illustrates the sequential events associated with hazardous waste incineration in boilers and resulting pollutant emissions.

RESULTS

- A delineation has been established regarding significant decisions which may be made concerning methods to control the emissions of pollutants. The delineation is presented in the

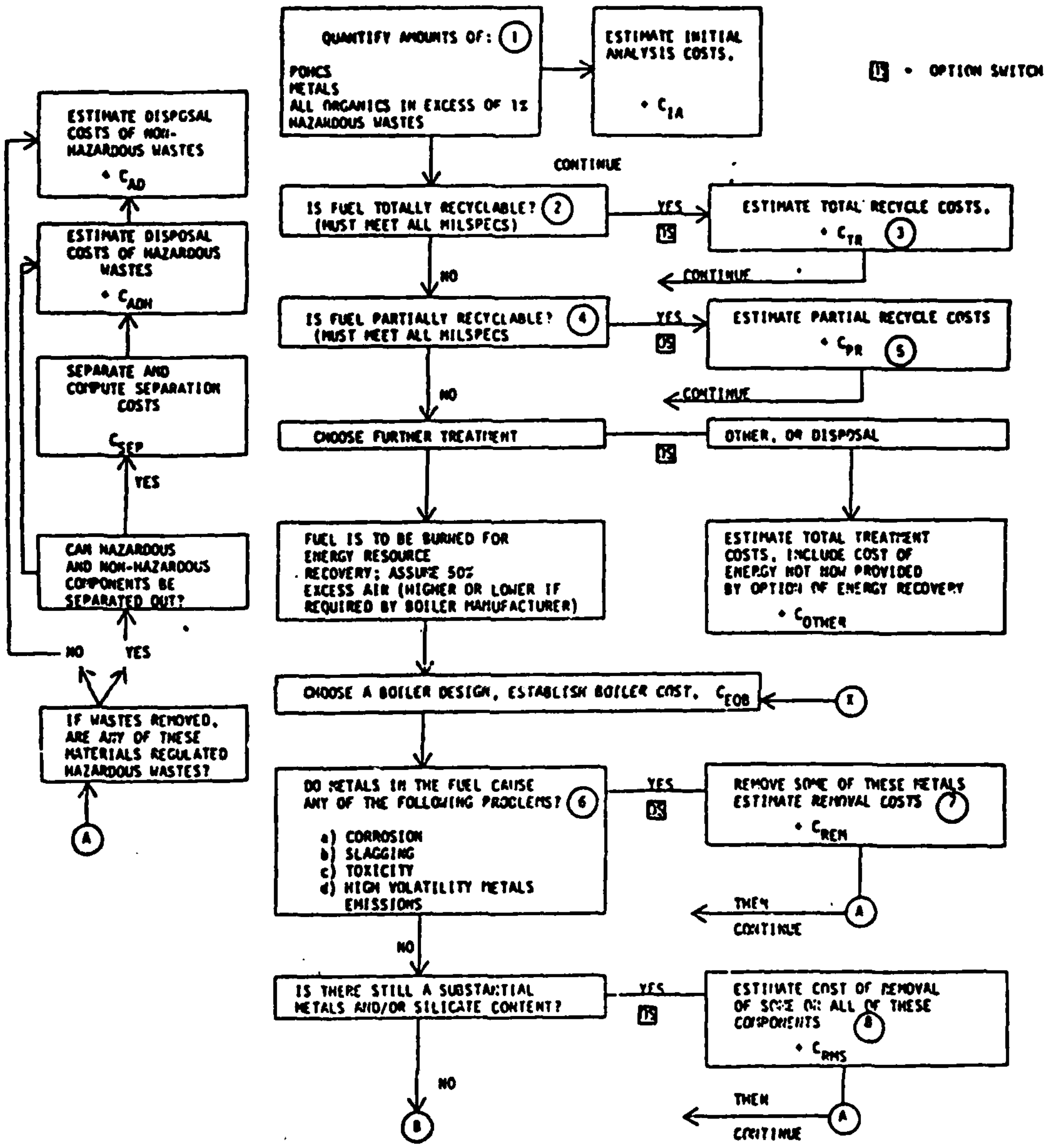


Figure 1. A Decision Scheme for Hazardous Waste Incineration and Energy Recovery in Boilers.

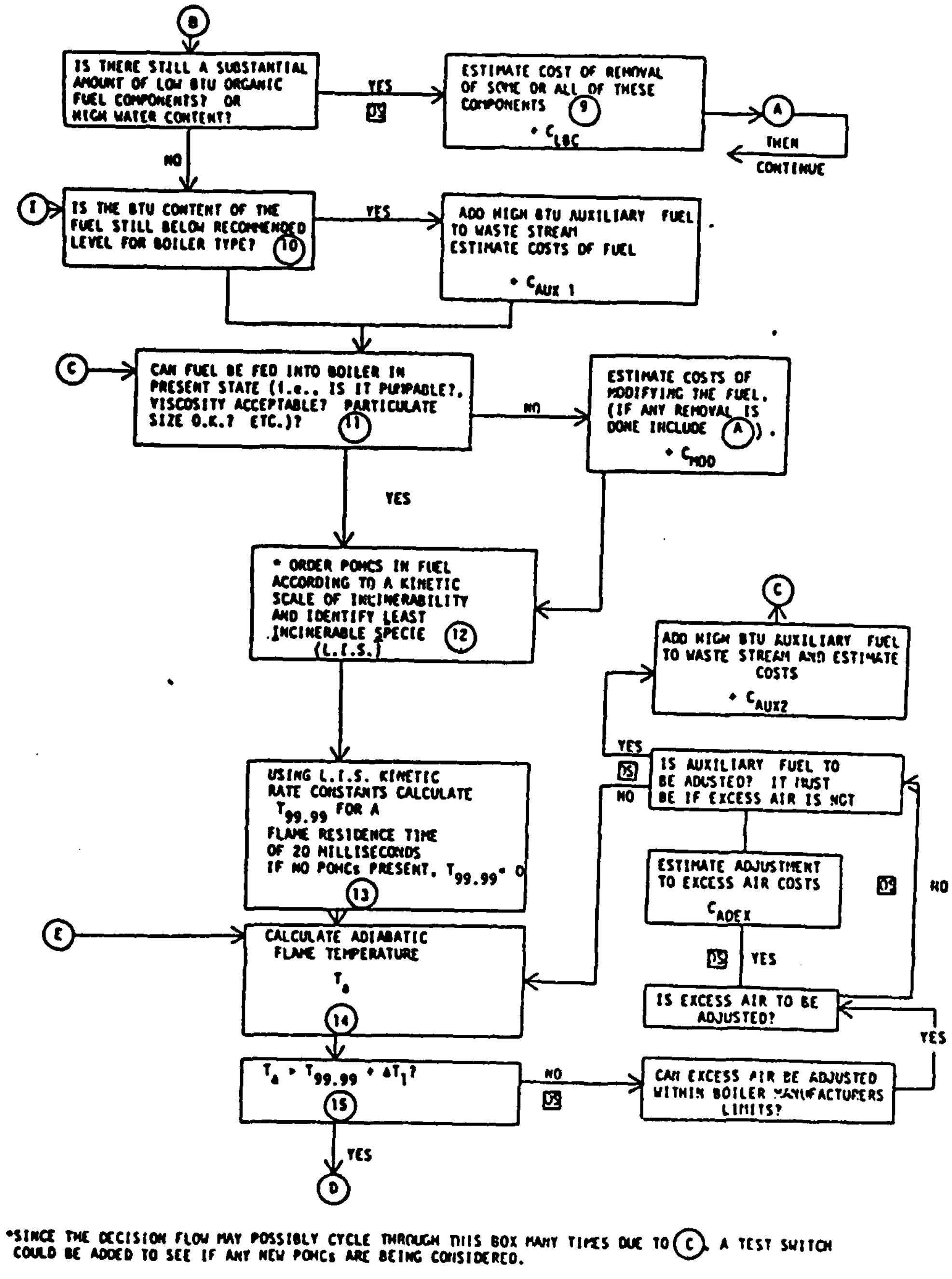
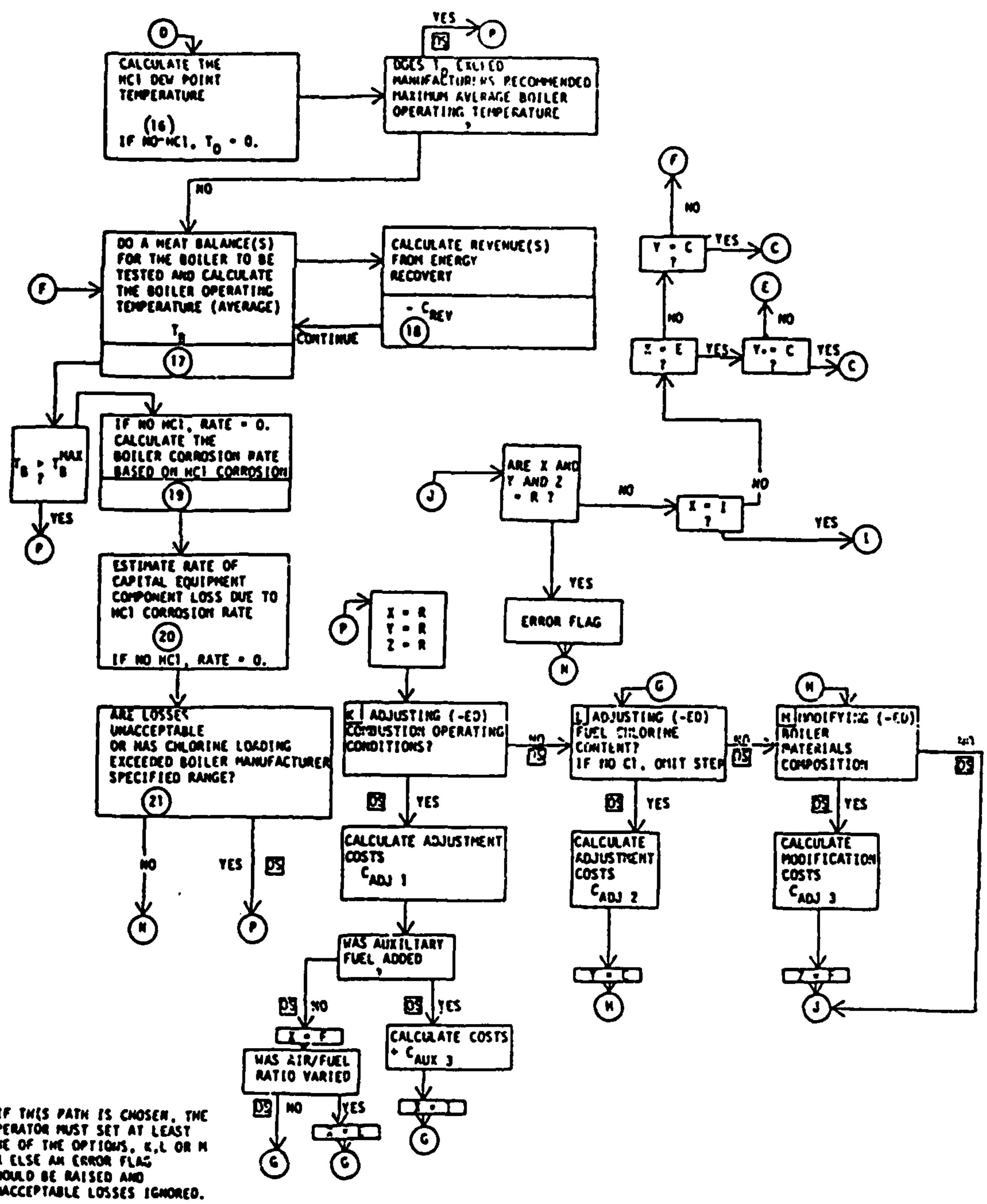


Figure 1. A Decision Scheme for Hazardous Waste Incineration and Energy Recovery in Boilers. (Continued)



*IF THIS PATH IS CHOSEN, THE OPERATOR MUST SET AT LEAST ONE OF THE OPTIONS, K,L OR M OR ELSE AN ERROR FLAG SHOULD BE RAISED AND UNACCEPTABLE LOSSES IGNORED.

Figure 1. A Decision Scheme for Hazardous Waste Incineration and Energy Recovery in Boilers. (Continued)

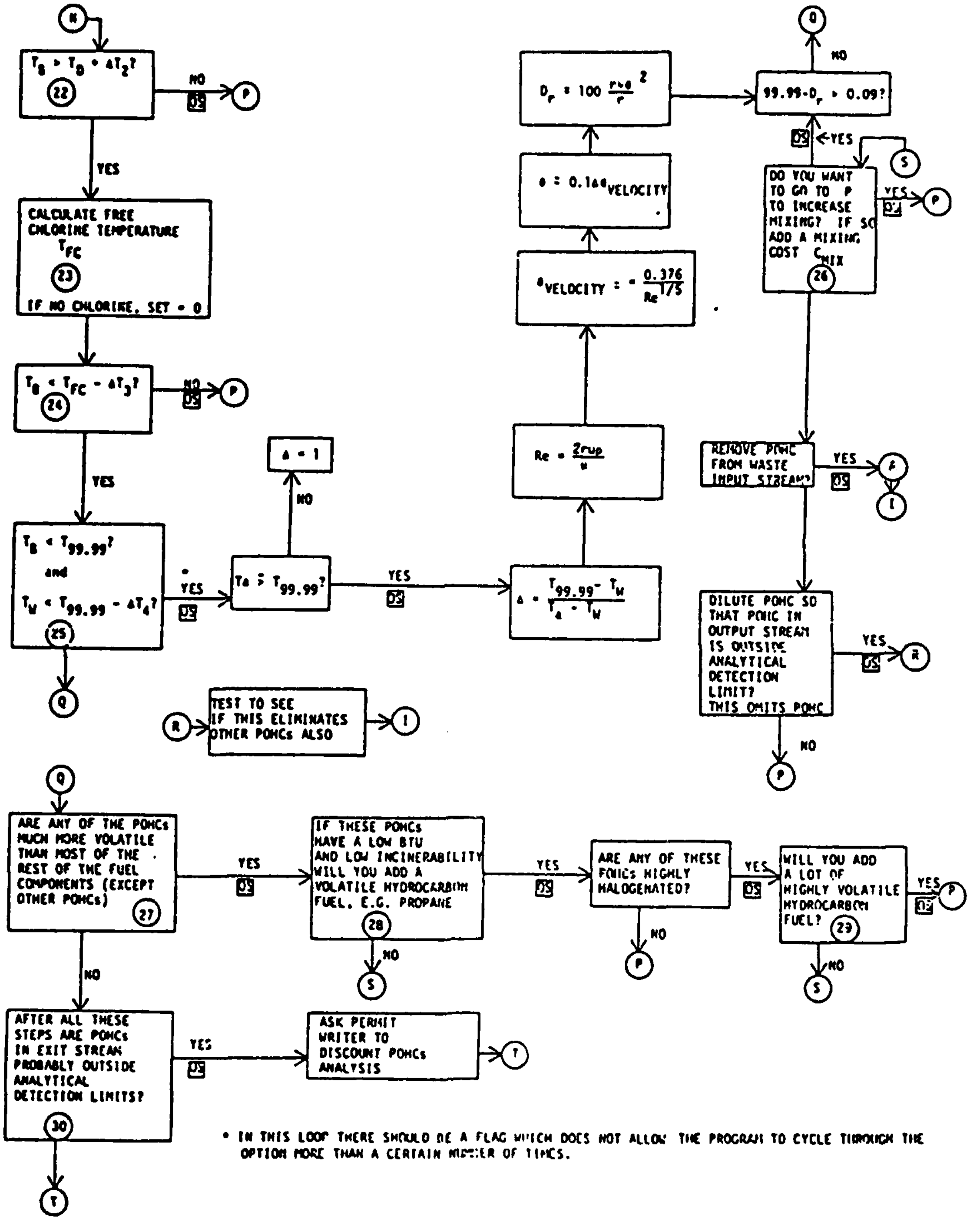
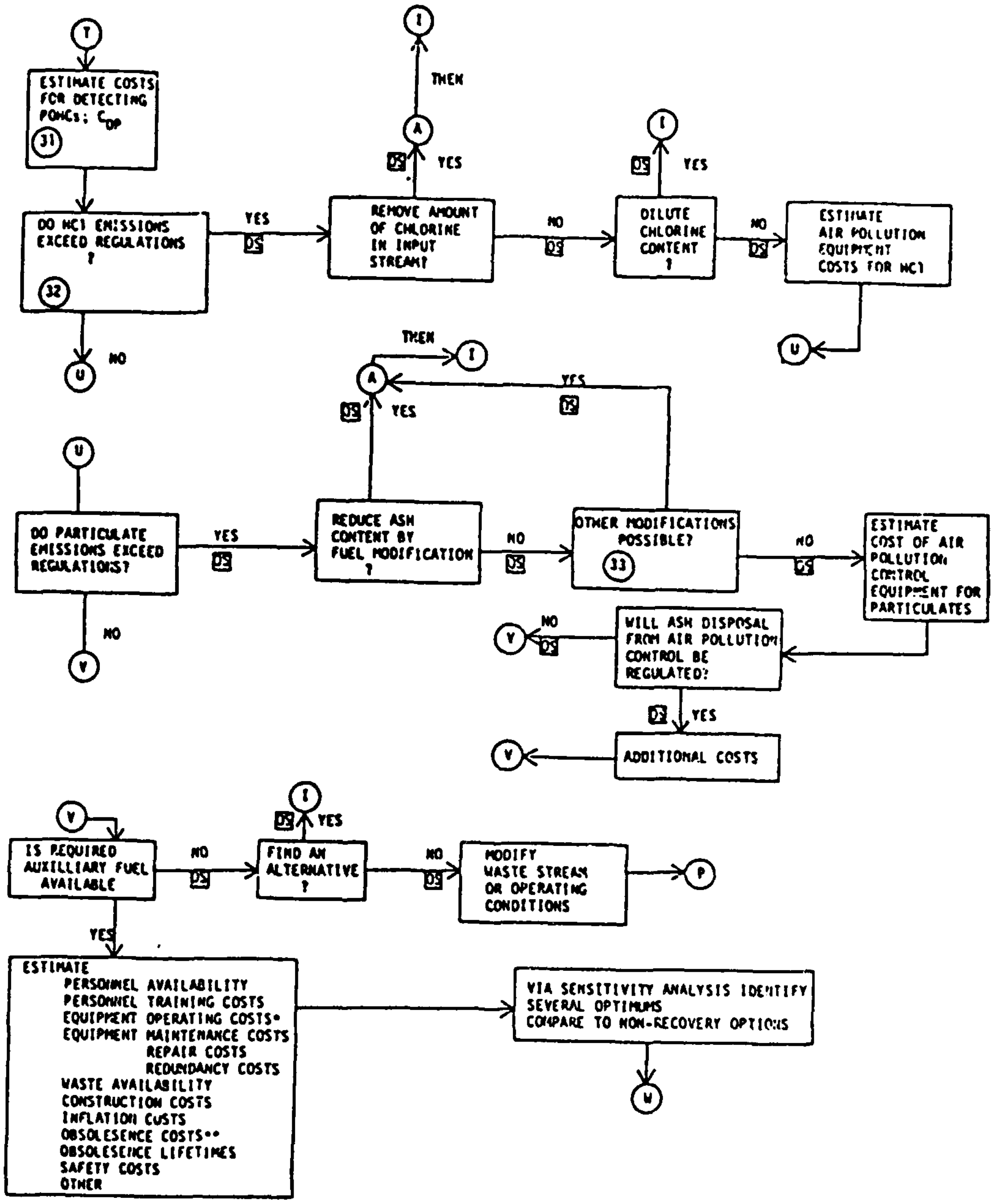


Figure 1. A Decision Scheme for Hazardous Waste Incineration and Energy Recovery in Boilers. (Continued)



* ANY NOT PREVIOUSLY ACCOUNTED FOR
** E.G. DISQUALIFIED BY BOILER CODES

Figure 1. A Decision Scheme for Hazardous Waste Incineration and Energy Recovery in Boilers. (Continued)

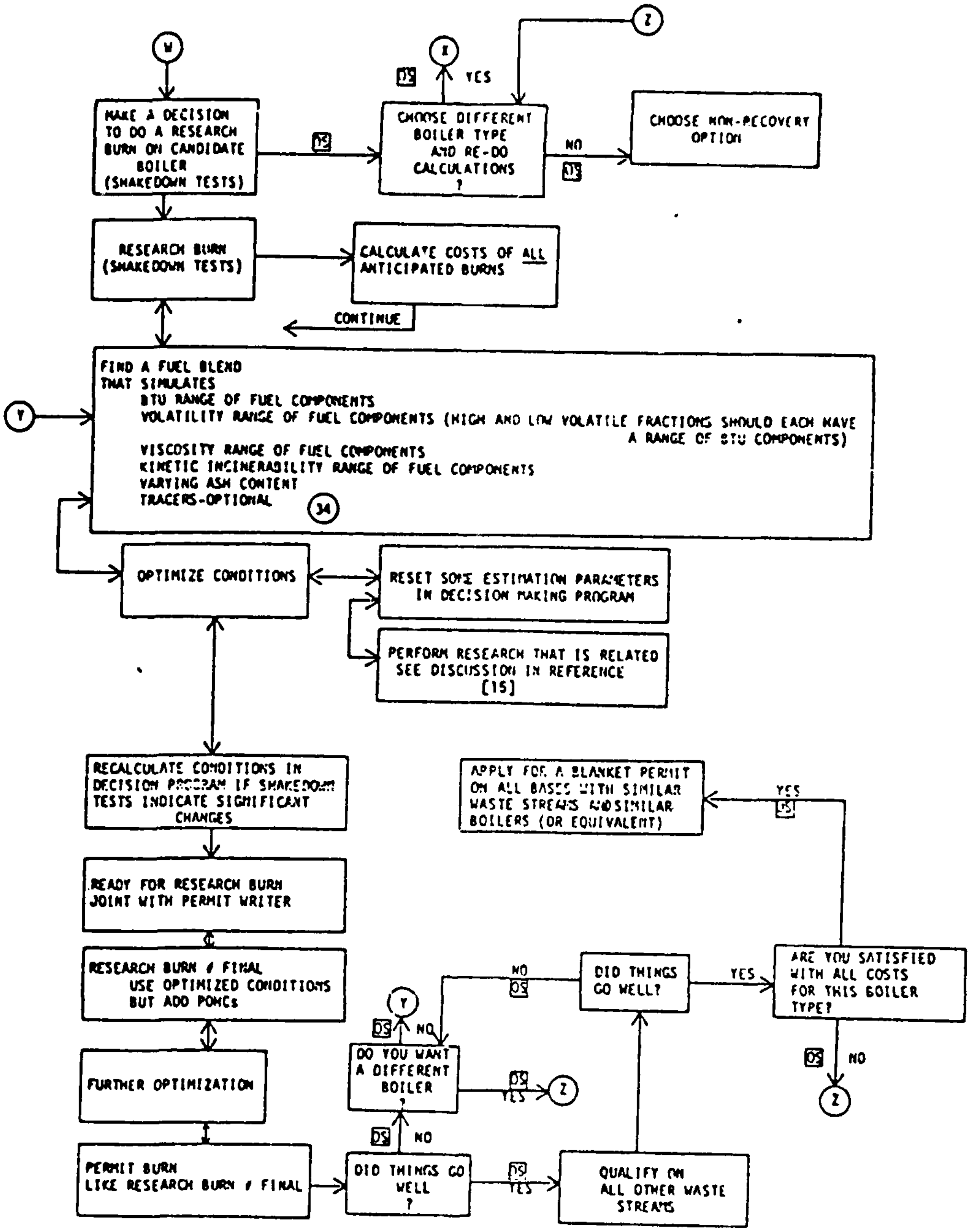


Figure 1. A Decision Scheme for Hazardous Waste Incineration and Energy Recovery in Boilers. (Concluded)

form of a diagram (Figure 1) which: (1) suggests the relationships between technical problems and control options, and (2) illustrates the sequential events associated with hazardous waste incineration in boilers and resulting pollutant emissions. In the diagram, encircled numbers correspond with a numbered commentary following Figure 1 which provides additional discussions about the information presented in the diagram.

DISCUSSION

- The constructed diagram is useful for making decisions on hazardous waste incineration in boilers. Refinements are required: (1) to optimize the logic of the diagram, and (2) to implement the suggested options for pollutant control.

FURTHER COMMENTS TO THE DECISION FLOW SCHEME PRESENTED IN FIGURE 2

1. This first step would be mandatory if RCRA regulations were extended to hazardous waste disposal in boilers. Some overlap in the listings occur, but each class, e.g., POHCs, metals, etc., plays a part in the suggested decision-making process. Identifying the weight percent of chlorine in any particular waste stream is also useful. In energy recovery units, chlorine content of waste streams should be carefully controlled, unless the boiler is constructed from corrosion-resistant materials, e.g., silicon carbide-lined furnace walls, monel boiler tubes, etc. (Reference 4).

2. Volatile materials may be recoverable by simple distillation. Components recovery may depend on whether or not MILSPECS on the original materials would have to be met.

3. The extensions of the Resource Recovery Plan (RRPLAN) discussed in this report can provide guidance for estimating recycling costs.

4. Some components (particularly the most volatile) such as methylene chloride, are probably recyclable within MILSPECS.

5. Contact recyclers for quotes.

6. Metals including RCRA-regulated toxic metals, chromium, lead, zinc, cadimum, copper, potassium, calcium, sodium, and aluminum should be kept to a minimum, if not completely excluded (References 5,6).

7. To be realistic, removal cost estimates must also include the disposal alterative.

8. These removals help to reduce ash content and erosion problems, eliminate materials which have no intrinsic heating value and act as catalytic surfaces for probable (Reference 3) secondary product formation. As in 7, alternate disposal costs need to be factored in.

9. There are general rules of thumb for determining the relative merits of retaining fuel for use when the BTU content is low (References 4,7,8). These guidelines can be used with regional energy pricing to determine lower limits of acceptability for the BTU content of candidate fuels.

10. If the BTU content of the fuel falls below the recommended cutoff limit of the boiler manufacturer, makeup fuel must be provided. Local pricing and availability must be considered.

11. Blockage of the input feedstream can be economically undesirable in energy recovery operations, particularly if no

system redundancy exists. In the case of liquid injection, ease and extent of atomization can affect sooting, flame stability and related parameters (References 7,8). Technological solutions are available for dealing with these problems.

12. A procedure for ordering POHCs according to a kinetic scale of incinerability has been reported in the literature (References 9,10).

13. This is a subjective estimate of residence time of a POHC in the hot zone of a flame (Reference 1). A hot-zone flame length of 10 centimeters and a gas-flow velocity of 500 centimeters per second are assumed. $T_{99.99}$ is the temperature required for achieving "four nines" (0.9999) Destruction and Removal Efficiency (DRE) of POHCs.

14. The calculation of adiabatic flame temperatures has been reported in the literature (Reference 11).

15. As a minimum, the adiabatic flame temperature must exceed the maximum four nines destruction temperature to achieve successful destruction of POHCs. Temperature fluctuations are extensive in turbulent diffusion flames (Reference 12). The ΔT_1 factor is an attempt to correct for this observation. If an estimate of ΔT_1 is not available from fast transient (>100 Hz) thermal fluctuation measurements, ΔT_1 should be set to a value of at least 200 °C. This is based on the observation that, at least for turbocombustors, these fluctuations can be quite large (Reference 12).

16. The HCl dewpoint temperature is the temperature at which substantial amounts of HCl in the gas stream will begin to condense out onto the boiler surfaces. If substantial amounts of HCl are present, maintain boiler operating temperatures above the limiting dewpoint temperature (Reference 4).

17. See Reference 8 for information.

18. Revenues are artificial, since DOD is its own customer if the operation is in-house.

19. Boiler corrosion rates are difficult to estimate. These rates depend upon operating conditions, levels of chlorides and other corrosives in the flow stream, boiler materials of construction, etc. (References 4,7,8).

20. Commercial corrosion monitoring equipment is available (Reference 13).

21. Recommendations of the boiler manufacturer should be followed.

22. The boiler operating temperature should exceed the HCl dewpoint temperature if substantial amounts of chlorine are present in the flowing gas stream. The ΔT_2 adjustment is for reasons given in 15 above. The ΔT_2 should be at least 100 °C. However, since the dewpoint temperature of HCl is usually rather high, this will probably not be practical. If not, a lower ΔT_2 may be set by backing off on the chlorine loading in the boiler or by utilizing a boiler constructed from corrosion-resistant materials (Reference 7).

23. Calculation of the free chlorine temperature (the temperature at which substantial amounts of Cl_2 may cause downstream corrosion problems) is reported in the literature (Reference 7).

24. Comments apply here as applied in 15 and 22 above. ΔT_3 should be more than 100 °C, if practical.

25. These calculations deal with the difference in DRE likely to be achieved in incinerators and boilers due to the presence of relatively cool walls in the boilers. These calculations assume ΔT_4 is at least 200 °C and that the thermal boundary layer is 10 percent or less of the thickness of the velocity boundary calculated for fully developed turbulent flow. Since fully developed turbulent flow is unlikely in an actual boiler, the approximation has dubious validity in the absence of tests. A linear temperature drop is assumed between flame and boiler wall temperatures. A correction for kinetics is applied, assuming the reactions stop once the temperature falls below the four nines temperature. Where T_w exceeds $T_{99.99} - \Delta T_4$, this correction is minimal, since the flame fluctuations at the walls are probably sufficient to effect destruction. The parameters in the equations are:

T_w	wall temperature (Degrees Kelvin)
T_a	adiabatic temperature (Degrees Kelvin)
r	radius of cylindrical boiler - a cylindrical boiler is assumed (Meters)
x	length of cylindrical boiler (Meters)
Re	Reynold's number ($Re = 2ru\rho/\mu$)
u	gas flow velocity (Meters per Second)
ρ	gas density (Grams per Cubic Meter)
μ	gas viscosity (Grams per Meter per Second)
$T_{99.99}$	four nines destruction temperature of the POHC most difficult to incinerate, based upon a kinetic scale of incinerability (Degrees Kelvin)

26. If low destruction efficiencies for POHCs due to cold-wall effects are indicated, one approach would be to increase mixing of gases to get the unburned POHCs near the cold walls back out into the main hot-gas flow stream.

27. In liquid droplet burning (References 14,15), droplet batch distillation effects will cause initial evaporation of the most volatile components. This can be problematical if the evaporating chemical species contained in droplets are chlorinated and flame-inhibiting (see also discussions in Reference 3).

28. If the BTU content of the selectively evaporating components is low, it must be boosted by adding a high-volatility, high-BTU-fuel.

29. If the evaporating components are chlorinated, large amounts of high-BTU, high-volatility fuel must be added to compensate for flame-inhibiting effects.

30. If POHCs cannot be detected, concentration levels should not be set equal to lower-bound analytical detection limits.

31. These costs tend to be high: equipment is very complicated and analyses are manpower-intensive.

32. The RCRA has set limits on HCl emission levels.

33. References 7 and 8 provide some guidance. The RCRA has set limits on particulate emission levels.

34. NBS is developing cost-effective alternatives to POHCs as monitors of DREs.

SECTION V

UNKNOWN (3): MEASUREMENT METHODS TO VERIFY SUCCESSFUL CONTROL AND/OR PREVENTION OF ORGANIC EMISSIONS FROM ENERGY RECOVERY UNITS

GOAL

- Identify candidate chemical tracer methods for verifying high Destruction and Removal Efficiencies (DREs) of Principal Organic Hazardous Constituents (POHCs) in Energy Recovery Units (ERUs).

OBJECTIVES

- Use existing literature to establish a basis for the selection of candidate chemical compounds which may be used as tracers to verify high DREs of POHCs.
- Apply a scale of incinerability to compare the thermochemical kinetic stability of candidate tracers with POHCs.
- Suggest analytical methods for detecting tracers: (1) prior to introduction into, (2) while inside of, and (3) on emission from ERUs.
- Suggest possible technical uncertainties which must be further investigated to refine and make a kinetic scale of incinerability more reliable.

DEFINITIONS (AS USED IN THIS SECTION)

- THERMAL STRESS: Stress due to elevated temperatures. The more the temperature of an environment exceeds some defined reference temperature, the greater the stress at the elevated temperature when compared to the stress at the reference temperature.
- THERMOCHEMICAL KINETIC STABILITY: A measure of the dynamic (time-dependent) unimolecular or bimolecular decomposition of chemical species, when subjected to thermal stresses.
- UNIMOLECULAR DECOMPOSITION: The self-decomposition of chemical species due to thermal stresses.
- BIMOLECULAR DECOMPOSITION: The decomposition of one chemical species through reaction with another chemical species, while subject to thermal stresses.
- KINETIC SCALE OF INCINERABILITY: A hierarchical ordering of chemical species according to their relative thermochemical kinetic stability.

- PRINCIPAL ORGANIC HAZARDOUS CONSTITUENTS (POHCs): Hazardous chemical species contained in a hazardous waste mixture. POHCs are identified according to current federal regulations, as promulgated under the authority of the Resource Conservation Recovery Act (RCRA). To comply with mandated federal incinerator emission standards, fractional DREs of 0.9999 (or higher) must be demonstrated for certain POHCs when combusted in an incinerator. These regulations do not presently apply to the combustion of hazardous wastes in ERUs.

- DESTRUCTION and REMOVAL EFFICIENCY (DRE): A number taken from a numerical scale ranging from 0.0 to 1.0. A DRE of 1.0 corresponds to complete destruction and removal of a POHC upon incineration. A DRE of 0.0 corresponds to no thermal destruction and removal of a POHC upon incineration.

- INCINERATION: Thermal processing by combustion, with or without use of air pollution control equipment. The objective of thermal processing is to destroy chemical species, and the objective for using air pollution control equipment is to remove chemical species.

NOTE

In the following discussions, DREs will be considered in terms of combustion in incinerators or ERUs which are not equipped with auxiliary air pollution control equipment.

BACKGROUND

- Current federal regulations, as promulgated under RCRA, mandate the demonstration of 0.9999 (or higher) DREs of POHCs in hazardous waste mixtures treated by incineration.

- Under RCRA-promulgated regulations, an incinerator for which 0.9999 (or higher) DREs of POHCs are not demonstrated will not be permitted for treating hazardous waste mixtures.

PROBLEM

- The demonstration of 0.9999 (or higher) DREs of POHCs is often: (1) difficult, (2) expensive, (3) manpower-intensive, and (4) time- consuming.

PROGRAM

<u>Thesis</u>

o Specific chemical compounds can be used as surrogates for POHCs. These may result in the reduction of the difficulty, expense, manpower requirements and/or time required to demonstrate that 0.9999 (or higher) DREs of POHCs have been achieved when hazardous wastes containing POHCs are combusted in incinerators or ERUs. These specific compounds are referred to as tracers.

Action

- Identify candidate tracer compounds which are not indigenous to a hazardous waste mixture. If the hazardous waste mixture is to be combusted in incinerators or ERUs, determine methods for: (1) homogeneously mixing the tracers with the hazardous waste mixture prior to combustion, and (2) monitoring the emissions of tracers such that DREs of the emitted tracers may be determined.

- Identify and evaluate technical problems associated with the use of candidate tracer compounds.

Approach

- Develop a mathematical relationship which can be used to determine: (1) residence times of chemical species (POHCs or tracers) in an incinerator or ERU, and (2) corresponding temperatures which the chemical species must be subjected to in an incinerator or ERU; in order to achieve a specified DRE.

- Survey existing literature and collect thermochemical kinetic data necessary for using the mathematical relationship (as outlined above) to construct a kinetic scale of incinerability.

- Construct a kinetic scale of incinerability for: (1) POHCs in hazardous waste mixtures, and (2) candidate tracers which are added to the hazardous waste mixtures.

- Describe methods so that one or more tracers may be homogeneously mixed with the hazardous waste mixture prior to incineration.

- Describe methods for monitoring emissions of tracers from incinerators or ERUs.

- Describe methods for determining the DREs of tracers.

- (1) survey the literature to identify the technical problems in using candidate tracers , (2) evaluate these technical problems, and (3) suggest approaches for solving them.

Results

- Candidate tracer compounds have been identified. Tracer compounds include, but are not limited to: SF_6, CF_4, C_2F_6, C_3F_8, and C_4F_{10}.

- A mathematical relationship has been developed which can be used to determine: (1) residence times of chemical species (POHCs or tracers) in an incinerator or ERU, and (2) corresponding temperatures which the chemical species must be subjected to in an incinerator or ERU; in order to achieve a specified DRE. The mathematical relationship is:

$$t = -(\ln(\Delta))/k \qquad (1)$$

where t is the residence time in seconds, $\Delta = 1 - DRE$, and $k = k_u + k_{bi}(OH_{EQ})$. At any specified temperature, for each candidate tracer or POHC, the parameters, k_u and k_{bi}, may be obtained from measurements or estimation techniques which are reported in the literature (References 9,16). A method for calculating a value for the parameter OH_{EQ} is also described in the literature (Reference 2).

- A kinetic scale of incinerability which uses these mathematical equations is illustrated in Figure 2. The example shown in Figure 1 compares the thermochemical kinetic stability of SF_6 with several POHCs, including several explosive compounds. For each chemical species shown, a temperature-versus-time curve has been plotted,assuming a 0.9999 DRE is always to be achieved. The kinetic scale of incinerability follows from the observation that,at any given temperature, the longer the time required to achieve 0.9999 DRE for a chemical species, the more stable (thermochemical kinetic stability) the chemical species is. Thus, the rightmost curves in Figure 1 correspond to the most stable chemical species. Therefore, for the chemical species shown in Figure 2, SF_6 is the chemical species most difficult to destroy at any specified temperature. If a mixture containing these chemical species is incinerated, a high DRE for SF_6 effectively guarantees all POHCs in the combusted mixture will have even higher DREs, subject to technical uncertainties discussed below.

- On the basis of numerous comparisons of the relative thermochemical kinetic stabilities of candidate tracer compounds with POHCs likely to be found in hazardous waste streams, SF_6 is recommended for further consideration in developing a chemical tracer method for verifying that high DREs of POHCs are achieved.

- Technical problems associated with the use of the candidate tracers have been identified, as reported in the literature (Reference 10). These problems include multicomponent phase separation, flame inhibition, mass transport and heat balance effects. When these problems develop, combustion can be nonuniform.

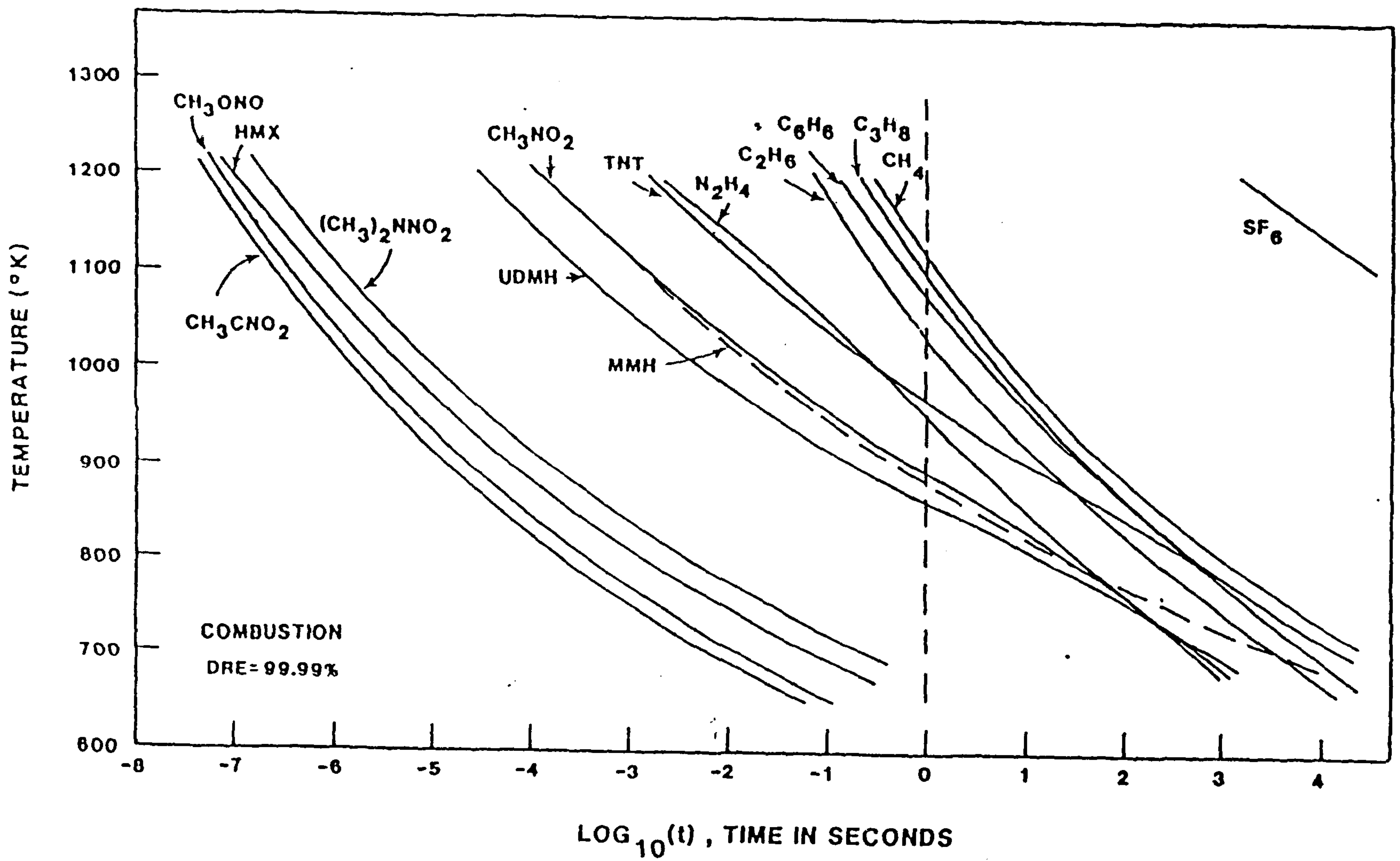


Figure 2. Incinerability Curves for Some Representative Chemical Species.

- Solutions for technical problems associated with the use of tracers have been reported in the literature (Reference 10). These solutions include: (1) improving fuel atomization, (2) improving mixing of fuels with combustion air, (3) providing for a high temperature combustion zone transit time which significantly exceeds fuel droplet burnout and mixing times, and (4) employing afterburners.

- Methods for monitoring emissions of tracer compounds from incinerators and ERUs have been reported in the literature (Reference 10). These methods include the use of gas chromatography and infrared spectroscopy.

- Technical problems remain on how to homogeneously mix candidate tracer compounds with hazardous waste mixtures to be treated by incineration.

Discussion

- Further research is required to resolve technical uncertainties and is ongoing at NBS.

- The likelihood that chemical tracer methods will be incorporated into federal regulations concerned with incineration of hazardous waste mixtures is uncertain at this time.

SECTION VI

UNKNOWN (4): METHODS TO ASSESS HAZARDS TO HUMANS AND ECOSYSTEMS AS A RESULT OF INCINERATION OF INDUSTRIAL PROCESS WASTES IN VARIOUS COMBUSTION CHAMBERS

GOAL

Achieve an appropriate risk assessment (RA) system for Air Force decision makers to use when electing options for dealing with industrial process wastes.

OBJECTIVES

Provide a basis for such a risk assessment system.

BACKGROUND

Components of risk assessment include, but are not limited to, the following:

1. Are any supplemental fuels stored and/or treated at an Air Force site prior to firing? If so, what is the probability for:
   a. Improper release?
   b. Adverse effects on the exposed population and/or ecosystem?

2. Is there an increased possibility of improper release of potentially harmful constituents from the combustor effluent when industrial wastes are being used as supplemental fuels? If so, what is the probability for:
   a. Such constituents to migrate to a place where harm might occur?
   b. Computing accurately the time lapse for such migration to occur?
   c. Accurately measuring the concentration of such constituents at the new time and place, i.e., after migration?
   d. Evaluating the potential for harm at this new time and place?

3. What safeguards might be considered in coping with allegations of improper release of potentially harmful constituents? Activities might include, but not be limited to, the following:
   a. Baseline studies prior to using such wastes as supplemental fuels.
   b. An approved monitoring system for the effluents and for the engineering aspects of the combustion operation itself.

c. An agreed method between the permit grantor and the grantee, i.e., Air Force or Air Force Contractor, concerning levels of concentration to be used as targets (i.e., how clean is clean?).
d. An agreed method between permit grantor and grantee on evaluating risks from the facility.
e. An appropriate economic protection arrangement.

The evaluation of the issues associated with 1 and 2 above is uncertain and controversial. For example, the EPA established an Agency-wide task group to deal with toxic material. This group is reportedly considering policy in the areas of:

- Science risk assessment and policy.

- Coordination of interagency risk assessment efforts, e.g., mutual policy issues between EPA and the Occupational, Safety, and Health Administration (OSHA), Consumer Product Safety Commission (CPSC), and the Food and Drug Administration (FDA).

Existing judicial rulings which involve certain issues of 1 and 2 are conflicting. Therefore, clear-cut resolution of these issues is not expected soon. In that case, a strong program dealing with the requirements of 3 may well afford the permit seeker a reasonable probability of obtaining permission to utilize industrial wastes as supplemental fuels and still realize an acceptable return on total investment. Lack of such a program might well be the basis for lengthy continuations of the permit process or even permit denial. The remainder of this brief discussion of RA will therefore deal with the components of Question 3 as related to the Air Force.

COMPONENTS OF RISK SAFEGUARDS PROGRAM FOR ENERGY-RECOVERY OPERATIONS

Baseline Studies

Data might be obtained on certain potentially harmful effluents from operations utilizing industrial wastes as supplemental fuels. These data may be taken over time to establish the degree of cleanliness prior to initiating routine operations. Involvement of state officials in designing studies and "certifying" the results might be useful. The downside risk is that opponents of using industrial wastes as fuels might suggest that any increase in concentration of the constituents being monitored is due to Air Force activities.

Monitoring Systems

1. A step-by-step process should be developed to show that release of potentially harmful constituents is minimized or eliminated.

2. Monitoring methods to prove that such release is minimized or eliminated need to be developed, and the strengths and weaknesses of such methods need to be evaluated. Of special importance is the sampling methodology.

How Clean is Clean?

Rosenblatt and co-workers at the U.S. Army Biomedical Research and Development Laboratory have developed a technique known as the Preliminary Pollutant Limiting Value (PPLV) method for evaluating the question of cleanliness (References 17-24). Briefly, in Rosenblatt's words:

> Initially, each pathway for transfer of a pollutant from the environment to man is treated as if it involved either (a) one environmental compartment, or (b) a series of successive compartments containing the pollutant at equilibrium. Transfer from the final compartment to humans is considered a nonequilibrium process occurring at an assumed rate. A PPLV is that concentration of the pollutant in the first compartment that is calculated to result in reception by the target human being of exactly the acceptable daily dose, D_T, via one or more pathways. The basic concept may be modified as the situation requires.

Rosenblatt has indicated that PPLVs are not standards or criteria, but are values which can be used to choose alternative courses of actions for:

- Developing renovation options for contaminated areas.
- Suggesting land utilization limits near facilities.
- Specifying monitoring procedures.
- Establishing analytical sensitivity requirements.

The basic premise is that once a PPLV is found for a specific area in which the treatment-storage-disposal facility is presumably contained, and if the concentration of the constituents can be reduced to PPLV or are never allowed to exceed PPLV, then the interaction of humans with the area or its products is "safe" for any exposed population (i.e., the acceptable daily dose of the pollutants will not be exceeded).

As for uncertainties in PPLV, Rosenblatt and co-workers have discussed sources of error in some detail but have not carried out a formal numerical analysis. Three major sources of uncertainty are:

- The assumption of equilibrium between environmental compartments.
- The statistical extrapolations yielding "safe" doses of various constituents.
- Data uncertainties of likely fate of various constituents in various environments. For example, the following summarizes some relations of physicochemical properties to environmental behavior:

Physical-Chemical Data	Related to
(1) Solubility in Water	Leaching, degree of adsorption, mobility in environment
(2) Latent Heat of Solution	Adsorption, leaching, vaporization from surfaces
(3) Partition Coefficient	Bioaccumulation potential, adsorption by organic matter
(4) Hydrolysis	Persistence in environment and biota
(5) Ionization	Route and mechanism of adsorption or uptake, persistence, interaction with other molecular species
(6) Vapor Pressure	Atmospheric mobility, rate of vaporization

Reference 25 has considered both the availability and validity of current data in these areas.

Evaluating Risk from the Facility

The PPLV method can be extended to suggest the probability that no one in the exposed population to a potentially harmful constituent will be harmed, even if the PPLV is exceeded (Reference 25). The basic conclusions of this work are given in Appendix 3. The user of hazardous industrial wastes as supplemental fuels can thus argue that small excursions of a potentially harmful constituent above PPLV are unlikely to cause harm.

Economic Risk Issues

One unit of measurement in dealing with improper release of potentially harmful constituents is the dollar. Indeed, the first question put to the Governor of New Jersey by a homeowner whose land was near a site found to contain 0.04 to 11 parts per billion of "dioxin" was: "Does this influence the price of our homes here?" [New York Times, June 19, 1983, Section I, page 1.] The Governor's reply was: "It should not," but no quantitative data are available to evaluate this issue. However, if property owners conclude that the existence of an Air Force operation which burns industrial waste as supplemental fuel may cause economic downgrading of their holdings and/or the possibility for adverse health effects, then the Air Force operation may, in turn, suffer adverse economic effects. In fact, many property owners near such Air Force operations may oppose the issuing of a permit. Therefore, an approach which serves to reduce possible adverse economic consequences through the use of some form of insurance could be a strong positive influence in obtaining the permit.

In this approach, certain important financial issues can be taken into account in advance. This data will be required in any case under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 USC 9601 et seq.) at Section 108[b](1) which requires the President to promulgate financial responsibility requirements for all classes of facilities involved in the production, transport, treatment, storage and disposal of hazardous substances. CERCLA requires operators of a facility involved with hazardous substances to establish and maintain evidence of financial responsibility consistent with degree and duration of risk associated with the hazardous substances at the facility. Issues which the EPA are currently examining include:

- What constitutes "Risk of Injury"?
- How should "Risk of Injury" be used to rank classes of facilities?

Therefore, consideration of RA alternatives by the prospective user of hazardous industrial wastes as supplemental fuels is likely to be useful in current permit activities and necessary in future dealings with state and Federal entities.

SECTION VII

UNKNOWN (5): SYSTEMS ANALYSIS METHODS TO CORRECTLY COMPARE ECONOMIC ASPECTS OF OPTIONS TO RECOVER ENERGY, REUSE, RECYCLE, MARKET, TREAT, OR DISPOSE OF VARIOUS WASTES CREATED IN VARIABLE QUANTITIES OVER WIDE GEOGRAPHIC AREAS

Methods have been developed at NBS for dealing with municipal solid wastes (Appendix II). Recently NBS personnel have suggested to the Defense Logistics Agency that the existing resource recovery planning model, known as RRPLAN, be modified to encompass hazardous wastes. Upon completion of such a transformation, Air Force decision makers could then select optimum economical means to deal with industrial process wastes.

GOAL

To provide a means of evaluating options for recycling, reusing or disposing of industrial wastes.

OBJECTIVE

This project will provide an economic model of hazardous waste recovery and management that will enable the DOD to comply with Executive Order 12088, "Federal Compliance with Pollution Control Standards." Specifically, the model will define the most cost-effective means for handling recyclable hazardous wastes generated by DOD. Disposal alternatives addressed by the model will include: (1) destructive disposal (incineration or landfill), (2) sale (commercial recycling), (3) off-base recycling (material is returned for reuse), (4) onbase recycling, and (5) removal (commercial firms are paid to remove the material with recycling or destructive disposal). A major transformation of the Resource Recovery Planning Model (RRPLAN) will be done to facilitate the development of an analytically sound approach for assessing the economics of recovering commodities from hazardous wastes.

BACKGROUND

Large volumes of industrial wastes are generated on a continuing basis at DOD installations. The final disposition of these wastes requires proper consideration of the environmental consequences, the economics, and the viability of the disposition method. These factors have always been integral parts of the disposition decision process. However, the environmental factors have assumed increasing importance as a result of the federal environmental regulations of hazardous waste materials under the Resource Conservation and Recovery Act (RCRA) of 1976. These regulations are designed to define responsibility for the environmentally acceptable disposition of a wide range of hazardous wastes.

DOD compliance with these, as well as other environmental regulations is mandated by Executive Order 12088. The military is complying with the regulations and with the regulatory structure as it evolves. Much of this effort centers on the identification and management of hazardous wastes, particularly at the installation level. The costs of handling and disposing of these wastes will be of increasing concern as hazardous waste regulations are promulgated.

Until recently, the individual services have been responsible for disposing of their own hazardous wastes. While the installation commander has the overall responsibility for complying with environmental regulations under current DOD policy (DEQPPM 80-8), the DOD has established the Defense Property Disposal Service (DPDS) under the Defense Logistics Agency (DLA). The DPDS is the focal point for hazardous waste disposal activities. To centralize the disposal management function and ensure DOD compliance with federal and local regulations, DOD assigned responsibility for storage and disposal of hazardous materials to DPDS. Recent Congressional Hearings (Subcommittee on Environment, Energy and Natural Resources of the Committee on Government Operations) re-emphasized reliable planning and control systems for monitoring DOD wastes which could be reused, recycled, or, if necessary, disposed.

THE RESOURCE RECOVERY PLANNING MODEL (RRPLAN)

The economic analysis of resource recovery options is extremely complicated, requiring an in-depth analysis of facility design and cost as well as market size, structure and location. To address these complicating factors, RRPLAN deals with two interdependent issues. On the one hand, RRPLAN explicitly incorporates potential economies of scale in the construction and operation of a solid waste processing facility. The model is thus able to support the basic trade-off of savings from centralized processing versus the costs of additional hauling required to bring such savings about. On the other hand, RRPLAN uses a detailed cost accounting system to attack the economic issues by carefully estimating the effects on overall program costs from decisions on siting, routing, marketing and financing. By integrating the technical issues of processing with these four major decision points, RRPLAN carefully examines a variety of questions.

RRPLAN is a computer model designed with three purposes in mind: (1) the ability to generate a preferred plan for resource recovery, (2) the capability to evaluate a scenario specified by the decision maker for technical and economic feasibility, and (3) its use as a tool to facilitate the decision-making process by providing answers to many "what-if" questions through an in-depth sensitivity analysis.

To handle the three types of issues just mentioned, RRPLAN includes a set of cost categories, energy categories, and commodities. Cost categories are the heart of RRPLAN's accounting system. They are included so that the differential impacts of the regional plan on the various segments of the population can be measured as well as financial transfers into the region from marketing activities. Individual cost categories are classified as either operating (i.e., recurring annual costs) or capital. Each cost category has a cost-growth scenario (differential inflation rate) associated with it, so that it may increase more (or less) rapidly than the general rate of inflation. Financial arrangements are explicit in all capital cost accounting. All capital items, except those currently in use, are assumed to be purchased at the beginning of the planning period. Replacements which occur within the planning period are inflated by the differential inflation rate from the first year of the planning period to the year of replacement. A standard amortization calculation is used to generate an annual cost for each year of the capitalization of the loan. A series of cost-summation categories permits the user to aggregate cost categories having differential inflation rates, useful lives, etc., into a single-cost summation category for further analysis. Energy categories may be handled in a similar manner. The model greatly facilitates the process of performing a detailed cost analysis, once a solution has been found, by leaving the user ample opportunity to define the types of commodities processed and sold (e.g., municipal solid waste (MSW) and steam). The use of separate commodity categories also permits one to measure the effects of differential transportation costs (e.g., handling MSW versus newsprint) as well as cost-sharing arrangements for processing and/or revenue-sharing arrangements among municipalities for marketing activities.

The model approaches the challenge of siting and sizing solid waste management facilities by first approximating nonlinearities in the capital and operating cost functions due to economies of scale with up to three linear segments. Each segment has an intercept (a fixed charge) and a slope (an incremental cost associated with increased processing activities). Decreasing returns to scale in the market revenue functions are allowed due to the potential for market saturation.

The introduction of fixed charges imposes certain complications, due to the existence of local optima. Such circumstances require a specially designed optimization technique to generate meaningful solutions. The technique used in RRPLAN involves a fixed-charge linear programming algorithm with a forcing procedure meant to insure that the model can pass over an area of temporarily increasing cost in the solution domain (i.e., a local optimum) to find the true optimum. RRPLAN adds new forcing methods representing a significant improvement over methods used in other models in which each site (or site-process combination) which was in the solution is forced out of the solution and vice-versa. This approach permits the solution domain to be searched in a more coordinated way of operating on all activities (e.g., transportation, processing, marketing) associated with a particular site (or site-process combination).

Equation (2) is a general economic expression governing resource recovery or most other businesses where a product is produced via the use of capital equipment and sold on a per unit basis. For the case of resource recovery, the values of a, b and c should be minimized. In effect, the fixed-charge linear programming algorithm of RRPLAN implicitly selects values for a, b and c, given the problem structure imposed by the input data, to minimize the cost per unit (CPU).

$$CPU = a + b \cdot (CAP/UPY) + c \cdot RPU + \varepsilon \qquad (2)$$

where CPU = cost per unit (the variable of interest),
CAP = capital cost,
UPY = units per year,
RPU = revenues per unit,
a,b,c = parameters of interest,
ε = a (stochastic) disturbance.

The term ϵ, accounts for uncertainties in the input data (e.g., discount rate, inflation rate, useful life of capital stock, transport network) which can affect estimates of the parameters, a, b and c. Equation (2) is thus a capsule summary of the economic and technical challenges facing planners and decision makers in selecting the best resource recovery scenario. Using this equation, planners can assess the effect of specific uncertainties on the economics of any resource recovery scenario. The basic approach involves selecting values for CAP, UPY, and RPU, based on their expected ranges, and analyzing their effect with the model. Application of the model permits the decision maker to monitor changes in the cost per unit (CPU). Parameters a, b and c can then be estimated through the use of statistical techniques. The risk of a specific plan can then be evaluated through the use of computer-based applications of probability theory.

TECHNICAL APPROACH

A hazardous waste recovery and management computer program could be developed through a major transformation of the RRPLAN model. The resulting model would include a front end, an optimizer and a back end. The front end would read all data inputs and construct the application problem. The optimizer would use a fixed-charge linear programming algorithm to solve the application problem. The back end would interpret the solution and output the results of the analysis. The outputs of the hazardous waste recovery and management model would be patterned after those of RRPLAN. (A sample of this output and guidelines for interpreting it are given in Chapter 4 of NBS Special Publication 657 (Reference 26). Persons from DOD responsible for hazardous waste activities would be contacted to identify the assumptions and data requirements needed to design, construct and implement the model.

The model's primary objective would be minimizing life cycle costs. A separate scenario evaluation capability would also be incorporated into the model so that a prespecified plan could be evaluated for feasibility.

The model would allow for user-defined commodity categories. Commodities would include generated hazardous wastes, various intermediate recoverable products, final recoverable products and residues. Intermediate recoverables would be inputs into secondary recovery processes. Those process outputs which could be treated specifically in the model (e.g., marketed, entered into secondary recovery, destructive disposal) would be declared as commodities. The user would also have the option to represent recoverables as revenues (net cost of hauling to market) and residues as costs (hauling cost plus disposal) without declaring such recoverables and residues as commodities. The model would allow for user-defined cost categories. All cost categories would be summarized in the back end. The full-cost accounting system of RRPLAN would be included.

The input file would define each hazardous waste source, its location, commodities produced, generation rates and cost accounting system. Each process would be defined by type, input commodity, output commodities and cost accounting system. Markets would be defined by location, input commodity and revenue schedule. The full range of market analysis included in RRPLAN would be built into this model. Each site would have a location associated with it. A set of site-process combinations would be used to specify the cost structure of the problem for analysis as well as to set constraints on processing activities. Sources, sites and markets would be linked together via a transportation network. Transportation categories would be used to cover the costs of hauling that commodity. All linkages in the solution would be summarized in the back end.

The model could be tested using data (supplied to NBS by DOD) on an actual facility or region. The test case should have sufficient detail to exercise all major features of the model.

Guidelines would be developed for performing a systematic sensitivity analysis which permits the values of a, b and c in Equation (2) to be estimated. Techniques for measuring risks, in terms of the overall costs of the plan, would also be developed.

Documentation for the model would be summarized in two reports. The first report would provide the information necessary to assess the model's input requirements (including time, money, and other resources) and the usefulness of the model's results. This report would be designed for the nonprogramming model user. The second report would be designed for use by programmers and analysts. Information contained in this report would have sufficient detail to enable the programmer to understand the operation of the model, trace through it for debugging, make modifications, and determine if and how the model can be converted to other computer systems. An in-depth discussion of the model's functional structure, the algorithms used, and the techniques employed for model verification and validation would also be included.

A series of tutorials would be developed and taught to give potential model users "hands on" experience in a controlled environment.

Extensions of the model dealing with the risks from releases of toxic substances into the environment would also be studied. Emphasis would be placed on how these extensions could address the issues (implementing procedures for the coordination of response actions to releases of hazardous substances into the environment) raised in Executive Order 12316.

The hazardous waste recycling and management model would:

- Define the most cost-effective means of handling the wastes generated.
- Contain a scenario evaluation capability.
- Help determine a cost-effective allocation of funds among hazardous waste sites.
- Help decision makers rank sites according to which ones give the biggest payoff for the funds allocated.
- Combine sensitivity analysis with a technique for assessing risks.

SECTION VIII

UNKNOWN (6): POSSIBLE IMPACT OF PENDING LEGISLATION, REGULATIONS AND JUDICIAL INTERPRETATIONS OF EXISTING LAWS AND REGULATIONS

GOAL

Estimate possible impacts of legal and regulatory actions on aspects of industrial wastes used as supplemental fuels.

OBJECTIVE

List current and proposed actions which could require alterations in Air Force plans and programs to deal with industrial wastes.

BACKGROUND

Specific rules on incineration of potentially hazardous wastes were promulgated in the Federal Register (47FR27520) on June 14, 1982. A listing of various regulations and references in the Federal Register and Code of Federal Regulations is summarized below. At the present time, there are no regulations governing the burning of hazardous wastes in heat recovery thermal processing units. In addition, any provisions of the Clean Air Act which may affect methods to utilize potentially hazardous wastes as supplemental fuels, are not yet under law, voted or enacted.

CFR REFERENCES TO RCRA REGULATIONS[a]

To implement the various sections of RCRA, Subtitle C, EPA has issued the following sets of regulations in TItle 40 of the Code of Federal Regulations:

Part 260: Hazardous Waste Management System: General

Part 261: Hazardous Waste Management System: Identification and Listing of Hazardous Wastes

Part 262: Standards for Generators of Hazardous Wastes

Part 263: Standards for Transporters of Hazardous Wastes

Part 264: Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities

Part 265: Interim Status Standards for Owners and Operators of Hazardous Waste Land Disposal Facilities

Part 122 - 124: Consolidated Permit Regulations (including permit regulations for hazardous waste facilities and State program authorization)

[a]Information provided by Mr. James Lyons of Coan, Couture, Lyons and Moorhead (a law firm in Washington, DC), on 19 October 1982.

These regulations have been promulgated in several stages and are contained chiefly in the following Federal Register publications, although there has been a continuing process of amendment:

1. 45 FR 33066, May 19, 1980: Parts 260-263 and 265, general provisions of Part 264, and Parts 122-124.

2. 45 FR 47832, July 16, 1980: Listing of additional hazardous wastes in Part 261.

3. 46 FR 2804, January 12, 1981: Parts 264 and 122, standards for storage and treatment facilities; and Parts 264, 265, and 122, standards for closure, postclosure care, and financial responsibility.

4. 46 FR 7666, January 23, 1981: Parts 264 and 122, standards for incinerators.

5. 46 FR 12414, February 13, 1981: Part 267, interim permitting standards for four classes of new land disposal facilities.

However, Congress is clearly intent on dealing with the use of industrial wastes as supplemental fuels. The Hazardous Waste Control and Enforcement Act of 1983 introduced in the House of Representatives as HR 2867 in May, 1983 and favorably reported by the Committee on Energy and Commerce (John Dingell, D., MI, Chairman) as Report 98-198, Part 1, states that stringent requirements are likely to be applied to wastes used as fuels (Appendix D). In addition, small-quantity generation of potentially hazardous waste is dealt with by HR 2867. Certain Air Force bases previously exempt from regulation by virtue of producing less than one metric ton of waste per month will be regulated if HR 2867 becomes law. Thus, Air Force personnel may need to plan for this contingency in advance. (The modifications proposed for RRPLAN could aid Air Force decision makers if the small generator exemption is revoked.)

A number of State laws may also affect Air Force activities using industrial wastes as supplemental fuels. Again, the RRPLAN modifications could aid Air Force decision makers in selecting least-cost options to deal appropriately with industrial wastes.

SECTION IX

CONCLUSIONS

The technical basis for using Air Force industrial wastes as supplemental fuels certainly exists. Suggestions made in this report should enable Air Force personnel to design and execute programs to destroy such wastes, recover energy and show empirically that applicable environmental laws and regulations have been properly taken into account. Furthermore, a technique to allow decision makers to select least-cost options to use the suggestions made in this report exists, i.e., a modified form of the resource recovery planning model (RRPLAN) developed at the National Bureau of Standards.

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APPENDIX A

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APPENDICES B-D

These Appendices were reproduced from multiple sources and are included as originally printed. Only the table, figure and equation numbers have been changed to avoid confusion with those in the text. Format, wording and usage are as the original authors intended.

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APPENDIX B
EVALUATING THE RISKS OF SOLID WASTE MANAGEMENT PROGRAMS: A SUGGESTED APPROACH

Robert E. Chapman
and
Harvey Yakowitz
National Bureau of Standards
Washington, DC 20234

BACKGROUND

Solid waste management is among the most complex municipal or regional governmental tasks facing policy makers today. The physical problem of where to locate needed facilities is further complicated by the increasing costs of disposal, new technologies, environmental regulations and the unavailability of the land for landfill. The problem becomes even more challenging when one notes that solid waste management facilities may exhibit economies of scale in construction and processing. This possibility implies that the benefits associated with lower per unit processing costs can only be achieved through regionalization. However, the process of regionalization creates two fundamental problems: (1) the complexity of the regional system design; and (2) the need for political consensus. Both of these problems may be addressed by developing and clearly presenting technical and economic data about the consequences of various regional approaches. Finally, by opting for regionalization, decisionmakers must weigh the benefits of reduced processing costs against the risks of cost overruns which are inherent in large construction projects.

The approach outlined in this paper attempts to integrate the regional planning problem with a technique for evaluating the risks of resource recovery options. This is accomplished in two stages. First, the Resource Recovery Planning Model (RRPLAN) is described. This section of the paper summarizes the model's assumptions, major components and modes of operation. An algebraic statement of the problem is then given along with a description of the solution algorithm. The second section consists of an in-depth case study for central Mississippi. A coordinated set of questions are hypothesized and solved to illustrate how the model would be applied in an actual planning context. The model's results are then used to develop statistical relationships which permit an explicit assessment of project risk.

THE RESOURCE RECOVERY PLANNING MODEL (RRPLAN)

Over the past decade, there has been a proliferation of mathematical models dealing with such issues as facility location, vehicle routing and manpower planning (Liebman [1975]). Due to unrealistic data requirements or the complexity of using and interpreting the model's results, the application of these models to the solid waste management problem has sometimes been disappointing. More recent modeling approaches have attempted to couple the analytical power of the computer with the ability to organize systematically the thoughts of the decisionmaker so that important pieces of information are not overlooked (Jenkins [1982], Chapman and Berman [1983]). From these experiences, it is possible to define a set of criteria that any model which purports to deal with solid waste management problems should satisfy. At a minimum, any such model should be able to derive explicitly the effects of alternative financial and cost-sharing arrangements, allow for economies of scale, and be amenable to sensitivity analysis associated with a well-chose set of "what if" questions.

Although the general solid waste management problem poses some formidable difficulties to decisionmakers, the economic analysis of resource recovery options is significantly more complicated, since an in-depth analysis of facility design and cost as well as market size, structure and location is required. In order to address these complicating factors, RRPLAN deals with two interdependent issues. On the other hand, RRPLAN explicitly incorporates potential economies of scale in the construction and operation of a solid waste processing facility. The model is thus able to support the basic tradeoff of savings from centralized processing versus the costs of additional haul required to bring such savings about. On the other hand, RRPLAN uses a detailed cost accounting system to attack the economic issues by carefully estimating the effects on overall program costs due to decisions affecting siting, routing, marketing, and financing. By integrating the technical issues of processing with these four major devision points, RRPLAN permits a wide variety of questions to be examined carefully.

RRPLAN may be thought of as a descendant of two earlier models. These models are known as WRAP, Waste Resource Allocation Program (Berman [1977], Hensey [1977]), and RAMP, Recovery and Market Planning (Berman [1976]). Both models were developed by the Mitre Corporation, the former through funding from the Environmental Protection Agency. There are substantial differences between the two models, especially regarding their software support systems and their treatment of market structure. Both models use the same optimizer as RRPLAN. In WRAP, as in RRPLAN, a front end is available to build the equations for input into the optimizer, and a back end is available to interpret the solution. In RAMP a more sophisticated equation structure is available, including the full market structure in RRPLAN, but the user must prepare equations for direct input into the optimizer, and must interpret its solution. The major focus of WRAP is on the identification of a preferred plan which includes the best candidate sites, the appropriate processing and disposal technology at each site, the sizing of each site and all transportation linkages among centers of waste generation, processing sites, and disposal sites. A major weakness of WRAP is its implicit assumption that any market for recoverables (e.g., ferrous products and newsprint) is unlimited. If market saturation is an important consideration, then WRAP's solution would represent an overly optimistic plan which could lead to serious cash flow problems if the plan were implemented. RAMP adds the saturation effect by incorporating both declining price and limited size markets.

RRPLAN, on the other hand, incorporates all of the capabilities of WRAP and RAMP, as well as numerous enhancements which render its cost accounting system far superior to those used in it predecessors. Furthermore, RRPLAN's more reasonable data requirements than WRAP, coupled with the type and nature of its output, should permit RRPLAN to greatly facilitate the regional planning and decision making processes. RRPLAN contains a more realistic cost model, built-in source-separation options, an automatic dedicated transfer station function, user defined cost, energy, and commodity categories, and an extensive analysis of costs by source and site, including a projected full cost tipping fee for each site.

RRPLAN is a computer model designed with three purposes in mind. First and foremost, is the ability to generate a preferred plan for resource recovery. Second, is the capability to evaluate a scenario specified by the decision maker for technical and economic feasibility. Third, is its use as a tool to facilitate the decision making process by providing answers to many what-if equations through an in-depth sensitivity analysis.

The model has five basic modes of optimization. Each mode serves to define the type of objective which is to be minimized or maximized. The first two modes of optimization minimize the total cost of the regional plan over a specified planning period. The first mode minimizes the discounted costs of the Regional plan. Such an objective function would be required if both the timing and magnitude of cash flows are important. If only the magnitude of each flows the important, then the second mode, minimization of undiscounted cases should be chosen. The choice of discounted rather than undiscounted costs or vice versa, may cause both the costs of the plan and the physical flows with the system to differ. The first mode, minimize lifetime discounted costs, is the preferred criterion for plan selection and evaluation. The third mode of operation seeks to maximize the net energy of the regional plan (i.e., energy produced (saved) from (due to) resource recovery activities minus all other energy inputs). Such an objective function might be useful in comparing various waste-to-energy programs. The fourth mode of operation seeks to minimize a linear form (weighted sum) of program cost and net energy categories this approach might prove useful in comparing mixtures of traditional and waste-to-energy programs if some form of matching formula for funds was in effect. This mode of optimization will permit the user to weight cost of energy categories other than equally. The fifth mode focuses on the topic of scenario evaluation. For example, a region may propose a plan which needs to be evaluated from the viewpoint of technical and economic feasibility. Typical questions addressed under this mode of operation would include the following: Are all facilities able to process the indicated waste stream without exceeding their rated capacity, or that of plants down the line into which they feed? Can resources be reallocated so that overall costs are reduced?

In order to handle the five types of objectives just discussed, RRPLAN includes a lot of cost categories, energy categories, and commodities. Cost categories are the heart of RRPLAN's accounting system. They are included so that the differential impacts of the regional plan on the various segments of the population, as well as financial transfers into the region from marketing activities, can be measured. Individual cost categories are classified as either operating (i.e., recurring annual costs) or capital. Each cost category has a cost growth scenario (differential inflation rate) associated with it, so that it may increase more (or less) rapidly than the general rate of inflation. Financial arrangements are explicit in all capital cost accounting. All capital items, except those currently in use, are assumed to be purchased at the beginning of the planning period. Replacements which occur within the planning period are inflated by the differential inflation rate from the first year of the planning period to the year of replacement. A standard amortization calculation is used to generate an annual cost for each year of the capitalization of the loan. A series of cost summation categories permit the user to aggregate cost categories having differential inflation rates, useful lives, etc., into a single cost summation category for further analysis. Energy categories may be handled in a similar manner. The model greatly facilitates the process of performing a detailed cost analysis, once a solution has been found, by leaving the user ample opportunity to define the types of commodities processed and sold (e.g., municipal solid waste (MSW) and steam). The use of separate commodity categories also permits one to measure the effects of differential transportation costs (e.g., handling MSW versus newsprint) as well as cost-sharing arrangements for processing and/or revenue-sharing arrangements among municipalities for marketing activities.

The basic structure of RRPLAN consists of a set of equations and activities relating sources of solid wastes, sites where the wastes can be processed and markets for energy or recovered materials. Figure B1, a capsule summary of the major physical system details, outlines the relationship between the model's equations and activities.

Both the model and the physical system begin with a source of waste, or "waste generation zone." At this point RRPLAN permits the user to offer two types of source separation for consideration or to ship the mixed MSW directly to a processing facility. Under the first source separation scenario, the model assumes that all paper, glass and cans are removed from the waste stream, sent to a central collection point, and then shipped to the respective market. This option is referred to as unconditional source separation. Under the second source separation scenario, paper, glass and cans are always removed but paper is treated separately. As in the previous scenario, cans and glass are sent to the central collection point and marketed. Paper, on the other hand, is put to two possible uses which reflect both its fiber value in recycling and its energy value in combustion. This option is referred to as conditional source separation. The rationale behind this scenario is as follows. If the price of paper exceeds some prespecified price (up to five such "trigger" prices are available) then it will be marketed for its fiber value; otherwise the paper will be burned. If multiple options are offered at a source, the model selects the preferred option. For example, all transportation linkages emanating from the source in Figure B1 are coded to differentiate whether the link is carrying wastes or recoverables. The same coding system is used throughout the diagram. If source separated paper, cans and glass (or any other marketable commodity) are to be shipped to the market, then they flow along the clear linkage. If, on the other hand, mixed MSW or the residue from source separation is to be shipped, then flow occurs along the shaded linkage. Note that <u>all</u> wastes generated enter into transportation.

Each transportation, processing, and marketing activity has associated with it a set of costs. For transportation, these costs include the periodic replacement of the rolling stock as well as the cost of physically hauling the wastes or recoverables. The facilities where processing takes place require greater care in cost accounting. For example, there may be site preparation costs (e.g., access roads) over and above the plant construction costs and the normal costs of day-to-day operations. No economies of scale are assumed in transportation. However, economies of scale are admissible for both facility construction and all future processing activities. Thus, the model can capture the basic trade off of savings from centralized processing versus the costs of additional haul required to bring such savings about. In addition to costs, the appropriate capacity associated with a processing facility at a particular site (site-process combination) can be selected. The setting of capacity can be based on either political or technical constraints. Setting a capacity would thus prevent the model from shipping to a single site more waste than would be technically or politically feasible.

Two types of markets are also shown in the diagram. RRPLAN treats the markets for energy (e.g., steam or electricity) and materials in a much more comprehensive manner than WRAP. RRPLAN can handle four types of market structure: (1) unlimited fixed price markets; (2) capacitated fixed price markets; (3) declining price markets with no upper limit; and (4) capacitated declining price markets. An example of an unlimited fixed price market might be an electric utility which will purchase any amount of electricity from the plant at a flat rate of 4¢ per kWh. An example of a capacitated declining price market might be a nearby industrial facility which will purchase process steam for $3 per K (thousand) lbs for the first 900 M (million) lbs; but will pay only $2 per K lbs for the next 900 M lbs; and cannot productively use the steam above 1800 M lbs. The market is considered saturated at 1800 M lbs. RRPLAN also permits revenue sharing arrangements among municipalities to be incorporated into the market analysis.

The model approaches the difficult problem of siting and sizing solid waste processing facilities by first approximating nonlinearities in the capital and operating cost functions with up to three linear segments. Each segment has an intercept (a fixed charge) and a slope (an incremental cost associated with increased processing activities). The introduction of fixed charges imposes certain complications, due to the existence of local optima. Such circumstances require a specially designed optimization technique to generate meaningful solutions. The technique used in RRPLAN involves a fixed-charge linear programming algorithm with a forcing procedure meant to insure that the model can pass over an area of temporarily increasing costs in the solution domain (i.e., a local optimum) to find the true optimum (Walker [1976]). RRPLAN adds new forcing methods representing a significant improvement over methods used in other models (Berman, Chapman, and Jung [1983]) in which each site (or site-process combination) which was in the solution is forced out of the solution and vice-versa. This approach permits the solution domain to be searched in a more coordinated way by operating on all activities (e.g., transportation, processing, marketing) associated with a particular site (or site-process combination). WRAP's methods of single or double column (i.e., the activities described in table B2) forcing is of questionable efficiency, particularly where a site is linked to three or more sources or other sites.

Furthermore, column forcing operates from within the optimizer, so it is blind in the sense that there is no information within the optimizer on what the various columns (activities) represent.

Assuming that cost minimization is the sole objective of the decisionmaker, the problem to be solved by the optimizer may be states as

$$\text{minimize } Z = \sum_{j=1}^{n} f_j(x_j) \qquad \text{(B1)}$$

subject to the linear constraints

$$\underset{\sim}{A}\underset{\sim}{X} = \underset{\sim}{b} \qquad \text{(i)}$$

$$\underset{\sim}{X} \geqslant \underset{\sim}{0} \qquad \text{(ii)}$$

where

$$f_j(x_j) = c_j x_j + k_j \sigma_j \qquad \text{(iii)}$$

with

$$\delta_j = 0 \quad \text{if } x_j = 0$$

$$\delta_j = 1 \quad \text{if } x_j > 0.$$

The vector $\underset{\sim}{X}$ contains n elements known as activities (e.g., shipments of MSW from source to a site). The tilde is used to distinguish the vector, $\underset{\sim}{X}$, from the elements x_j. The matrix A contains m rows and n columns. (It is assumed that n is greater than m.) The rows refer to the equations defined in table 1 and the columns to the activities defined in table 2. The c_j in condition (iii) are variable costs and the k_j are the fixed charges. (The k_j values are required to be greater than or equal to zero. If the activity has no fixed charges, then k_j is equal to zero. If the activity has no fixed charges, then k_j is equal to zero.)

RRPLAN AS A PLANNING TOOL: A CASE APPLICATION FOR CENTRAL MISSISSIPPI

After preliminary testing of the RRPLAN model with data from New York City's Department of Sanitation and the California Solid Waste Management Board, the model was applied to data from a three county area surrounding the city of Jackson in central Mississippi. The primary objective was to determine how RRPLAN could be used as the basis for developing the economic requirements for a variety of municipal solid waste options which might be exercised in the Jackson area.

Data on costs, markets, amount of MSW, inflation rates, and sites in the Jackson area were provided by the Bureau of Pollution Control of the Mississippi Department of Natural Resources. In summary, approximately 360 thousand tons per year (KTPY) of MSW were calculated to be generated in the area. Steam and/or electricity from a potential waste-to-energy facility could be marketed--steam to the packing industry and electricity to the local utility. Source separation was not to be implemented regionally; there was little or no market for recovered materials except aluminium. Landfill could be used if necessary (i.e., siting could be accomplished). Financing for a

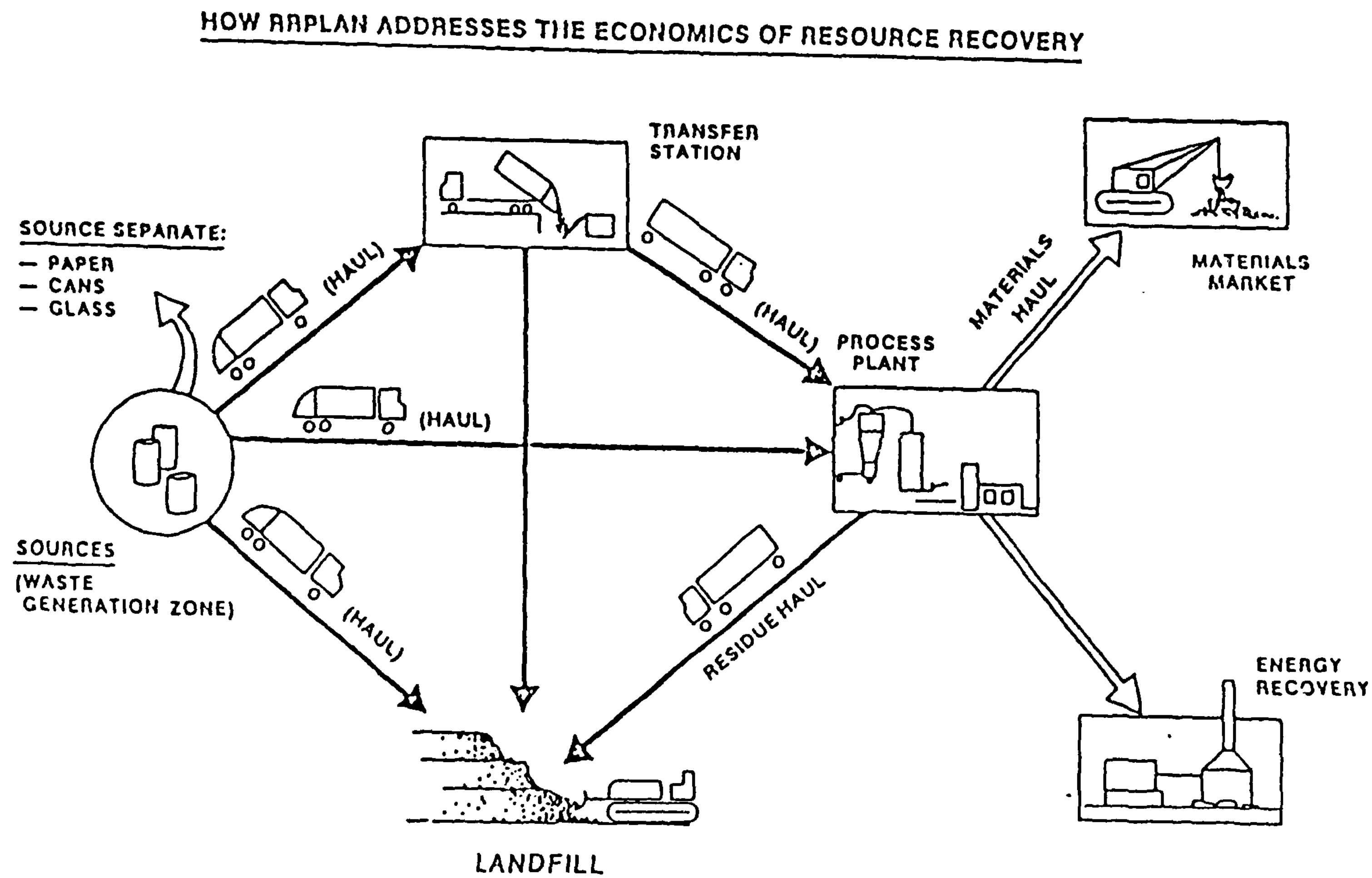

Figure B-1. How RRPLAN Addresses the Economics of Resource Recovery.

TABLE B-1. EQUATIONS USED BY RRPLAN

Equation Type	Purpose
Source balance equations	Requires all waste generated at each source to be entered into transportation.
Source paper balance equations	Requires all source-separated paper to be entered into transportation.
Site input residue balance equations	Generates a residue activity at a site equal to the residue arriving at the site.
Site input paper balance equations	Generates a paper activity at a site equal to the paper arriving at the site.
Site input balance equations for MSW and other commodities	Requires the total amount of MSW and other commodities arriving at a site to equal the amount of processing activity at the site.
Site output balance equations	Generates transportation activities of a commodity from a site equal to the process output of the commodity at that site.
Market input balance equations	Generates a total market activity equal to the amount of commodity arriving at the market.
Site capacity constraints	Insures that processing at a site does not exceed capacity.
Land capacity constraints	Insures that land uses does not exceed land available at any landfill.
Market bounds	Requires the sum of activity at a market in segments less than or equal to the jth ($1<j<5$) segment to be less than or equal to the jth cumulative bound for the market.
Constraint on artificial processing activities	Provides an upper bound for artificial activities used to preserve the structure of the A matrix.

TABLE B-2. ACTIVITIES CONSIDERED BY RRPLAN

Activity	Purpose
Transportation category 2	Site-to-site shipments.
Transportation category 3	Site-to-market shipments.
Transportation category 4	Source-to-site shipments of unseparated MSW.
Transportation category 5	Source-to-site shipments of unconditional source separated MSW (national paper market[a]).
Transportation category 6	Source-to-site shipments of unconditional source separated MSW (local paper market).
Transportation category 8	Source-to-site shipments of pre-separated paper (local paper market).
Transportation category 9	Source-to-market shipments of pre-separated paper (local paper market).
Transportation categories 11-15	Source-to-site shipments of conditional source separated MSW (national paper market) with 1 to 5 trigger prices.
Residue activities	Measures thousands of tons per year of source-separated residue arriving at a site.
Paper activities	Measures thousands of tons per year of source-separated paper arriving at a site.
Process activities	Measures number of commodity units processed per year per linear segment at a site.
Market activities	Measures number of commodity units purchased per year per linear segment at a market.
Artificial processing	Take on arbitrarily small values to preserve structure of the A matrix.
NZ	Relieves infeasibilities associated with an advanced starting point.
NZX	Relieves infeasibilities when evaluating a prespecified plan.

[a]The nature of the paper market depends on whether the quantities of paper processed by the model will or will not affect the price. If the price is unaffected, then the market is designated as national. If the price is affected, then the market is designated as local.

waste-to-energy facility could probably be obtained at a 10 percent rate for a 15 year term; the useful life of the facility was anticipated to be 20 years.

The first task for RRPLAN was to estimate the cost of an all landfill-no recovery option given collection costs, disposal costs, land costs and labor and transportation costs in the Jackson area. This computation was meant to provide a datum against which all other options could be compared. RRPLAN computed the discounted cost of this option as $21.20 per ton for the 20-year period beginning January 1, 1985 and ending December 21, 2004. This cost can be interpreted to mean that it would take $21.20 of money at January 1, 1985 value to collect, transport, and dispose of one ton of Jackson area MSW (i.e., all MSW for 20 years could be disposed at this discounted costs.) All subsequent RRPLAN calculations were discounted on the same basis. Hence, in what follows, all costs are on the same basis (i.e., discounted to a present value as of January 1, 1985). A cost difference between two options of $1 per ton on this basis results in a $7.2 million cost difference for the total of 20 years since 20 years times 360 KTPY is 7.2 million tons of MSW.

A waste-to-energy facility was then considered at a site in the city of Jackson. In the absence of such a plant, eight landfills in the tri-county region surrounding Jackson would continue to receive 360 KTYP of MSW at a discounted cost of $21.20 per ton. Once the new facility was in place, RRPLAN predicted that about 300 KTPY of waste could be processed there. Several landfills would cease operations; the remainder of the MSW would go to the rest. RRPLAN never predicted that siting, construction and use of transfer stations would be economically advantageous for the Jackson area. Note that RRPLAN selects the optimum activity level for each site (i.e., waste tonnage) and the most economical transportation linkages to utilize these sites. For an input of 300 KTPY, facility capacity needs to be about 1150 tons per day.

A sensitivity analysis was then performed to determine how variations in the capital cost of the facility and anticipated revenues would affect the discounted cost per ton. Two basic scenarios were analyzed. The first was based on steam sales to the packing industry. The second was based on electricity sales to the local utility. For both scenarios, we assumed that one tone of MSW would yield either 6 MBTU (million BTUs) of steam or 625 kwh of electricity for delivered use. These figures assume an incinerator efficiency of 67 percent for steam conversion and a turbine efficiency of 35.6 percent. The results of the sensitivity analysis are summarized in Tables B3 and B4. The steam and electricity revenues shown in these tables should be viewed as representing likely ranges for the facility rather than negotiated contract values.

The data from Tables B3 and B4 were fitted using the ordinary least squares routine of the DATAPLOT statistical analysis package (Filliben [1982]). In both cases, the response variable was the discounted cost per ton. The explanatory variables were: (1) an intercept term constrained to a value of $21.20, representing the cost of the all landfill option; (2) the capital cost of the facility in millions of dollars; and either (3) the revenue per MBTU of steam output; or (4) the revenue per kwh of electricity output. The estimated values of these relationships are shown in Equations (B2) (steam) and (B3) (electricity):

TABLE B-3. DISCOUNTED COST PER TON OF MSW PROCESSED FOR A WASTE-TO-ENERGY PLANT SUPPLYING STEAM

STEAM REVENUES[a]	FACILITY COST IN MILLIONS OF DOLLARS		
	75	85	100
2.50	23.16	24.93	25.93
3.33	20.93	22.04	23.71
4.17	18.70	19.81	21.48
5.00	16.08	17.20	18.87

[a]Dollars per MBTU.

TABLE B-4. DISCOUNTED COST PER TON OF MSW PROCESSED FOR A WASTE-TO-ENERGY PLANT SUPPLYING ELECTRICITY

ELECTRICITY REVENUES[a]	FACILITY COST IN MILLIONS OF DOLLARS				
	80	90	100	110	120
4	21.21	22.33	23.44	24.55	25.66
5	18.03	19.14	20.25	21.37	22.48
6	15.19	16.30	17.42	18.53	19.64

[a]Cents per kwh.

$$DC_S = 21.20 + \underset{(65.55)}{0.118 \cdot CAP_S} - \underset{(-68.34)}{2.775 \cdot REV_S} \qquad (B2)$$

and

$$DC_E = 21.20 + \underset{(29.35)}{0.129 \cdot CAP_E} - \underset{(-31.42)}{2.749 \cdot REV_E} \qquad (B3)$$

where

DC* = discounted cost per ton;
CAP* = capital cost of the facility in millions of dollars;
REV* = revenue per unit of output delivered; and
* = S (steam) or E (electricity)

The values in parenthesis beneath each coefficient are the t-statistics associated with the fit. The importance of the explanatory variables is reflected in the high values of the t-statistics. A cursory review of Equations (B2) and (B3) indicates that the coefficients have the proper signs and assume values which are of the same order. However, an important difference is that, other things being equal, the discounted cost of the electricity supplying facility is somewhat more sensitive to changes in capital cost and less sensitive to changes in revenues.

If ST* (* = S or E) is designated as the savings per ton of MSW handled as compared to the all landfill option, then

$$ST^* = 21.20 - DC^* \qquad (B4)$$

The value for DC_S (Equation (B2)) or DC_E (Equation (B3)) may then be inserted into Equation (B4). If ST* is positive, then the recovery option is more economical then the all-landfill option. Conversely, if ST* is negative, then the recovery option is less economical than the all landfill option. A value of ST* equal to zero defines the break-even points, in terms of revenue per unit of output, for each type of recovery facility are given by equations (B5) (steam) and (B6) (electricity):

$$REV_S = (0.0425) \cdot CAP_S \qquad (B5)$$

and

$$REV_E = (0.0469) \cdot CAP_E \qquad (B6)$$

Break-even points for five capital cost figures are summarized in Table B5. As may be seen in equations 5 and 6, the revenues required to break even are more sensitive to changes in the capital cost of the electricity producing facility.

TABLE B-5. BREAK-EVEN POINTS FOR SELECTED CAPITAL OUTLAYS

TYPE OF FACILITY	FACILITY COST IN MILLIONS OF DOLLARS				
	80	90	100	110	120
STEAM[a]	3.40	3.83	4.25	-	-
ELECTRICITY[b]	3.75	4.22	4.69	5.16	5.63

[a]Dollars per MBTU in revenue required to break-even.

[b]Cents per kwh in revenue required to break-even.

Since the turbine represents a considerable additional first cost, the cost of a facility to generate electricity is likely to be higher than that of a facility to generate steam. Thus the value of $DC_E - DC_S$ is of interest in evaluating the additional initial risk:

$$DC_E - DC_S = (0.129 \cdot CAP_E - 0.118 \cdot CAP_S) - (2.749 \cdot REV_E - 2.775 \cdot REV_S) \qquad (B7)$$

Equation 7 may now be used to calculate the affordable extra turbine costs for any given value of $DC_E - DC_S$ which is deemed to make the risk acceptable. In general, if a firm value of REV_E is available, then the revenue per MBTU of steam to be equivalent is:

$$REV_S = -(0.046 \cdot CAP_E - 0.043 \cdot CAP_S) + 0.[illegible] \cdot (DC_E - DC_S) + 0.991 \cdot REV_E \qquad (B8)$$

If, on the other hand, a firm value of REV_S is available, then the revenue per kwh of electricity to be equivalent is:

$$REV_E = (0.047 \cdot CAP_E - 0.043 \cdot CAP_S) - 0.364 \cdot (DC_E - DC_S) + 1.009 \cdot REV_S \tag{B9}$$

Thus, a complete risk analysis for any reasonable baseline scenario can be performed in terms of the market prices for steam and electricity as well as for the capital cost of the facility. It is important to point out, however, that all of these calculations assume that approximately 300 KTPY will actually be processed at the facility, and that all of the energy recovered from the MSW processed can be sold. The effect of changes in the baseline tonnage processed ($KTPY_b$) on the discounted cost per ton remains to be analyzed.

In order to compute the relationship, and hence sensitivity of DC* to the baseline tonnage processed, the following equation may be used:

$$DC^* = a + b \cdot (CAP^*/KTPY) + c \cdot RPT^* + \varepsilon \tag{B10}$$

where RPT* = the revenue per ton of MSW input; and
ε = a (stochastic) disturbance term.

If a tipping fee is charged per ton of MSW input, then its value would be incorporated into RPT* along with any revenues from steam or electricity sales. The values of a, b and c in Equation (B10) are functions of the RRPLAN input data (e.g., discount rate, terms of loan, useful life of the facility).

The analysis of the central Mississippi case study indicates that

$$DC^* = 21.20 + \beta^* \cdot (CAP^*/KTPY) - 0.449 \cdot RPT^* \tag{B11}$$

where β^* = 39.50 if * = E (electricity); or
34.37 if * = S (steam).

As in the previous cases, a, has been constrained to a value of $21.20, the discounted cost per ton for all-landfill option.

Equations (B10) and (B11) closely resemble the one suggested by Yakowitz [1981] for the approximate break-even cost for any resource recovery facility. The crucial difference is that Equation (B10), if based on results from RRPLAN, represents fully discounted dollars over the lifetime of the facility whereas the relation given by Yakowitz represents current dollars for the first year of a publicly owned facility.

The relationship given in Equation (B10) is a general economic expression governing resource recovery or most other businesses where a product is produced via the use of capital equipment and sold on a per unit basis. For the case of resource recovery, one wishes to minimize the values of a, b, and c. In effect, the fixed-charge linear programming algorithm of RRPLAN implicitly selects values for a, b and c, given the problem structure imposed by the input data, so as to minimize DC*. However, uncertainties in a, b and c depend upon:

(1) the mathematical formulation of the problem;
(2) the algorithm used to implicitly solve for the optimal mix of a, b and c;
(3) the input data (e.g., discount rate, inflation rate, useful life of the capital stock, transportation network); and
(4) the stochastic nature of a, b and c (e.g., as reflected by the width of the confidence intervals about the predicted values).

If all variables in equation (B10) are subject to uncertainty, then the total differential may be used to approximate the risk associated with the baseline values:

$$\Delta DC^* = a\cdot(\Delta a/a) + b\cdot(CAP^*/KTPY)\cdot[\Delta b/b)+(\Delta CAP^*/CAP^*)-(\Delta KTPY/KTPY)] + c\cdot RPT\cdot[(\Delta c/c)+(\Delta RPT/RPT)] \qquad (B12)$$

The first, second and fifth Δ ratio terms of equation (B12) are associated with uncertainties in the estimates of a, b, and c. The other Δ ratio terms are associated with uncertainties in the input data. Note that uncertainties in the input data will affect the estimates of the parameters a, b, and c. These effects will be of a second order nature, however, and are modeled through the inclusion of the stochastic term in Equation (B10).

Equation (B12) is a capsule summary of the economic and technical challenges facing planners and decisionmakers in selecting the best resource recovery scenario. Through reference to this equation, local planners can assess the effect of specific uncertainties on the economics of any resource recovery scenario. For example, if only KTPY can vary, then equation 12 becomes

$$\Delta DC^* = - b\cdot(CAP^*/KTPY)\cdot(\Delta KTPY/KTPY) \qquad (B13)$$

where the minus sign in equation (B13) indicates that a decrease in tonnage will result in an increase in the discounted cost per ton, DC*. For example, if the capital cost of the facility was $100 million and 300 KTPY were to be processed, then a decrease of 15 KTPY would result in an increase of approximately 50 cents per ton for a steam-producing facility of 60 cents per ton for an electricity-producing facility.

A closer examination of equation (B12) is now in order. If a nominal revenue of $30 per ton is assumed along with a five percent range on each variable and a two percent range on each of the three parameters (based on the width of their 90 percent confidence intervals), then the increase in discounted cost could be as high as $3.00 per ton, or 15 percent of the estimated value of the discounted cost per ton. Hence, for purposes of planning, the uncertainty can perhaps be approximated by a figure of 20 percent. Thus, if a combination of costs, tonnages and income can be obtained such that RRPLAN predicts a reduction in DC* of $3 to $4 with respect to the all landfill option (which is also subject to similar uncertainty calculations), then the risk associated with investing in the resource recovery facility is probably worth serious consideration. Although equation (B12) provides valuable information on how costs may vary due to uncertainty, it does not yield an explicit measure of risk. In order to remedy this deficiency, a series of Monte Carlo experiments was performed. The three explanatory variables (CAP*, RPT* and KTPY) in equation (B11) were the focus of the experiment. Based on previous work on probablistic cost estimation (Vergara [1977]), the capital cost of the facility, CAP*, was assumed to be lognormally distributed with a mean of $85 million and a standard deviation of $7 million for the facility serving the steam market an a mean of $105 million and a standard deviation of $10 million for the facility serving the local utility. The lognormal distribution is particularly attractive for large construction projects because it is asymmetric. Consequently, the lognormal distribution explicitly allows for low-probability high-cost events. Since the revenue per ton, RPT*, is dependent on the outcome of contract negotiations, we assumed that the revenue per unit (i.e., per MBTU or kwh) was uniformly distributed. For a uniform distribution, each value within the range is equally likely. The range considered was $2.50 to $6.00 per MBTU for steam and 4¢ to 6¢ per kwh for electricity.

The treatment of random variations about the volume of waste processed is more complicated since the rate of waste generation may increase. Two scenarios were thus hypothesized. In the first, the amount of MSW processed was assumed to be normally distributed with a mean of 300 KTPY and a standard deviation of 30 KTPY; this case corresponds to a "No Growth Scenario." In the second, the amount of MSW processed was assumed to be lognormally distributed with a mean of 300 KTPY and a standard deviation of 40 KTPY, this corresponding to a "Growth Scenario." A lognormal distribution was selected for the growth scenario because it shifts the bulk of the probability distribution towards higher rates of processing (e.g., more waste is generated, so more is available for processing). The standard deviation was increased from 30 to 40 KTPY to highlight the uncertainty associated with such growth projections.

The Monte Carlo experiments were carried out through application of the NBS DATAPLOT statistical analysis package. As a first step, a vector of random numbers from the standard forms for each of the three probability distributions were generated. Vectors of length 100, 200, and 500 were tried to assess the impact of sample size on the results. A qualitative analysis of the experiments indicated that the results were relatively insensitive to sample size. The random numbers were then used to generate a vector of random values for CAP*, KTPY and RPT* based on the ranges and parameter values given earlier. These values were then inserted into equation (B11). The resultant estimates of discounted cost per ton were then sorted from smallest to largest. The ranked estimates (i.e., order statistics) were then used to construct a frequency based probability distribution.

For a given value of discounted cost per ton, dc, such a distribution shows the probability that the "true" cost will fall below dc. If dc is taken to be the cost of the all-landfill option, then the experiment shows the probability that the cost of the waste-to-energy facility will fall below the all-landfill option. A similar statement can be made for a selected risk margin (say $3, or a value of dc equal to $18.20). The results of the Monte Carlo experiment based on a sample size of 500, are summarized in Figures B2 and B3. Figure B2 presents the results of the no-growth scenario experiment; figure B3 summarizes

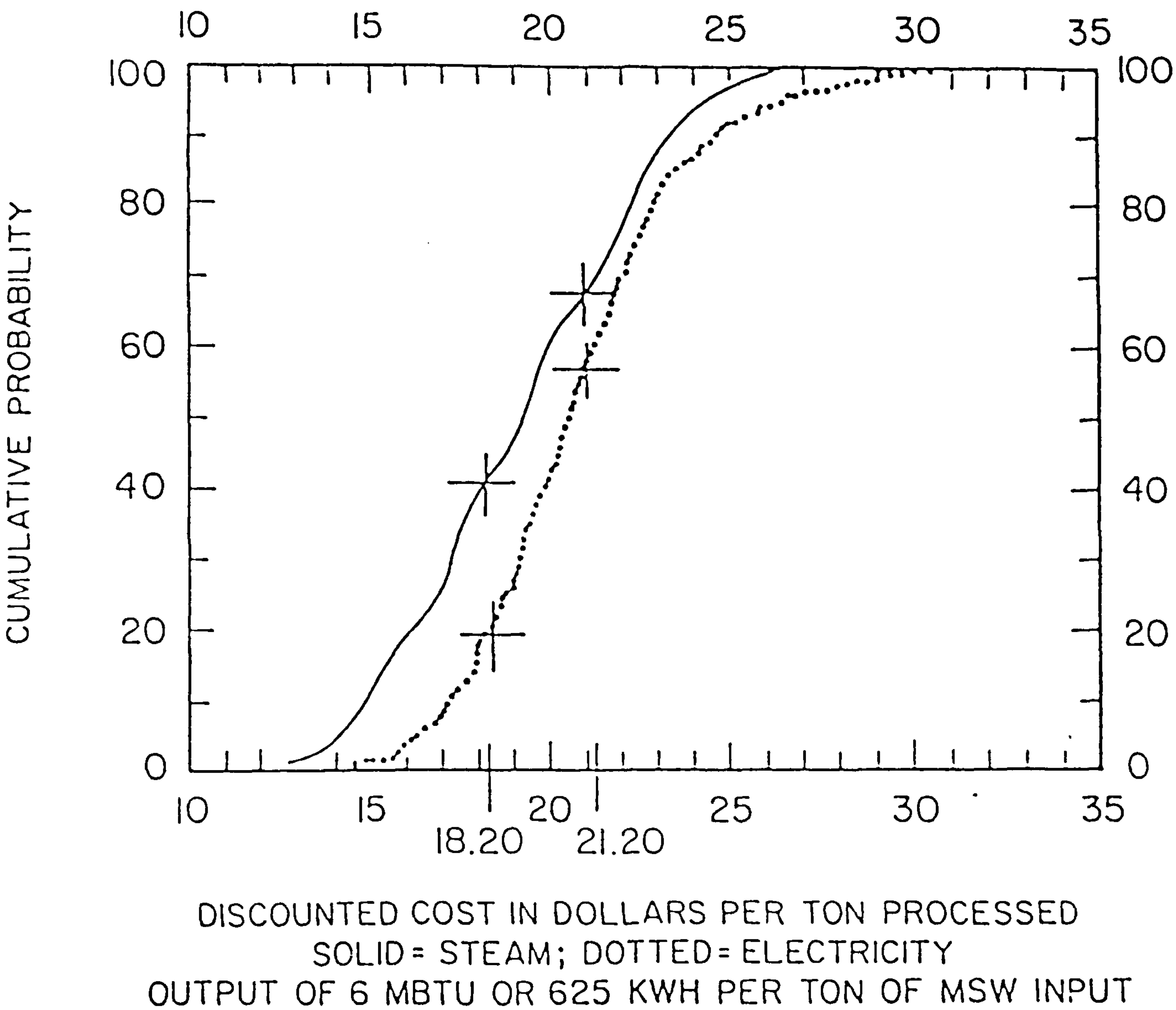

Figure B-2. Risk Assessment for Steam Vs Electricity (No Growth).

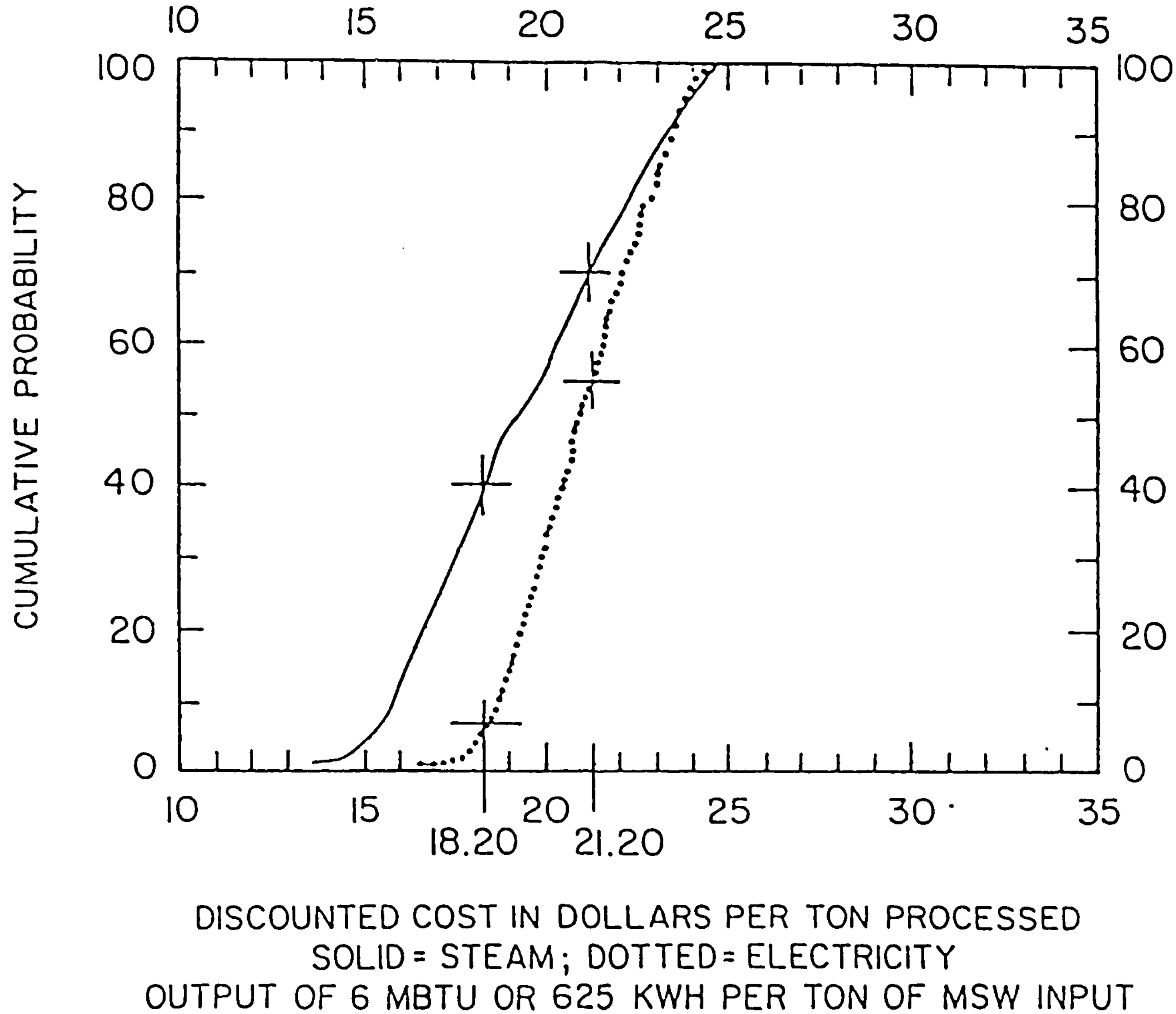

Figure B-3. Risk Assessment for Steam vs Electricity (Growth Scenario).

the growth scenario experiment. The horizontal axis of each figure records the discounted cost per ton, whereas the vertical axis records the probability that discounted cost falls below the estimate.

An examination of figure B2 reveals several important points. First, the discounted cost per ton for the facility producing steam is always less than the discounted cost for the facility producing electricity. The major reasons for this difference are the magnitude of the capital outlay ($105 million vs $85 million on the average) and the size of the β coefficient in equation 11 (i.e., $\beta_E > \beta_S$). Second, if the discounted costs for each facility are compared to those of the all-landfill option, the facility generating steam has a probability slightly in excess of 0.7 that the incurred costs will fall below the $21.20 figure. The facility generating electricity, on the other hand, has a corresponding probability of approximately 0.6 (i.e, investment in the electricity generating facility is about 15 percent more risky than investing in the steam generating facility). Third, the $3 margin (i.e., a discounted cost of $18.20) can be achieved with a probability of slightly over 0.4 if the facility which generates steam is selected. If the facility which generates electricity is chosen, however, the probability is reduced to a value of approximately 0.15. These figures imply that investment in a stream generating facility could be expected to better the $3 margin 40 percent of the time, whereas investment in the electricity generating facility could be expected to better the $3 margin only 15 percent of the time. Finally, highly unprofitable events can occur with both types of facilities. For example, the probability of exceeding a discounted costs of $22.00 per ton is 0.2 for the steam generating facility and 0.3 for the electricity-generating facility.

When the rate of generation of the waste stream is allowed to grow, a slightly different picture emerges. Figure B3 shows that the probabilities that the facilities will incur costs below the $21.20 figure are virtually unchanged at 0.7 for steam and 0.6 for electricity. This result may be explained in part by noting that a switch from the normal to the lognormal distribution was made for the volume of MSW produced. The ratio of two lognormal (CAP/KTPY) distributions can be converted to a normal distribution through a non-linear transformation of variables. The variance resulting from the transformation is the sum of the variances of the two distributions. The symmetry of the normal distribution and a slightly tighter variance (hence standard deviation) therefore tends to reduce the maximum and increase the minimum values of DC. The changes are not in the same proportion, however. Since KTPY enters equation 11 in the denominator, equal increased above 300 KTPY will result in smaller changes in DC than will equal decreases below 300 KTPY. Both probability distributions are therefore steeper than their no-growth counterparts. With regard to the $3 margin, the steam-generating facility still has a probability of 0.4 of incurring costs less than $18.20, whereas the electricity generating facility has fallen to a probability under 0.05.

The data shown in the two figures thus provide a strong argument in favor of the facility supplying steam to the local packing industry. The decision of whether or not to proceed with a resource recovery facility should also include a similar analysis of the costs of landfilling. Such an analysis, based on a coordinated set of RRPLAN runs, would establish the likely lower and upper limits on the discounted cost for the all-landfill option. These costs could then be compared with those presented in figures B2 and B3 to determine if the steam-producing facility is still competitive.

CONCLUDING REMARKS

The role of RRPLAN in assessing resource recovery options can be summarized as follows:

(1) RRPLAN identifies a minimum cost plan by comparing the various DC* values for each option.

(2) In every case, the optimizer minimizes individual DC* values as a function of the specific input data offered by the user.

(3) RRPLAN does not compute unique values for the variables a, b, and c in Equation (B10).

(4) By varying the input data to RRPLAN, specific estimates for a, b, and c, as well as preliminary estimates for the uncertainties in these variables can be obtained. RRPLAN probably provides the best available means to predict a, b, and c accurately.

(5) Equation (B12) represents the "risk evaluator" for a specific set of data and the uncertainties in these data.

(6) A planning basis for a waste management strategy is incomplete until all terms in equations (B10) and (B12) are evaluated numerically for various options.

Thus, RRPLAN, if used properly, provides the foundation for planning. But considerable additional assessment may well be necessary in order to choose the proper strategy for a given region. This assessment involves probabilistic estimation for the input variables (discount rate, costs, etc.), followed by multiple RRPLAN evaluations. The results will provide values for all terms in equations 10 and 12. Unless all of these steps are taken, RRPLAN results need to be treated with extreme caution. The lack of a coordinated approach or reliance on outmodel or inaccurate data significantly increases the risks of adopting a resource recovery plan. The U.S. has had several cases where resource recovery options have not lived up to proponents' expectations. RRPLAN and the approach outlined in this paper provides an opportunity to avoid some of these pitfalls.

RRPLAN, as developed for and by the National Bureau of Standards' Office of Recycled Materials, represents an appropriate means to begin evaluation of specific resource recovery options for a city, state, or region. The input data requirements will tend to require the prospective RRPLAN client to determine each item of data as accurately as possible. Careful data assessment, intelligent use of RRPLAN and solutions to Equations (B10) and (B12) should help to reduce the risk associated with resource recovery. In turn, the data gathering process and the subsequent RRPLAN and probablistic analysis should clearly highlight potential or actual institutional problems.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to Jack McMillan, Director, Division of Solid Waste Management, Bureau of Pollution Control of the State of Mississippi for providing data upon which the case study was based and for critiquing our results. Dr. Grace Yan and Stefan Leigh, National Bureau of Standards, also provided many useful comments on how to apply DATAPLOT to the problem of risk assessment. Special thanks goes to Ed Berman, Edward B. Berman, Associates, Inc., for his pioneering role in the development of the RRPLAN model.

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APPENDIX C. A SIMPLE DEGREE OF HAZARD SYSTEM FOR HAZARDOUS WASTES

H. Yakowitz

National Measurement Laboratory
National Bureau of Standards
Washington, DC 20234

The purpose of this brief exposition is to suggest a method for classifying waste treatment, storage and disposal facilities with respect to potential hazard posed by the existence of the facility. Existing, proposed and inactive or abandoned facilities can be classified by the method to be described; final disposal may be by thermal destruction or burial.

HAZARD-CONCENTRATION RELATIONSHIPS

The dose experienced by some population or ecosystem as a result of hazardous waste operations or storage--via any path of escape from a facility--needs to be related to observed instances of harm or the possibility of harm at some undefined future date. In all of the following discussions, assume that the exposure or dose occurs as a result of a hazardous waste facility. Further, assume that the exposure can be measured accurately and that the sampling procedure is statistically valid; these are admittedly large assumptions.

Toxicity testing for incidence of adverse effects in animals and humans as related to exposure or dosage usually results in a sigmoidal or S-shaped dose-hazard curve (see fig. 1). Here zero dose means zero hazard. But, the probability of harm to the exposed population as a function of very low dose or levels of exposure is extremely difficult to measure or to predict theoretically as indicated in Figure C1. Note that "hazard" suggests a threat posed by chance or something largely beyond one's control while "risk" may imply voluntary exposure to harm or loss.

Consider models for extrapolating from measurable exposure data to the hazard at lower exposures. In one experiment, some 24,000 female mice were subjected to a known bladder and liver carcinogen in order to study dose responses down to a one-percent tumor incidence, i.e., the concentration of the carcinogen which would cause one mouse in 100 to develop liver or bladder tumors[1]. Results of these tests were not especially enlightening. For example, a linear extrapolation and a Weibull model were applied to the data.

For a one-in-a-million risk ($P = 10^{-6}$) of liver cancer in the mice, an 0.045 part-per-billion dose of the carcinogen was predicted by the linear model; the Weibull model predicted a 4.5 part-per-billion dose for $P = 10^{-6}$ or an exposure of 100 times greater for the same risk[1].

The EPA Carcinogen Assessment Group has stated that:

> "There is no really solid scientific basis for any mathematical extrapolation model which relates carcinogen exposure to cancer risks at the extremely low level of concentration that must be dealt with in evaluating the environmental hazard."

With respect to the prediction of "time-to-tumor" data, there is no agreement between available models. Results are different, and reliable prediction appears impossible at present[1].

As stated by the Congressional Office of Technology Assessment:

> "The accuracy of the relation between exposure and incidence (of adverse effects) is always limited. Practical restraints on the number of animals that can be tested means that the data are always subject to significant experimental error; it also means that only relatively high incidences, almost always greater than 10%, can be measured in the experiments. There is also no agreement about which mathematical models best extrapolate from the exposure levels measured in studies to those encountered in the environment. Linear models, which assume that incidence is proportional to exposure at low exposure levels, are used by Federal agencies."[1]

Note that use of a linear model as compared to other possible extrapolation models, e.g., log-normal, log-logistic, Weibull, predict a higher probability for harm at lower exposure levels. As a practical matter, there is often no alternative to the linear model, since there are essentially no empirical data to support other extrapolation schemes.

Some of the technical difficulties will be apparent from an examination of Table C1 in which two objective and competent groups of scientists attempted to define cancer hazard from drinking-over an entire lifetime-water containing one part-per-billion (one microgram per liter) of known carcinogens. The table purports to indicate the number of persons per million exposed who are likely to fall victim to cancer from drinking this water. Note that in several cases, a tenfold to hundredfold difference exists between the two estimates. Data taken from Table C1 are shown plotted in Figures C2 and C3 assuming a linear relationship between concentration and cancer risk, in excess of that which would obtain if C_x were zero, i.e.,

$$P_R = m_x C_x \quad \text{where} \qquad (C1)$$

P_R is the proportion of the exposed population who are likely to suffer the adverse effect, m_x is the slope of the linear relationship obtained by dividing the value tabulated (Table C1) by C_x of 1 PPB, and C_x is the concentration of the constituent, x, which is presumed to pose the hazard.

DETERMINING THE EXPOSED POPULATION

Determining the exposed population, i.e., the group subjected to higher than baseline concentrations of the substances from a site, is no simple challenge. In principle, the various paths by which substances might reach the group can be identified. Monitoring, which relies on qualitative and quantitative determinations at various points away from the site, can be implemented. Thus, what--if anything--is escaping and how much will be known as a function of distance from the site. When the slope of the concentration against distance curve changes upward, the boundary for a particular path can be located. Wind, other climatic factors, and water flow patterns may well alter the results over a period of time. Airborne or rain-based factors may enter. Concentrations of substances produced by other means than the waste disposal site may intervene, e.g., from the plants generating the waste or other sources. Thus, attempting unambiguous identification of who is exposed to higher concentrations of potentially harmful substances from a waste disposal site is likely to be exceedingly difficult, time-consuming, expensive, and inaccurate.

ESTIMATION OF HAZARD

But, even if the exposed population, N, could be accurately determined and the hazard of cancer or other disease were known accurately, prediction of adverse events due to hazardous waste requires a probabilistic estimation scheme. Since the hazards tend to be fairly small in a probabilistic sense, the Poisson distribution function may represent an appropriate model.

Consider a fixed unit of time, T, in which certain events may occur. Assume that the events occur independently and that for periods of time, Δt, which are very short in comparison to T, the probability of one event is proportional to the length of time Δt, i.e., is equivalent to $C\Delta t/T$, where "C" is constant during the time period T. Assuming the probability of two or more events in time Δt is negligible and defining Ct/T as λ:

$$F(k) = \frac{\lambda^k \ell^{-\lambda}}{k!} \tag{C2}$$

In other words, the probability that "k" events will occur before time "t" is given by the Poisson distribution.

If the time interval is taken to be a human being's lifetime and if the "event" is taken to be the occurrence of an adverse effect due to exposure to the hazardous waste constitutents, then the value of λ for an exposed population of human beings, N, can be estimated. Assume some proportion, "p" of individuals in the population, N, suffer an adverse effect due to exposure to the hazardous waste; the remaining proportion, (1-p), do not suffer the adverse effect. If the product Np is equal to or less than five, then the parameter "λ" in equation (C2) can be taken as Np. Since the time interval is taken to be a lifetime, the value of λ is the mean number of occurrences of the event, i.e., adverse effect due to exposure to hazardous waste, within the exposed population. The probability of occurrence of the event within the specified time interval will be very small compared with the total number of occurrences of such events, and the Poisson distribution thus may represent an appropriate model for our purposes.

If 1000 persons were exposed to 1.1 PPM of chloroform in their water according to Figure C2, the hazard (or p) is 10^{-3} and $\lambda = Np = (1000)(10^{-3}) = 1.0$. Note Equation (C2) indicates that the probability that no one in the exposed population will be adversely affected, P_o, is simply:

$$P_o = e^{-\lambda} \qquad \text{(C3)}$$

Furthermore, if the linear risk relationship of equation (C1) is utilized to determine the proportion of individuals likely to be adversely affected due to the presence of constituent x at concentration C_x, then

$$\lambda = m_x N C_x \qquad \text{(C4)}$$

since $\lambda \approx NP_R$, i.e., λ is related to population size. Hence, if the slope, m_x, the exposed population, N and the concentration C_x can be determined:

$$P_o = \exp[-(m_x N C_x)] \qquad \text{(C5)}$$

The parameter P_o, the probability that no one in the exposed population is adversely affected, provides an appropriate figure of merit for ranking the potential hazard from a site. But uncertainties in determining the value of N and C_x for specific situations and the more general problem of ascertaining values of "m" for potentially harmful substances suggest that large uncertainties in determining P_o are likely to occur. In any event, the uncertainty ΔP_o can be estimated as:

$$|\Delta P_o| = \left| P_o \ell n P_o \left[\left(\frac{\Delta m_x}{m_x}\right)^2 + \left(\frac{\Delta N}{N}\right)^2 + \left(\frac{\Delta C_x}{C_x}\right)^2 \right]^{\frac{1}{2}} \right| \qquad \text{(C6)}$$

Equation (C6) assumes errors are independent. Furthermore, the approximation to $|\Delta P_o|$ becomes worse as the values of $(\Delta m/m)$, $(\Delta N/N)$, $(\Delta C_x/C_x)$ become large. Nevertheless, equation (6) can be used as an indicator to show that unacceptably large values of $|\Delta P_o|$ are likely to occur.

Members of the exposed population can point to the difficulties in ascertaining m, N, and C_x as a means to exclude proposed facilities, or to demand immediate remedial action--which may or may not be warranted--in the case of existing facilities. Finally, uncertainties in P_o could increase the chances for persons associated with the facility to be held liable under state and/or Federal statutes.

While the concept of utilizing P_o as an appropriate means to classify possible risk from the facility is appealing, practical application of equation (C5) could be exceedingly difficult. Therefore, some means to deal in a practical sense with site specific characteristics in an appropriate fashion is needed. In particular, the issues of "How clean is clean?" for inactive sites as well as reasonable performance measures for existing and proposed facilities need to be addressed. Furthermore, whatever method is selected must provide a means to account for cost effectiveness of proposed actions based on the results of applying the method. The remainder of this paper will propose a method which:

- o Utilizes P_o as the basic measure of hazard.
- o Takes into account site specific characteristics.
- o Is amenable to fairly rigorous uncertainty analysis.
- o Provides guidance as to the monitoring and analytical regime required for a specific facility.
- o Avoids the problems associated with determining the "exact" population exposed, N and with determining the slope of the hazard relation, m_x.
- o Utilizes--in most instances--critically evaluated data as inputs.

THE EXTENDED PRELIMINARY POLLUTANT LIMIT VALUE METHOD

The Preliminary Pollutant Limit Value (PPLV) method for human health effects was developed by Rosenblatt and co-workers at the U.S. Army Medical Bioengineering Research and Development Laboratory. These authors have published a series of articles and reports detailing the basis of the method as well as various practical applications[2-7]. In addition, basic chemical data required for input to the model have been critically evaluated and published[8]. Therefore, only a brief summary of the basic PPLV method will be presented here:

> "Initially, each pathway for transfer of a pollutant from the environment to man is treated as if it involved either (a) one environmental compartment, or (b) a series of successive compartments containing the pollutant at equilibrium. Transfer from the final compartment to humans is considered a non-equilibrium process occurring at an assumed rate. A PPLV is that concentration of the pollutant in the first compartment that is calculated to result in reception by the target human being of exactly the acceptable daily dose, D_T, via one or more pathways. The basic concept may be modified as the situation requires."[7]

Figures 4 and 5 indicate the basic processes and assumptions in schematic form. Table C2 presents some results from Reference 2 giving some PPLV values for seven compounds in soil. Rosenblatt has indicated that PPLV's are not standards or criteria but they are values which can be used to choose alternative courses of action for:

- o Developing renovation options for contaminated areas.
- o Suggesting limits on land utilization near facilities.
- o Specifying monitoring conduct.
- o Establishing analytical sensitivity requirements.

The basic premise is that once a PPLV is found for a specific area in which the treatment-storage-disposal facility is presumably contained, if the concentration of the constituents can be reduced to PPLV or are never allowed to exceed PPLV, then the interaction of humans with the area or its products is "safe" for any exposed population, i.e., the acceptable daily dose of the pollutants will not be exceeded. However, the questions of what occurs if PPLV is exceeded or if the cost of achieving PPLV is prohibitively large remain to be dealt with.

If PPLV is achieved, the exposed population is presumed to have some extremely small probability to suffer adverse effects. Note well that PPLV is site specific and only the population for which the particular PPLV has been computed is included in this assumption. If linearity between the proportion of affected individuals and PPLV is assumed, then

$$P_R = (PPLV)m_x \quad (C7)$$

But since PPLV supposedly includes N, then, in this case,

$$P_R = \lambda = (PPLV)m_x \quad (C8)$$

If PPLV is achieved, then the probability that an adverse effect will occur is supposedly very small. If an assumption is made that this probability is to be 10^{-4}, then m_x may be estimated as:

$$m_x = 10^{-4}/PPLV \quad (C9)$$

If P_R were taken as something other than 10^{-4}, clearly m_x would then be different. Hence, under these assumptions, λ at PPLV is 10^{-4} and P_0 which is $\exp(-\lambda)$ is 0.9999. Thus, if PPLV is achieved there is a 99.99% chance that no one in the exposed population will be harmed. If PPLV is exceeded we assume that λ increases linearly with concentration of constituent x, i.e.:

$$\lambda = 10^{-4}\, C_x/PPLV \quad (C10a)$$

and

$$P_o = \exp[-(10^{-4}\ C_x/PPLV)]. \qquad (C10b)$$

The assumption that λ increases linearly with C_x seems likely to provide a reasonable rate of increase for λ in view of the previous discussion pertaining to extrapolation models. The concept of acceptable daily dose, D_T, is related to lifetime hazard in the PPLV formulation so that Equation (C10) is consistent with our previous assumptions regarding the applicability of the Poisson process as well as with the PPLV basis. Nevertheless, the assumption of independence of N remains to be investigated in more detail. Figure C6 shows P_o vs. the ratio (C_x/PPLV). Clearly, Figure 6 indicates that C_x can exceed PPLV by a considerable amount before P_o falls to 0.95. But the uncertainty in P_o due to uncertainties in the computation of PPLV and the measurement of C_x still needs to be considered:

$$\frac{\Delta P_o}{P_o} = \left(\frac{10^{-4} C_x}{PPLV}\right) \left[\left(\frac{\Delta C_x}{C_x}\right)^2 + \left(\frac{\Delta(PPLV)}{PPLV}\right)^2\right]^{1/2} \qquad (C11)$$

If a term, E, is defined as:

$$E \equiv \left[\left(\frac{\Delta C_x}{C_x}\right)^2 + \left(\frac{\Delta(PPLV)}{PPLV}\right)^2\right]^{1/2} \text{, then} \qquad (C12)$$

$$\frac{\Delta\lambda}{\lambda} = E \qquad (C13)$$

As with Equation (C6), the errors are assumed independent and the approximations for $\Delta P_o/P_o$ and $\Delta\lambda/\lambda$ become worse as ΔPPLV/PPLV and/or $\Delta C_x/C_x$ increase. If some estimates for "E" can be made, then cumulative probability as a function of E can be estimated as well. With regard to the term ($\Delta C_x/C_x$), the National Bureau of Standards (NBS) evaluated analytical data obtained in the vicinity of the Love Canal in Niagara Falls, New York[9]. In addition, NBS has investigated several aspects of the challenges to the analytical chemist posed by low levels of constituents in variable matrices[10]. Based upon these results, a reasonable range for the uncertainties in determining the concentration of constituent X is $0<\Delta C_x/C_x\leq 5$, with a most probable value being about 0.5 to 1.

So far as uncertainties in PPLV are concerned, Rosenblatt and co-workers have discussed sources of error in some detail but have not carried out a formal quantitative analysis. Three major sources of uncertainty are:

- The assumption of equilibrium between environmental compartments.

- The statistical extrapolations yielding "safe" doses of various constituents.

- Uncertainties in data with respect to likely fate of various constituents in various environments. For example, the following summarization indicates some relations of physicochemical properties to environmental behavior:

Physical Chemical Data	Related To:
1. Solubility in Water	Leaching, degree of adsorption, mobility in environment.
2. Latent Heat of Solution	Adsorption, leaching, vaporization from surfaces.
3. Partition Coefficient	Bioaccumulation potential, adsorption by organic matter.
4. Hydrolysis	Persistence in environment and biota.
5. Ionization	Route and mechanism of adsorption or uptake, persistence, interaction with other molecular species.
6. Vapor Pressure	Atmospheric mobility, rate of vaporization.

Reference 8 has considered both the availability and validity of current data in these areas. In addition, NBS has sponsored critical data reviews and original research aimed at improving these data[10-13] as have many other institutions. Given these uncertainties, a range for $\Delta(PPLV)/PPLV$ of $0<\Delta(PPLV)/PPLV\leq 15$ with the most probable value being about 5 or 6 seems to be reasonable. Nevertheless, more formal analysis is warranted to provide a better estimate.

From these considerations an approximate cumulative probability curve for the term $E \equiv \Delta\lambda/\lambda$ could be constructed. This curve is shown as Figure C7; the curve indicates that there is a 95% cumulative probability that the term "E" does not exceed eleven. Given this result, the 95% upper bound for P_o can be calculated. Figure C8 shows this result as well as a repeat of Figure C6. These results indicate fairly clearly that if the ratio C_x/PPLV exceeds 100, then significant uncertainty in determining P_o may occur. Nevertheless, the 95% probability curve for the upper bound of P_o is available as a guide for personnel responsible for action at the site in question.

SUMMARY AND CONCLUSIONS

The Poisson statistical distribution is suggested as an appropriate approximation to the potential distribution of adverse effects in a population exposed to substances, such as toxic wastes. The probability that no one in the exposed population will be harmed is a reasonable ranking parameter to describe the hazard from a facility treating, storing and/or disposing of such wastes. However, this parameter may be subject to a number of uncertainties.

A method to estimate both the probability that no one in an exposed population will be adversely affected and the uncertainty associated with this estimate has been developed. The basis for this method is the preliminary pollutant limiting value (PPLV) technique developed by Rosenblatt and co-workers at the U.S. Army Medical Bioengineering Research and Development Laboratory. The PPLV method has been extended to consider the possible consequences of exceeding the safe limiting concentration calculated as PPLV. Results indicate effects for exceeding PPLV by factors up to 100. If PPLV is exceeded by more than 100, the probability for adverse effects in the exposed, population increases rapidly.

Nevertheless, the extended PPLV method can be applied to proposed, existing or inactive treatment, storage, and disposal facilities including those that dispose by thermal treatment or burial. Application of the extended PPLV method can provide a basis for selecting economically and environmentally sound options regarding activities associated with the site. Inactive or abandoned sites can also be ranked if necessary. Thus, the extended PPLV method might provide a simple degree of hazard system.

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TABLE C-1. Concentration of Drinking Water Contaminants and Calculated Excess Cancer Hazard of One-in-a-Million

	NAS[a]	CAG[b]
	ug/l[c]	ug/l[c]
Acrylonitrile	0.77	0.034
Arsenic	ND[d]	0.004
Benzene	ND	3.0
Benzo(a)pyrene	ND	ND
Beryllium	ND	0.02
Bis(2-chloroethyl)ether	0.83	ND
Carbon tetrachloride	9.09	0.086
Chlordane	0.056	0.012
Chloroform	0.59	0.48
DDT	0.083	ND
1,2-Dichloroethane	1.4	1.46
1,1-Dichloroethylene	ND	0.28
Dieldrin	0.004	ND
Ethylenedibromide	0.11	0.0022
ETU	0.46	ND
Heptachlor	0.024	2.4
Hexachlorobutadiene	ND	1.4
Hexachlorobenzene	0.034	ND
N-nitrosodimethylamine	ND	0.0052
Kepone	0.023	ND
Lindane	0.108	ND
PCB	0.32	ND
PCNB	7.14	ND
TCDD	ND	5.0×10^{-6}
Tetrachloroethylene	0.71	0.82
Trichloroethylene	9.09	5.8
Vinyl chloride	2.13	106.0

[a] Standardized to hazards from National Academy of Sciences Drinking Water and Health for consumption of 1 l/water/day.

[b] Recalculated to exclude aquatic food intake from Cancer Assessment Group, Ambient Water Quality Criteria. Standardized to 1 l/water/day intake.

[c] Average adult water consumption is 2 l/day.

[d] Not discussed.

SOURCE: Office of Technology Assessment.

TABLE C-2. Single Pathway PPLVs for Seven Compounds Originating in Soil ($mg\ kg^{-1}$)[a] after Reference [2]

Routes of Exposure	Chlorates	Arsenic Compounds	Mercury Compounds	Aldrin/ Dieldrin	Endrin	Toluene
Ingestion of water[b]	4.0	1.75	8.2×10^{-2}	3.5×10^{-3}	7×10^{-3}	53
Ingestion of food plants[c]	1.3×10^{-2}	56	2.6	0.22	0.44	1.7×10^{3}
Ingestion of foraging animals[d]	6.3×10^{3}	19	0.26	2.2×10^{-2}	4.4×10^{-2}	1.7×10^{2}
Ingestion of fish[e]	2.5×10^{4}	3.7	1.74×10^{-3}	7.4×10^{-5}	4.4×10^{-4}	4.2×10^{3}
Inhalation of vapors[f] (VD_o/C_{air})	0	63	5.4×10^{5}	4.6×10^{3} [g] 1.9×10^{2} [h]	17	1.56×10^{5}
Inhalation of particulates	∞	∞	3.0×10^{4}	6.3×10^{3}	1.3×10^{4} [i]	

[a] Except for inhalation of vapors.

[b] In the case of SPPPLVs derived for compounds originating in water, use MCL values.

[c] Root crop K_{wp} used, f = 0.1.

[d] Grain crop K_{wp} used, f = 0.2.

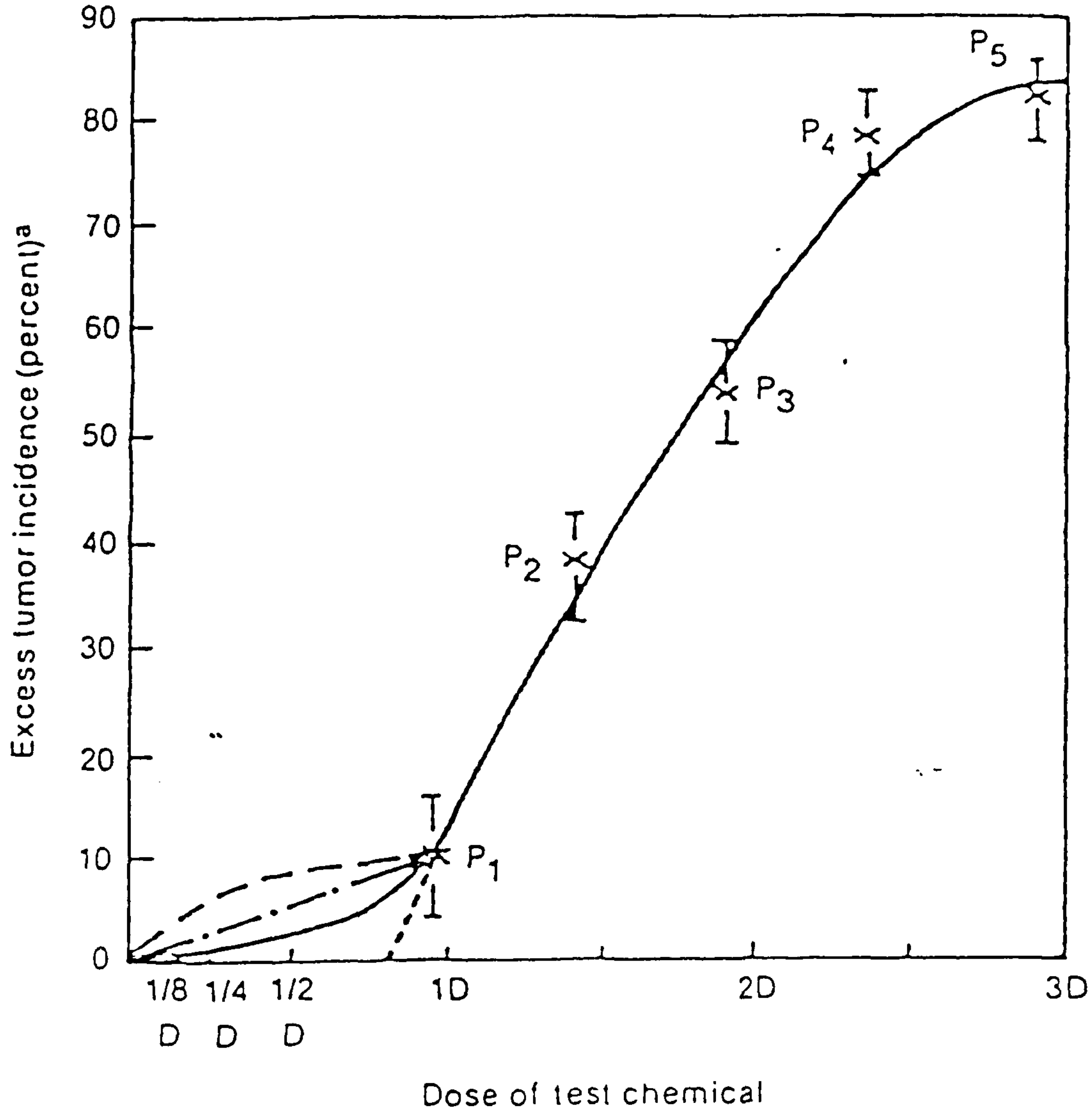
[e] Freshwater fish, f = 0.05.

[f] VD_o/C_{air} compares the saturation vapor pressure with the permissible concentration in air (which in all these cases is TLV/420).

[g] Value for aldrin.

[h] Value for dieldrin.

[i] Compound too volatile to adhere to particles.



[a]Excess tumor incidence (percent) is defined as:

$$\left(\frac{\text{tumors in exposed population}}{\text{number of exposed population}} - \frac{\text{tumors in control population}}{\text{number of exposed population}} \right) \times 100$$

——— a sigmoid dose-response curve; infralinear between O and P₁

—·—·— linear extrapolation

— — — supralinear extrapolation

- - - - - line projected to a threshold

SOURCE: Office of Technology Assessment.

Figure C-1. A Stylized Dose-Response Curve and Some Extrapolated Curves.

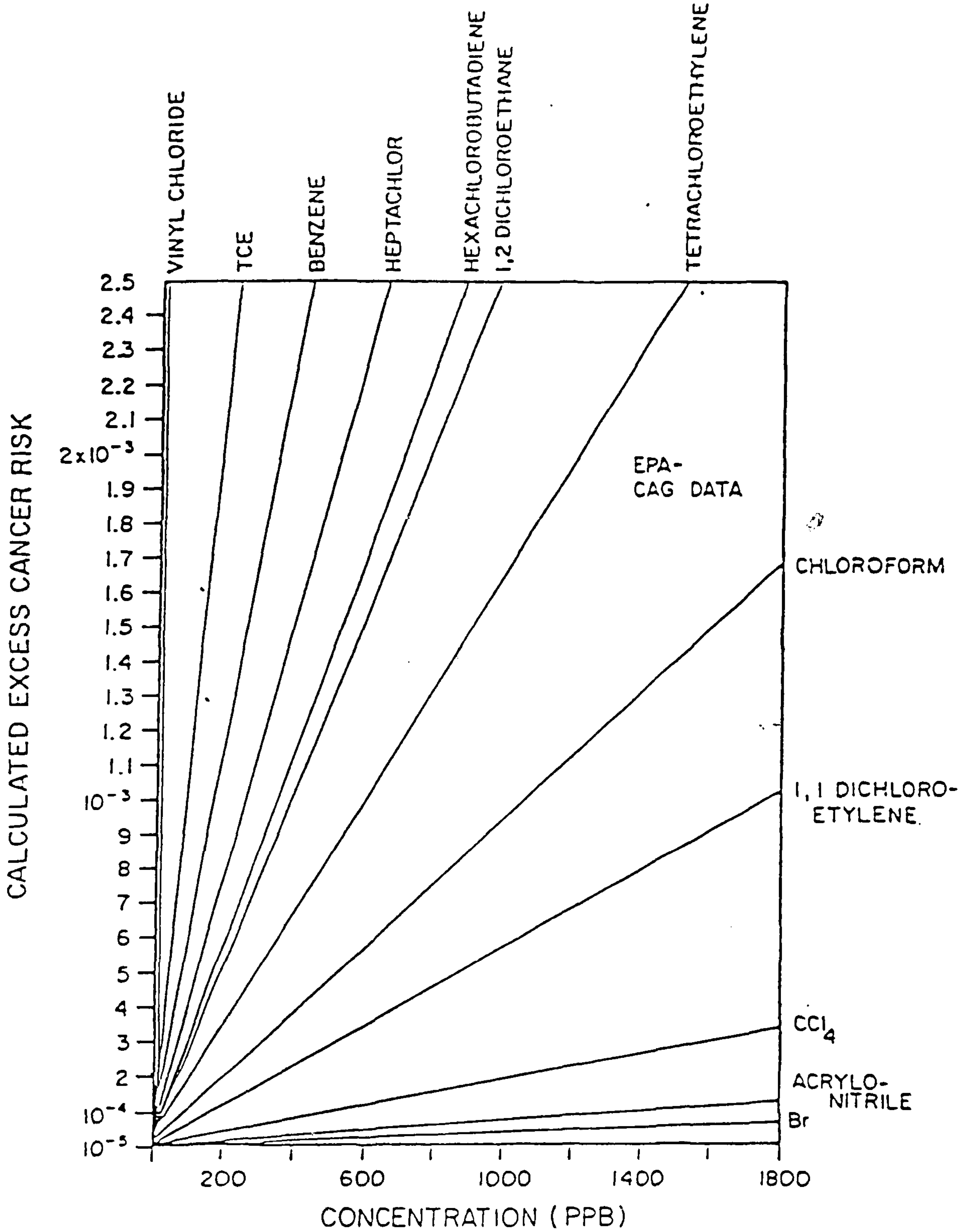


Figure C-2. Calculated Excess Cancer Risk as a Function of Concentration of Chemicals Shown in Drinking Water. Assumes Linear Dose-Response Relationship in Region Shown. (EPA Carcinogen Assessment Group Data.)

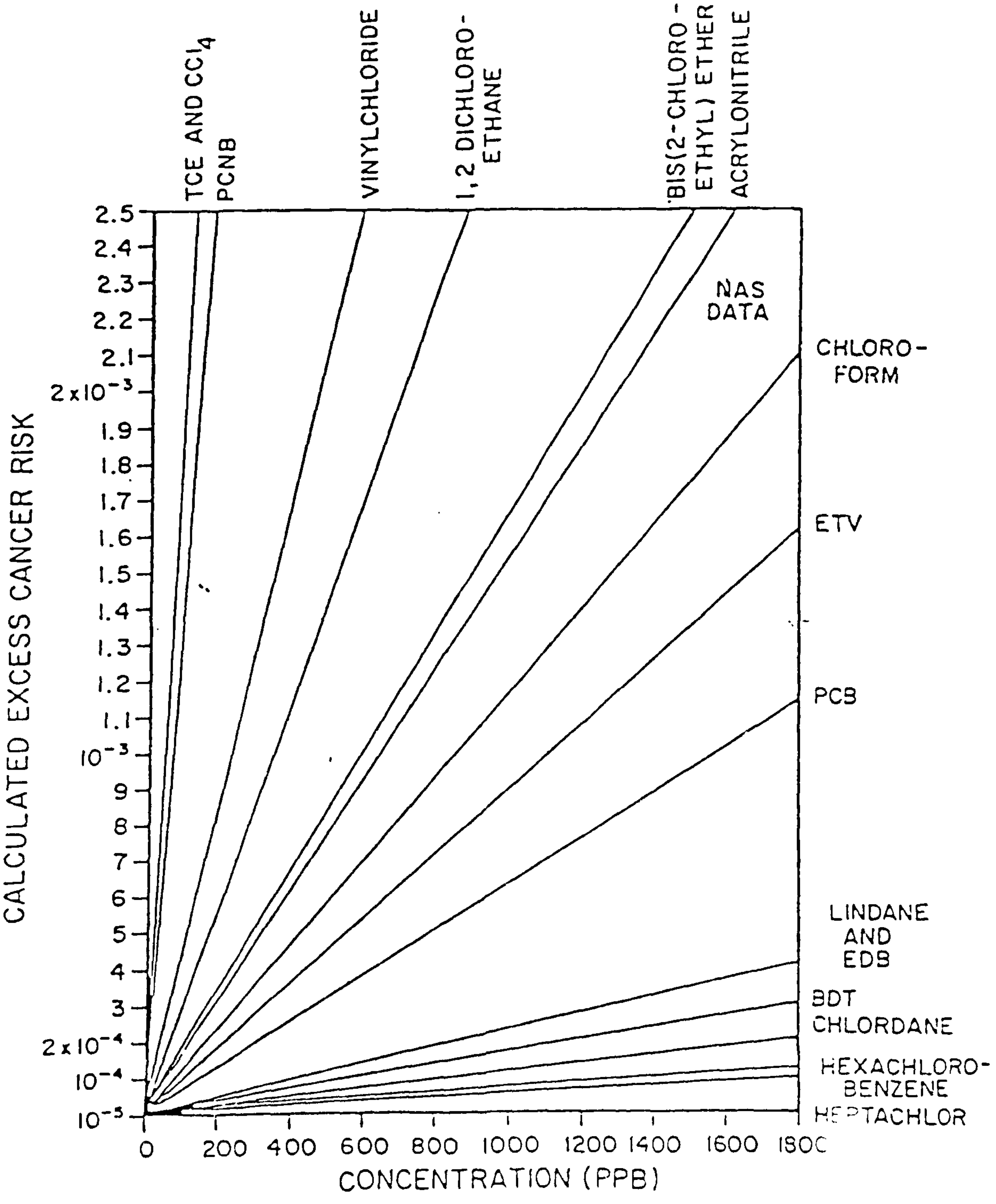


Figure C-3. Calculated Excess Cancer Risk as a Function of Concentration of Chemicals Shown in Drinking Water. Assumes Linear Dose-Response Relationship in Region Shown. (National Academy of Sciences Data.)

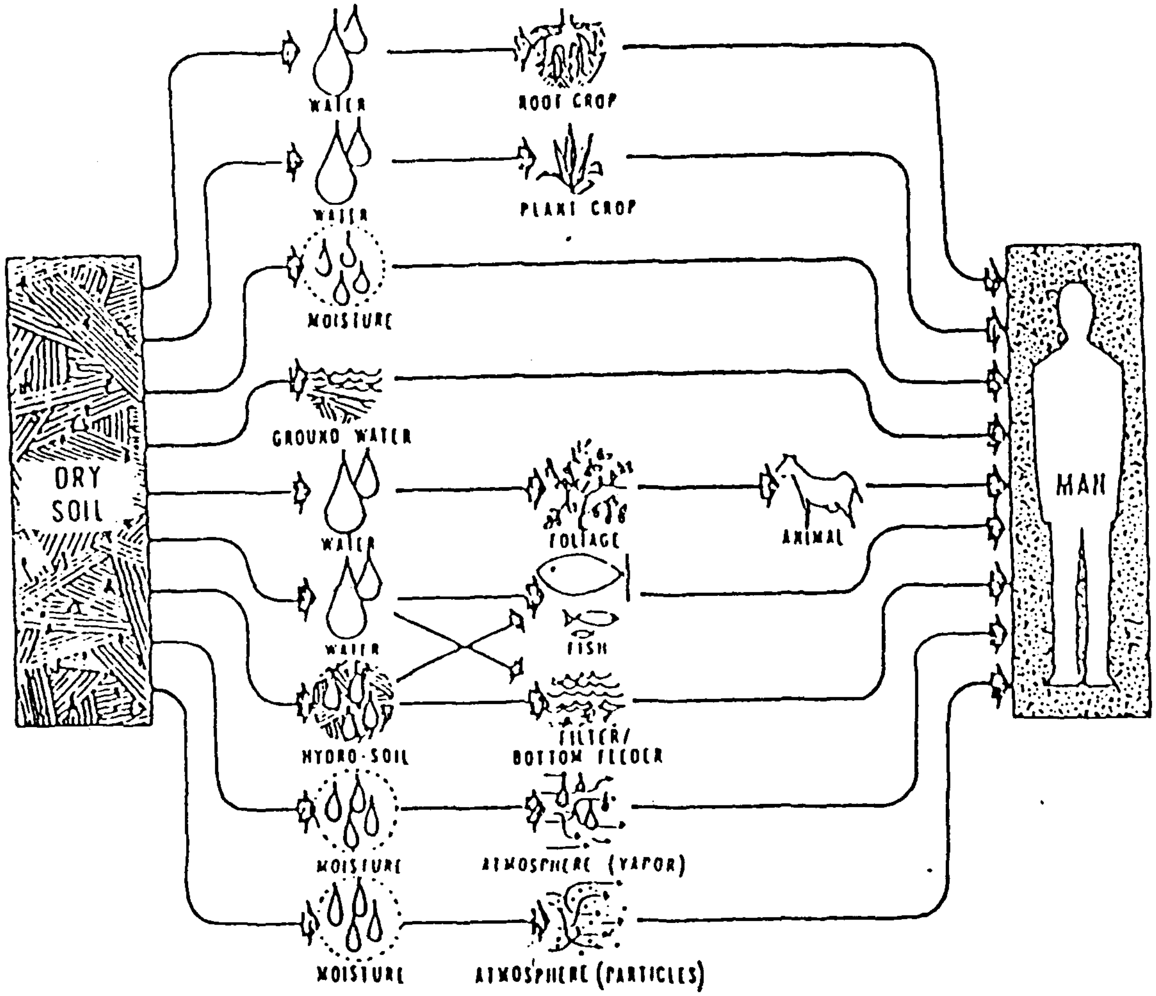
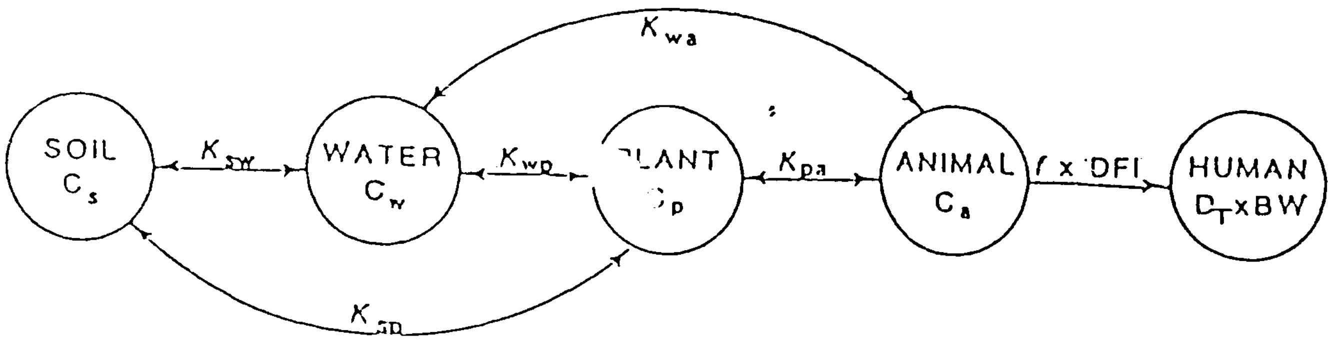


Figure C-4. Pollutant Pathways from Soil to Man. (After reference 2.)



In this fate model, the acceptable daily dose of toxicant, *Dl*, can be obtained from six sources of literature information. The equation for calculating the acceptable daily dose is:

$$D_T = \frac{f \times DFI \times C_a}{BW} = K_{pa} \times K_{wp} \times K_{sw} \times C_s \times f \times DFI/BW$$

$K_{sp} = K_{sw} \times K_{wp}$, etc.

$K_{sw} = C_w \div C_s$, etc.

Each K is an equilibrium constant for a pseudo-equilibrium between two compartments.

Figure C-5. Pollutant Pathway from Soil to Man via Water, Plant, and Animal Compartments. (After Reference 2.)

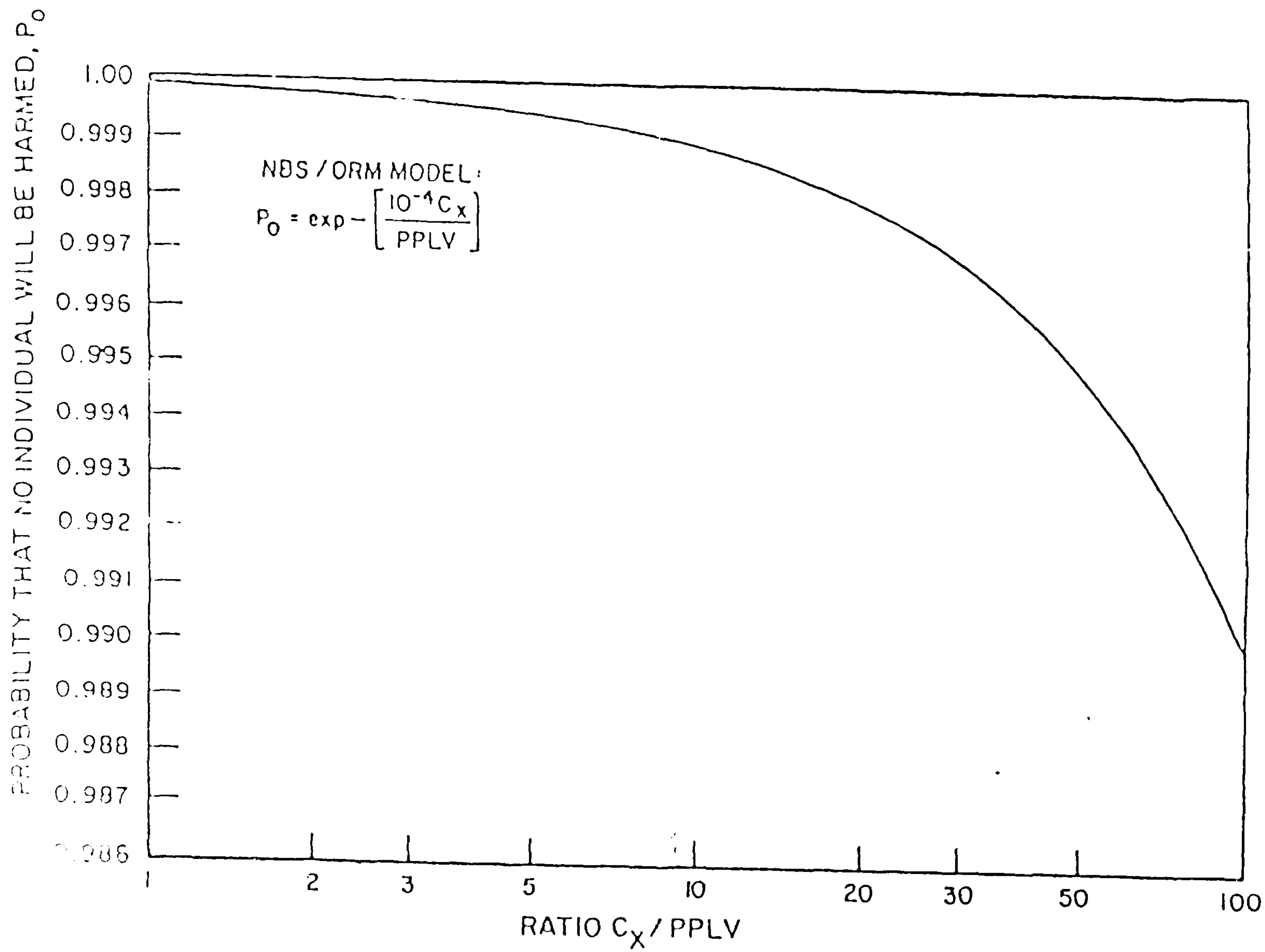


Figure C-6. Probability That No Individual in an Exposed Population is Harmed as a Function of the Ratio C_x/PPLV.

AD-A139 213 COMBUSTION TECHNOLOGY FOR INCINERATING WASTES FROM AIR FORCE INDUSTRIAL PROCESSES(U) NATIONAL BUREAU OF STANDARDS WASHINGTON DC W M SHAUB ET AL. FEB 84 2/2

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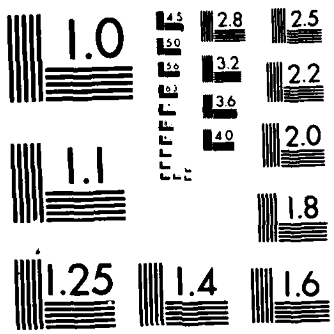

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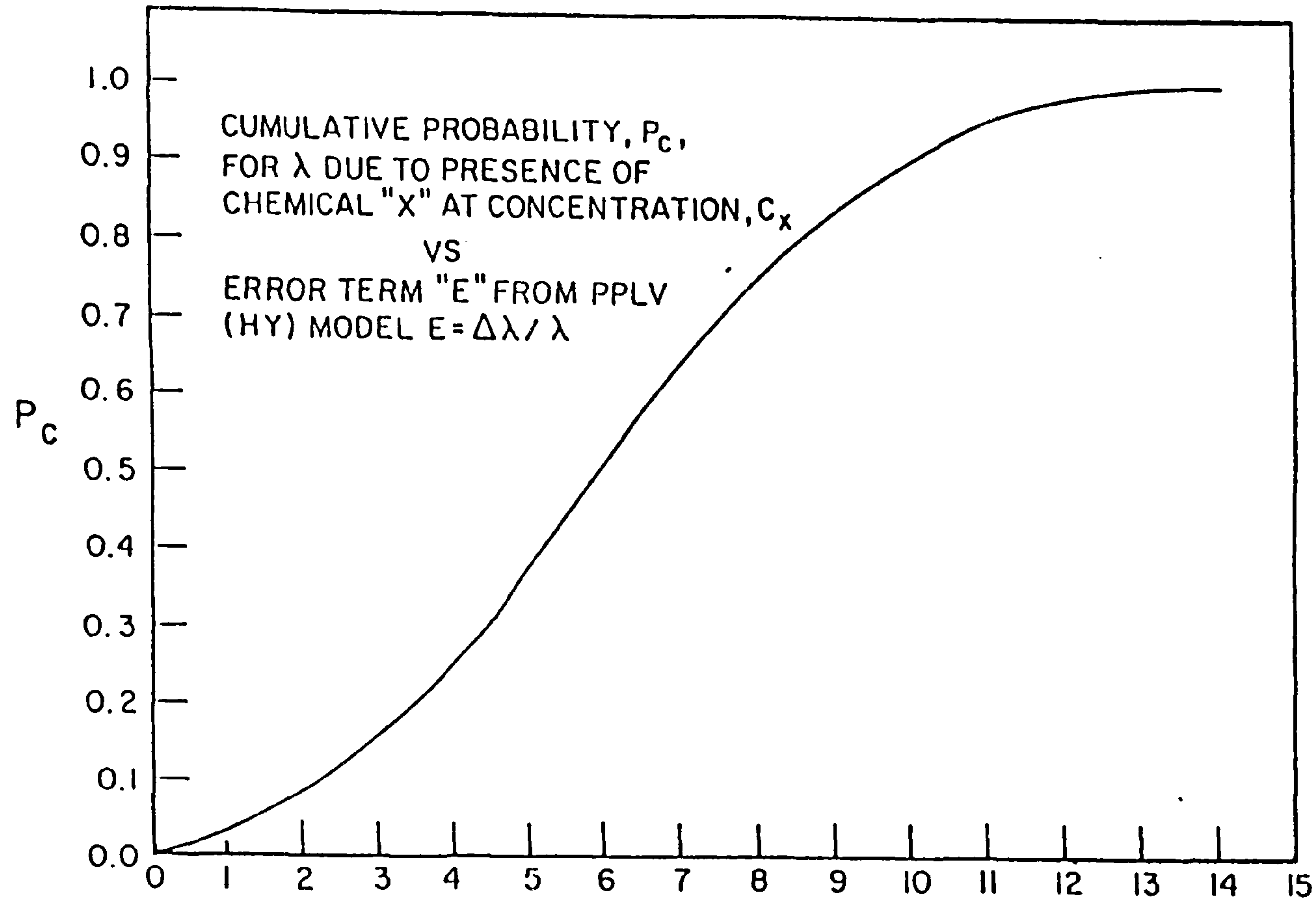

$$E \equiv \left[\left(\frac{\Delta C_x}{C_x} \right)^2 + \left(\frac{\Delta PPLV}{PPLV} \right)^2 \right]^{1/2} = (\Delta\lambda / \lambda)$$

Figure C-7. Cumulative Probability vs Error Term for the Extended PPLV Method.

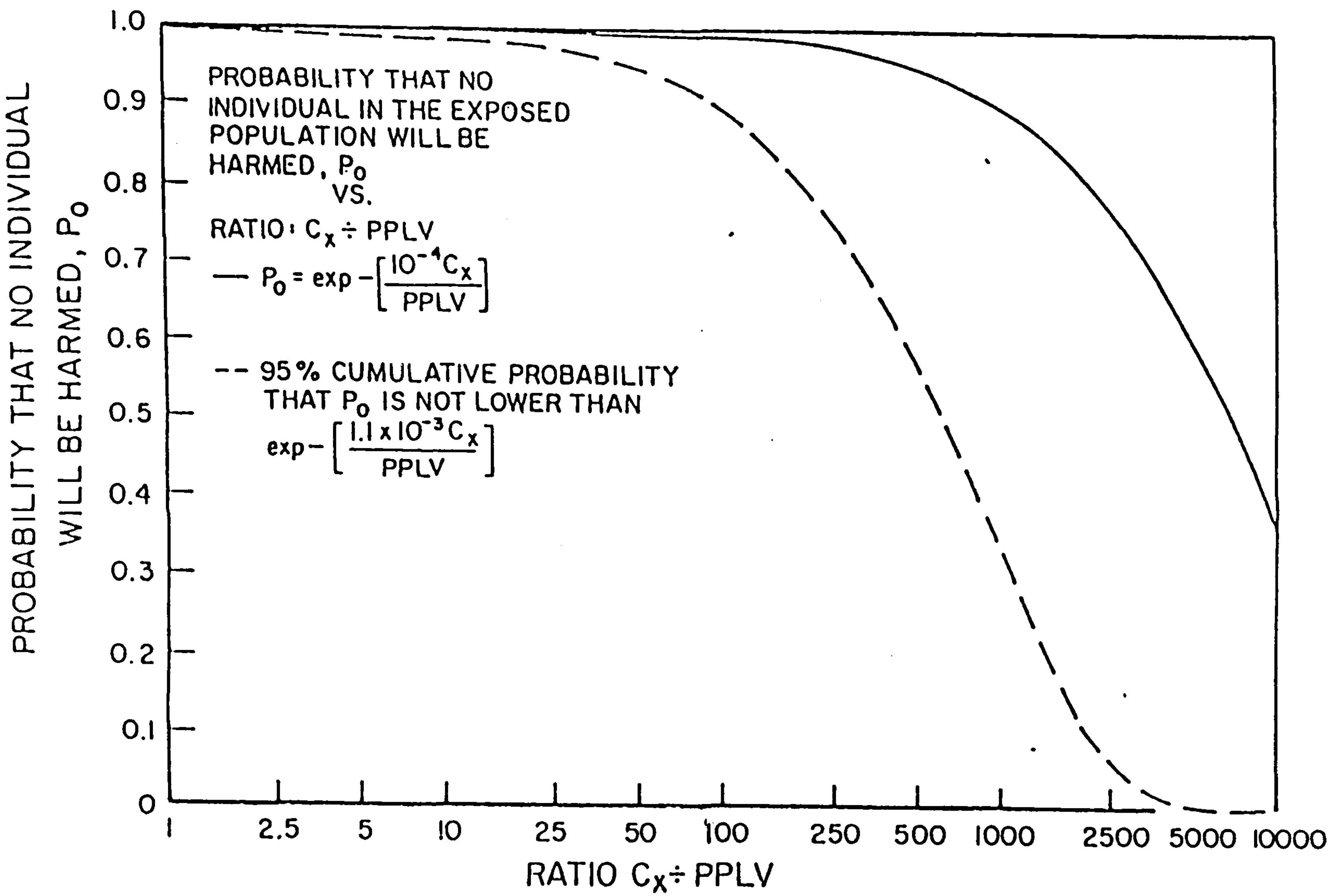

Figure C-8. Upper Bound of 95 Percent Confidence Limit (see Figure C-7) for P_o.

APPENDIX D.
RECENT LEGISLATIVE INITIATIVES PERTAINING TO INDUSTRIAL WASTES

98TH CONGRESS
1ST SESSION

H. R. 2867

[Report No. 98–198, Part I]

To amend the Solid Waste Disposal Act to authorize appropriations for the fiscal years 1984 through 1986, and for other purposes.

IN THE HOUSE OF REPRESENTATIVES

MAY 3, 1983

Mr. FLORIO (for himself, Mr. LENT, Ms. MIKULSKI, Mr. ECKART, Mr. TAUZIN, and Mr. RICHARDSON) introduced the following bill; which was referred to the Committee on Energy and Commerce

MAY 17, 1983

Reported with an amendment, referred to the Committee on the Judiciary for a period ending not later than June 15, 1983, *for consideration of such provisions of the bill and amendments as fall within that committee's jurisdiction pursuant to clause 1(m), rule X*

[Strike out all after the enacting clause and insert the part printed in italic]

[For text of introduced bill, see copy of bill as introduced on May 3, 1983]

A BILL

To amend the Solid Waste Disposal Act to authorize appropriations for the fiscal years 1984 through 1986, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, *"and $1,500,000 for each of the fiscal years 1984 through 1986".*

(i) CRIMINAL INVESTIGATORS.—Section 2007 is amended by adding the following new subsection at the end thereof:

"(e) CRIMINAL INVESTIGATORS.—There is authorized to be appropriated to the Administrator $3,246,000 for the fiscal year 1984, $2,408,300 for the fiscal year 1985, and $2,529,000 for the fiscal year 1986 to be used—

"(1) for additional officers or employees of the Environmental Protection Agency authorized by the Administrator to conduct criminal investigations (to investigate, or supervise the investigation of, any activity for which a criminal penalty is provided) under this Act; and

"(2) for support costs for such additional officers or employees.".

SMALL QUANTITY GENERATOR WASTE

SEC. 3. Section 3001 is amended by adding the following at the end thereof:

"(d) SMALL QUANTITY GENERATOR WASTE.—(1) Effective twenty-four months from the date of enactment of the Hazardous Waste Control and Enforcement Act of 1983, hazardous waste generated by any generator generating a total quantity of hazardous waste greater than one hundred

kilograms but less than one thousand kilograms during a calendar month shall be subject to the same requirements under this subtitle as hazardous waste produced by a generator in amounts greater than one thousand kilograms during a calendar month, until the standards referred to in paragraph (2) of this subsection have become effective.

"(2) Not later than eighteen months after the date of enactment of the Hazardous Waste Control and Enforcement Act of 1983, the Administrator shall promulgate standards under sections 3001, 3002, 3003, and 3004 for hazardous waste generated by a generator generating a total quantity of hazardous waste greater than one hundred kilograms but less than one thousand kilograms during a calendar month. Except as provided in paragraph (3), such standards, including standards applicable to the legitimate use, reuse, recycling, and reclamation of such wastes, may vary from the standards applicable to larger quantity generators but must be sufficient to protect human health and the environment.

"(3) Standards promulgated under paragraph (2) shall at a minimum provide that—

"(A) onsite storage of hazardous waste generated by a generator generating a total quantity of hazardous waste greater than one hundred kilograms but less than one thousand kilograms during a calendar month, may

occur for up to one hundred and eighty days without the requirement of a permit;

"(B) all other treatment, storage, or disposal of hazardous wastes generated by such generators shall occur at a facility with a permit under this subtitle; and

"(C) any hazardous waste generated by such generators which is shipped off the premises on which such waste is generated, shall be accompanied by a manifest, except that the specific requirements for entries on such manifest may vary from those applicable to the manifest required for larger quantity generators.

"(4) No later than ninety days after the enactment of the Hazardous Waste Control and Enforcement Act of 1983, any hazardous waste which is part of a total quantity generated by a generator generating greater than twenty-five kilograms but less than one thousand kilograms during one calendar month and which is shipped off the premises on which such waste is generated shall be accompanied by a copy of the Envirnomental Protection Agency Uniform hazardous waste manifest form signed by the generator. This form shall contain the following information:

"(A) the name and address of the generator of the waste;

"(B) the United States Department of Transportation description of the waste, including the proper shipping name, hazard class, and identification number (UN/NA), if applicable;

"(C) the number and type of containers;

"(D) the quantity of waste being transported.

If subparagraph (B) is not applicable, in lieu of the description referred to in such subparagraph (B), the form shall contain the Environmental Protection Agency identification number, or a generic description of the waste, or a description of the waste by hazardous waste characteristic. Additional requirements related to the manifest shall apply only if determined necessary by the Administrator to protect human health and the environment.

"(5) Except as provided in paragraphs (1) through (4), nothing in this subsection shall be construed to affect or impair the validity of regulations of the Administrator promulgated prior to the date of enactment of the Solid Waste Disposal Act Amendments of 1983 with respect to hazardous waste generated by generators of less than one thousand kilograms per calendar month.

"(6) The Administrator may promulgate regulations under this subtitle which establish special standards for, or exempt from regulations, hazardous wastes which are gener-

ated by any generator who does not generate more than one hundred kilograms of hazardous waste per calendar month.

"(7) Nothing in this subsection shall be construed to affect or impair the validity of regulations promulgated by the Secretary of Transportation pursuant to the Hazardous Materials Transportation Act.

"(8) Notwithstanding the last sentence of section 3010(b), no regulation promulgated by the Administrator as provided in this subsection may take effect before the date twenty-four months after the date of the enactment of this subsection.".

INTERIM CONTROL OF HAZARDOUS WASTE INJECTION

SEC. 4. (a) NEW SECTION 7010.—Subtitle G is amended by adding the following new section at the end thereof:

"INTERIM CONTROL OF HAZARDOUS WASTE INJECTION

"SEC. 7010. (a) UNDERGROUND SOURCE OF DRINKING WATER.—No hazardous waste may be disposed of by underground injection—

"(1) into a formation which contains (within one-quarter mile of the well used for such underground injection) an underground source of drinking water; or

"(2) above such a formation.

The prohibition established under paragraph (2) shall not apply if the person injecting such hazardous waste establishes *to pretreatment and detoxification prior to land disposal, and limitations on waste dilution.".*

BURNING AND BLENDING FOR ENERGY RECOVERY

SEC. 6. (a) NOTICE.—(1) Section 3010 is amended by inserting the following after the first sentence thereof: "Not later than twelve months after the date of the enactment of this sentence—

"(1) the owner or operator of any facility which produces a fuel (A) from any hazardous waste identified or listed under section 3001, (B) from such hazardous waste identified or listed under section 3001 and any other material, (C) from used oil, or (D) from used oil and any other material;

"(2) the owner or operator of any facility which burns for purposes of energy recovery any fuel produced as provided in paragraph (1) or any fuel which otherwise contains used oil or any hazardous waste identified or listed under section 3001; and

"(3) any person who distributes or markets any fuel which is produced as provided in paragraph (1) or any fuel which otherwise contains used oil or any hazardous waste identified or listed under section 3001;

shall file with the Administrator (and the State in the case of a State with an authorized hazardous waste program) a notification stating the location and general description of the *facility, together with a description of the identified or listed hazardous waste involved and, in the case of a facility referred to in paragraph (1) or (2), a description of the production or energy recovery activity carried out at the facility and such other information as the Administrator deems necessary. For purposes of the preceding sentence, the term 'hazardous waste listed under section 3001' also includes any commercial chemical product which is listed under section 3001 and which, in lieu of its original intended use, is (i) produced for use as (or as a component of) a fuel, (ii) distributed for use as a fuel, or (iii) burned as a fuel. Not more than one notification shall be required under this subsection in the case of a facility which burns for purposes of energy recovery any fuel which is generated at the site of such facility unless the burning practices to which such notice applies changes following such notification. Notification shall not be required under this subsection in the case of facilities (such as residential boilers) where the Administrator determines that such notification is not necessary in order for the Administrator to obtain sufficient information respecting current practices of facilities using hazardous waste for energy recovery. Nothing in this subsection shall be construed to affect or impair the provisions of section 3001(b)(3). Nothing in this subsection shall affect regulatory determinations under section 3012 (as amended by the Used Oil Recycling Act of 1980).".*

(2) Section 3010 is amended by striking out "the preceding sentence" and substituting "the preceding provisions".

(b) STANDARDS.—(1) Section 3004 is amended by adding the following at the end thereof:

"(g) HAZARDOUS WASTE USED AS FUEL.—Not later than two years after the date of the enactment of this subsection, and after notice and opportunity for public hearing, the Administrator shall promulgate regulations establishing such—

"(1) standards applicable to the owners and operators of facilities which produce a fuel (A) from any hazardous waste identified or listed under section 3001, or (B) from any hazardous waste identified or listed under section 3001 and any other material;

"(2) standards applicable to the owners and operators of facilities which burn for purposes of energy recovery any fuel produced as provided in paragraph (1) or any fuel which otherwise contains any hazardous waste identified or listed under section 3001; and

"(3) standards applicable to any person who distributes or markets any fuel which is produced as provided in paragraph (1) or any fuel which otherwise contains any hazardous waste identified or listed under section 3001 *as may be necessary to protect human health and the environment. Such standards may include any of the requirements set forth in paragraphs (1) through (7) of subsection (a) as may be appropriate. The standards under paragraph (2) may consider differences in destruction efficiency, and waste content of the fuel, and shall, where appropriate, not include requirements beyond the notification referred to in section 3010. Nothing in this subsection shall be construed to affect or impair the provisions of section 3001(b)(3). For purposes of this subsection, the term 'hazardous waste listed under section 3001' includes any commercial chemical product which is listed under section 3001 and which, in lieu of its original intended use, is (A) produced for use as (or as a component of) a fuel, (B) distributed for use as a fuel, or (C) burned as a fuel.*

"(h) LABELING.—Notwithstanding any other provision of law, it shall be unlawful for any person who is required to file a notification in accordance with paragraph (1) or (3) of section 3010 to distribute or market any fuel which is produced from any hazardous waste identified or listed under section 3001, or any fuel which otherwise contains any hazardous waste identified or listed under section 3001 if the invoice or the bill of sale fails—

"(1) to bear the following statement: 'WARNING: THIS FUEL CONTAINS HAZARDOUS WASTES', and

"(2) to list the hazardous wastes contained therein.

Such statement shall be located in a conspicuous place on every such invoice or bill of sale and shall appear in conspicuous and legible type in contrast by typography, layouts, or color with other printed matter on the invoice or bill of sale.

"(i) EXEMPTION.—(1) Unless the Adminstrator determines otherwise as may be necessary to protect human health and the environment, the requirements of subsection (h) shall not apply to fuels produced from petroleum refining waste containing oil if—

"(A) such materials are generated and reinserted onsite into the refining process;

"(B) contaminants are removed; and

"(C) such refining waste containing oil is converted along with normal process streams into petroleum-derived fuel products

at a facility at which crude oil is refined into petroleum products and which is classified as a number SIC 2911 facility under the Office of Management and Budget Standard Industrial Classification Manual.

"(2) For exemption of used oil which is recycled from standards under this section, see section 3012(c).".

(2) Section 3003 is amended by adding the following new subsection at the end thereof:

"(c) FUEL FROM HAZARDOUS WASTE.—Not later than two years after the date of the enactment of this subsection and after opportunity for public hearing, the Administrator shall promulgate regulations establishing standards, applicable to transporters of fuel produced (1) from any hazardous waste identified or listed under section 3001, or (2) from any hazardous waste identified or listed under section 3001 and any other material, as may be necessary to protect human health and the environment. Such standards may include any of the requirements set forth in paragraphs (1) through (4) of subsection (a) as may be appropriate."

INTERIM STATUS; PERMITS

SEC. 7. (a) EXPANSION DURING INTERIM STATUS.—Section 3005(e) is amended by inserting "(1)" after "INTERIM STATUS.—", redesignating paragraphs (1) through (3) as subparagraphs (A) through (C), and adding the following at the end thereof:

"(2) Any owner or operator of a treatment, storage, or disposal facility operating under interim status pursuant to this subsection who expands the capacity of the facility (except the capacity for storage or treatment in tanks or con-

RCRA

98TH CONGRESS *1st Session*	HOUSE OF REPRESENTATIVES	REPT. 98-198 Part 1

HAZARDOUS WASTE CONTROL AND ENFORCEMENT ACT OF 1983

MAY 17, 1983.—Ordered to be printed

Mr. DINGELL, from the Committee on Energy and Commerce, submitted the following

REPORT

together with

MINORITY VIEWS

[To accompany H.R. 2867]

[Including cost estimate of the Congressional Budget Office]

The Committee on Energy and Commerce, to whom was referred the bill (H.R. 2867) to amend the Solid Waste Disposal Act to authorize appropriations for the fiscal years 1984 through 1986, and for other purposes, having considered the same, report favorably thereon with an amendment and recommend that the bill as amended do pass.

The amendment is as follows:

Strike out all after the enacting clause and insert in lieu thereof the following:

SHORT TITLE AND TABLE OF CONTENTS

SECTION 1. (a) This Act may be cited as the "Hazardous Waste Control and Enforcement Act of 1983".

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for the personnel, equipment and other resources to conduct criminal investigations of any activity for which a criminal penalty is provided under this Act. The Committee strongly believes that the criminal enforcement program should be one of the EPA's and the Justice Department's highest priorities and therefore intends that adequate funding be available for that purpose. The Committee expects that criminal investigators be permanently stationed in each of EPA's regions and that the investigative program under this Act be closely coordinated with the Department of Justice, the Federal Bureau of Investigation, and other Federal law enforcement agencies as well as state and local law enforcement agencies.

Section 3. Small quantity generators

The purpose of this provision is to direct EPA to regulate under Subtitle C hazardous waste from generators who generate a total quantity of hazardous waste between 100 and 1,000 kilograms per calendar month (kg/mo). EPA is required to promulgate such standards within 18 months of enactment. However, if EPA fails to meet the statutory deadline for promulgation, then on the date 24 months after enactment, hazardous wastes generated by small quantity generators become subject to all of the Subtitle C standards applicable to hazardous waste generated by larger generators (i.e., generators of more than 1,000 kilograms of hazardous waste per month). Should this occur, hazardous waste from small quantity generators will remain subject to standards applicable to hazardous waste from larger generators until such time as special standards for small quantity generators are promulgated and in effect. For purposes of this provision, EPA is authorized to waive the six-month effective date requirement of Section 3010 and promulgate regulations which are either immediately effective or effective after some period of less than six months but in no event are the regulations to become effective before the date 24 months after enactment. In addition, this section also contains a notice requirement applicable to all off-site shipments of hazardous waste by generators of more than 25, but less than 1,000, kilograms of hazardous waste per calendar month.

The Committee has included this provision to correct a current regulatory exclusion from the Act that was not envisioned by the Congress. Under regulations promulgated on May 19, 1980 (40 CFR 261.5), the Agency excluded from most RCRA requirements generators who generate 1,000 kilograms/calendar month of hazardous waste or less. As a consequence of this exclusion such generators are allowed to dispose of their waste into permitted licensed and registererd sanitary landfills, or into sewer lines that are connected to publicly owned treatment works—facilities that frequently are not suited to manage or treat hazardous wastes. Such generators are also not required to manifest, transport, treat or maintain proper records for the wastes they generate.

The Committee believes that this exclusion is unwarranted and allows substantial quantities of otherwise hazardous waste to be disposed of in an environmentally unsound manner. The Agency estimates that only one percent of total hazardous waste escape coverage, yet, the Office of Technology Assessment has estimated that an amount up to 10 percent of the 40 million metric tons of hazardous waste that are currently regulated under the Act may be escaping proper controls through this exclusion. Furthermore, in its May 19, 1980 regulations the Agency committed to lowering the level of this exclusion from 1,000 kg/mo (one metric ton) to 100 kg/mo (1/10 of one metric ton). By enacting this provision, the Committee is ensuring implementation of the Agency's previous commitment to lower the present small quantity generators exclusion ten fold within 18 months so that the same universe of hazardous wastes is regulated for both large and small generators.

The Committee recognizes that the hazard of a given waste is imparted by its intrinsic toxicity and other inherent properties such as ignitability, corrosivity and reactivity, and is not a function of the specific volume in which the waste is produced by a given generator. The Committee also recognizes that the handling, transport, and disposal of hazardous wastes are important factors in controlling the magnitude and extent of the health and environmental hazards posed by such wastes. Given those considerations, it is the Committee's intention that the wastes produced by this class of newly covered generators (those who produce more than 100 kg/mo but less than 1000 kg/mo) will be manifested, transported, stored, treated, and disposed on in a manner consistent with the current requirements for generators of greater than 1000 kg/mo, while at the same time limiting the administrative burden. EPA is therefore given discretion to vary the standards applicable to small quantity generators (and the hazardous waste they generates) from the standards applicable to hazardous waste from larger generators except in three specific areas. Standards applicable to small quantity generators must, at a minimum, provide that:

1. Small quantity generators may store their wastes on-site for up to 180 days without a permit;
2. All other treatment, storage, and disposal of hazardous waste from small quantity generators must occur at a facility with interim status or a Subtitle C permit; and
3. All off-site shipments of hazardous waste from small quantity generators must be accompanied by a manifest; however, the manifest need not necessarily contain all the information required on the manifest used by larger generators.

In providing for on-site storage for up to 180 days, EPA may prescribe design or operating standards as necessary to protect human health and the environment. However, small quantity generators shall not be required to have or obtain interim status or a permit for such storage.

For those generators which generate 100 kg/mo or less of hazardous waste, the Administrator may promulgate requirements, in addition to those that apply under current regulation (40 CFR 261.5), as may be necessary to protect public health and the environment. Nothing in this provision shall be construed to remove the current disposal requirements for generators of acutely hazardous wastes as listed in 40 CFR 261.33(e) or to impair the Administrator's discretion to impose disposal requirements on other categories of acutely or chronically hazardous waste, irrespective of the quantities in which they are generated. The Committee also believes that it would be both prudent and reasonable for generators of 100 kg/mo or less of hazardous waste to be required to notify the disposer of such wastes of its qualitative content so as to minimize the hazards to personnel involved in the disposal of such wastes.

With regard to the requirement for a manifest, the Committee envisions that small quantity generators will be required to use the same manifest forms as larger generators but will not necessarily be required to fill out all the information on the form. EPA, in conjunction with the Department of Transportation (DOT), may choose to require some sort of indication on the manifest form that the source of the waste is a small quantity generator.

Other than these specified standards, EPA may vary the small quantity generator standard from the larger generator standards for waste identification, waste analysis, recordkeeping, reporting, pre-transport requirements, or any other requirements under Sections 3001, 3002, 3003, or 3004. However, in all cases standards for small quantity generators must be sufficient to protect human health and the environment.

Until special small quantity generator standards are in effect, or the full set of Subtitle C standards are applied by the operation of Section 3001(d), waste from small quantity generators can continue to be sent to Subtitle D facilities to the extent provided by existing EPA regulations. However, the Committee believes that there is an immediate need to provide notice to transporters, disposers, and other handlers of small quantity generator's wastes, of the type of waste they are handling. Such notice will enable handlers to institute proper precautions to assure that waste is safely managed. Accordingly, the amendment contains a requirement that any off-site shipments of hazardous waste by generators generating between 25 and 1,000 kilogram of hazardous waste per month must be accompanied by the EPA uniform hazardous waste manifest form, signed by the generator. This requirement is intended to be self implementing in that no regulations are necessary to implement it. The requirement becomes effective 90 days from enactment.

EPA and the DOT jointly proposed the uniform hazardous waste manifest form on March 4, 1982 (47 FR 9336). Under the proposal, both EPA and DOT would require use of the uniform manifest for all regulated shipments of hazardous waste. Although the uniform manifest form has not been promulgated as a final rule, EPA and DOT expect it to be promulgated prior to enactment of this legislation.

Under the amendment, small quantity generators are required to complete only the follwing information on the form: (1) the name and address of the generator; (2) the DOT description of the waste, including the proper shipping name, hazard class, and identification number; (3) the number and type of containers; and (4) the quantity of waste being transported. Although the form contains space for other specific information, small quantity generators are only required by this provision to supply the four specified pieces of information. If the DOT description of the wastes is not provided under applicable DOT and EPA regulations, then the form would contain, in lieu of the DOT description, the EPA identification number, or a generic description of the waste by hazardous waste characteristic. Furthermore, this provision does not impose recordkeeping or reporting requirements on small quantity generators. However, the Administrator is authorized to require that additional information be included on the form by small quantity generators or even to require recordkeeping and reporting, if deemed necessary to protect human health and the environment.

The notice provision is intended as an interim requirement for generators of between 100 and 1,000 kilograms of hazardous waste—that is, standards promulgated by EPA applicable to such generators will supersede this requirement. However, EPA may choose to continue to require a partially completed Uniform National Manifest. If EPA fails to promulgate standards on time and generators of between 100 and 1,000 kilograms of hazardous waste per month become subject to the full Subtitle C standards, then for such generators this interim requirement would be replaced by the full manifest requirements applicable by regulation to larger generators.

For generators of hazardous waste in the 25 to 100 kilogram range, the notice requirement in this amendment will remain in effect. EPA may add additional requirements for generators in this range, but at a minimum the notice provision shall remain applicable.

None of the requirements in this amendment are intended to supersede DOT requirements relating to the transport of hazardous materials. Thus, to the extent that any generator of less than 1,000 kilograms per month of hazardous waste is subject to DOT regulations under the Hazardous Materials Transportation Act, such generators shall remain subject to those rules.

Section 4. Interim control of underground injection

Section 4 establishes an interim program of regulation of underground injection of hazardous waste. This provision is similar to one included in last year's bill, H.R. 6307, that was adopted by the House.

Underground injection is the process of forcing liquid into a well. Because underground injection, if improperly done, can lead to contamination of underground sources of drinking water, the Safe Drinking Water Act requires that EPA develop minimum requirements for State programs controlling underground injection (Section 1421). If a State does not incorporate these requirements into its program, EPA is required to establish a satisfactory underground injection control program for that State (Section 1422).

Under the schedule established by the Safe Drinking Water Act Act, EPA was directed to promulgate the requirements within 360 days of the Act's enactment on December 16, 1974. In fact, these requirements were not even proposed until 1976 and were then reproposed in 1979 as a result of adverse comments from States and affected industries. (See 41 FR 36730, August 31, 1976, and 44 FR 23738 April 20, 1979). The requirements were not finally promulgated until June, 1980. (See 45 FR 42473, June 24, 1980).

Even this delay was apparently not sufficient to enable the Agency to carry out the statutory mandate fully. Instead, EPA announced when the requirements were promulgated that it would defer the promulgation of minimum requirements for injection of

Section 6. Burning and blending hazardous waste for energy recovery

Section 6 corrects a major deficiency in the present RCRA regulations by requiring EPA to exercise its existing authority over hazardous waste-derived fuels by regulating their production, distribution and use. The Committee intends that EPA exercise this authority in tandem with its authority over used oil so that used oil-derived fuels are regulated at the same time.

Currently, EPA exempts facilities that burn hazardous waste for the primary purpose of energy recovery. EPA has estimated that 10 or 15 million metric tons of hazardous wastes are burned each year in boilers; over one-half of all hazardous waste generated is burned in facilities not now regulated under RCRA. EPA has acknowledged that burning hazardous wastes for energy recovery is similar to incinerating then and "could pose a parallel or greater risk of enviornmental dispersal of hazardous waste constituents and products of incomplete combustion." (48 FR 14481-2 (April 4, 1983)).

Fuel blending is one of several areas where EPA's failure to promulgate regulations has led to direct threats to human health and the environment. Hazardous wastes have been blended with heating oil and sold to unsuspecting customers who burn them under conditions which may not protect human health or the environment.

The potential impact of this loophole is even more significant as more and more wastes may be burned in boilers, cement kilns, or other heat recovery units to avoid RCRA regulation and treatment costs. In addition to the obvious adverse health and environmental consequences of continued unregulated burning, the present loophole acts as a disincentive to the development and expansion of hazardous waste treatment facilities. The Committee intends his section and Section 5, restricting the land disposal of hazardous waste, to provide a meaningful regulatory program to increase the treatment of hazardous waste and the development of new treatment capacity.

EPA has asserted its jurisdiction over burning and blending of hazardous wastes for energy recovery. EPA also has established enforcement guidelines to identify "illegitimate" or "sham" burning for energy recovery and bring such practices under regulation.

The Committee commends these new initiatives by EPA. However, the Committee still believes, as it did last year, that legislation is necessary to assure that the Committee's objectives in compelling EPA to develop and implement a comprehensive regulatory program over burning and blending for energy recovery are achieved, within the timetables set by the Committee. The provisions of Section 6 do not grant EPA any new statutory authority; RCRA now provides EPA full authority to regulate hazardous wastes that are blended or burned for energy recovery and to regulate the owners and operators of the blending and burning facilities. The Committee wants to assure that EPA will exercise its authority over all facilities that blend or burn hazardous waste for energy recovery.

The term "facility," as defined under RCRA and as intended to be applied by the Committee, includes cement kilns and industrial furnaces, not just boilers, that burn hazardous waste for energy recovery. EPA has recently proposed that cement kilns and "industrial furnaces" that burn hazardous waste for fuel would continue to be exempt from regulation. The Committee does not consider such exemption, particularly for cement kilns, to be consistent with its intent in closing the burning and blending exemption if it were to be extended beyond the two year date for promulgating regulations contained in this Section. This continued exemption could well be inconsistent with the RCRA mandate to regulate hazardous wastes as necessary to protect human health and the environment. The Committee does not consider cement kilns burning hazardous waste for energy (not recycling cement kiln dust for clinker) to be distinguishable from a commercial hazardous waste incinerator in its potential impact on human health and the environment.

Notification.—Subsection (a) amends RCRA Section 3010 to require filing of a notification by anyone who is producing a hazardous waste-derived fuel, burning a hazardous waste fuel for energy recovery, or distributing and marketing a fuel produced from a hazardous waste (including transporters). This is a self-implementing requirement, so that if EPA fails to issue timely regulations, all persons covered by the provisions are required to notify. The Committee intends this program to apply to hazardous waste-derived fuels, fuels blended with hazardous wastes, and hazardous wastes burned without blending as fuels. Hazardous waste, as used in this provision, includes not only wastes identified or listed as hazardous under EPA's regulations, but also includes any commercial chemical product (and related materials) listed pursuant to 40 CFR 261.33, which is not used for its originally intended purpose but instead is burned or processed as fuel. (Under current EPA regulations, burning as fuel is not deemed to be a form of discard; hence listed commercial chemical products, unlike spent materials, byproducts or sludges, are not deemed to be "wastes" when burned as fuel. They are only "wastes" when actually discarded or intended for discard.) Hazardous waste or used oil generators who do not deal directly with the persons who ultimately burn the wastes (or used oil) as a fuel, and do not burn these materials themselves, are not covered by this provision because they neither produce, market, nor distribute a waste-derived fuel.

The Committee desires that the Agency assemble an accurate picture of the current nature and scope of current hazardous waste fuel production, distribution, and burning. In this regard, the Committee recommends that the 3010 notices that are required under Section 6 of these amendments contain the following information:

From Fuel Producers:

wastes utilized in fuel production, toxic constituents in the waste and in the waste portion of the fuel, and percentage of the waste component of the fuel;

BTU content of the fuel produced;

where and to whom the fuels are sent;

quantities of waste-derived fuels produced.

From Marketers/Distributors:

where they got the fuel from;

whether they change the content;
where and to whom they market the fuel;
quantities of fuel distributed, and frequency of distribution.

From Ultimate Users:

source of their waste-derived fuel;
types of wastes or waste-derived fuel burnt, and quantities burnt;
description of the combustion unit in which the fuels are burnt (including such information as boiler design, heat input and out-put, and temperature of combustion);
type of primary boiler fuel used and portion of heat input provided by the waste or the waste-derived fuel;
BTU content.

The notification requirement is contained in an amended Section 3010(a)(1). This has two-fold significance. First, all notifications filed under this provision will go to both EPA and to states with authorized hazardous waste programs rather than to one or the other, as with other notifications. Second, the notification is a prerequisite for interim status (see RCRA Section 3005(e)(2)) if EPA later determines that these persons should be regulated as hazardous waste management facilities. This should create a strong incentive for persons required to notify to comply with the requirement.

The bill also contains a provision indicating that special classes of waste material listed in Section 3001(b)(3)(A), which are not now subject to regulation as hazardous wastes, are not subject to the notification and regulatory provisions of these amendments. An example are the high volume wastes generated from the combustion of coal or other fossil fuel, typical of the utility industry. However, utilities that burn hazardous wastes such as spent solvents, spent acids, or corrosive boiler cleaning wastes in their boilers are subject to the notification requirement and could be subject to the standards requirements as well.

Standards for Production, Burning, Distribution, and Marketing.—Subsection (6)(b) of the bill amends Section 3004. It requires the Administrator to promulgate regulations, as may be necessary to protect human health and the environment, governing hazardous waste-derived fuel production, burning, distribution and marketing. Used oil, (whether or not a hazardous waste) mixed with other hazardous wastes can be regulated under these provisions. The regulations apply to anyone required to submit a Sec. 3010 notification under this section, e.g., the owners and operators of any facility that blends or burns hazardous wastes as a fuel or anyone who markets or distributes hazardous waste fuels.

The Committee believes that the standards should include the requirements listed in subsection (a) of Section 3004 as appropriate. EPA may make different standards effective at different times. For example, manifesting and recordkeeping may be immediately required, while other performance or technical standards may be imposed at a later time within the two year deadline. The technical standards applicable to facilities burning hazardous waste as a fuel may consider various factors, including destruction efficiency, and waste content of the fuel. Furthermore, it is the Committee's intention that the Administrator, in controlling the burning of hazardous waste and the emissions from such facilities, make no such distinction on the basis of whether the facility is on the site of the generator, or is an off-site facility.

Because EPA already has the authority to regulate the blending and burning of hazardous wastes for purposes of energy recovery, the Committee's objective is to accelerate the Agency's rulemaking to close a major gap in the present regulations and to set an outside deadline for the regulation of all burning of hazardous wastes and blended fuels. In promulgating regulations, the Agency must regulate all combustion units burning hazardous waste-deriving fuel for energy recovery—including boilers, cement kilns, and other industrial furnaces—under the same ultimate standards as other hazardous waste management facilities regulation as may be necessary to protect human health and the environment. This may lead to the result that these units are regulated under the same substantive requirements as apply to presently regulated treatment facilities. When a combustion unit operates like an incinerator—especially in terms of the type and volume of hazardous waste being burned—the Committee expects that the Agency will apply the same substantive requirements as are now applied to presently regulated treatment facilities.

Labeling.—The Committee intends that the Agency expeditiously implement a requirement for fuel blenders to notify their customers of the presence of hazardous wastes in their fuel. The Committee is concerned that people are unwittingly burning hazardous wastes in uncontrolled circumstances, with obvious health and environmental risks. The user could be at risk not only from boiler emissions, but could be exposed to fire or explosion hazard (since hazardous waste-derived fuels may have a lower flash point), or risk boiler damage (from hydrochloric acid formed by chlorinated wastes) as well. Transporters also may be unaware that they may be facing special risks from carrying hazardous waste-derived fuels.

Consequently, starting one year after the passage of the Hazardous Waste Control and Enforcement Act of 1983, distributors of hazardous waste-derived fuels who are required to notify must put a warning label on the invoices or bill of sale accompanying each shipment of hazardous waste-derived fuel. (The provision does not apply to fuels which contain used oil alone.) The label would have to warn the user (and transporter) that the fuel contains hazardous waste and identify the hazardous waste it contains. This latter requirement can be satisfied by identifying wastes by generic classes (for instance, "chlorinated solvents") rather than by the precise chemical name ("spent trichloroethylene").

Although this provision is self-implementing (i.e., regulations are not needed to effectuate the requirement), the requirement is tied to the noitification provisions of this bill. Thus, if EPA acts to limit the class of blenders and distributors required to notify, these persons may not have to prepare warning labels if EPA determines such labels would not be needed to protect human health and welfare and to carry out the Committee's intent in requiring a label.

It is the Committee's intent that this provision apply not only in those states where EPA is operating a hazardous waste program, but in authorized states as well. This will assure that users and transporters of hazardous waste-derived fuels in authorized states will not have to wait until their states adopt labeling legislation or regulations—a process that could take several years—before they receive the warnings required by this section.

Exemption for Petroleum Fuel Products Produced at Refineries.—This provision provides a limited and conditional exemption from the labeling requirement for certain petroleum fuel refiners. Refineries often take oily refining wastes and reintroduce these wastes into the refining process where the oil component is incorporated into product and contaminants are removed. The Committee does not believe that refineries should automatically have to place a warning label on these fuels should EPA fail to exempt refineries from the labeling requirements within 12 months.

The exemption from the labeling requirement is narrow, however. EPA may still explicitly require a warning label for these fuels as may be necessary to protect human health and the environment. In addition, the exemption applies only to wastes generated on-site in the refining process itself. It does not apply to other wastes generated at a refinery such as spent solvents or discarded pesticides. Finally, these wastes must be introduced into the refining process at a point where contaminants are removed. (This standard is drawn from the definition of "re-refined oil" contained in Section 1004(3) of RCRA.)

Standard for Transporters.—This provision amends Section 3003 by adding a new subsection (c) that requires EPA, no later than two years after enactment, to promulgate regulations, as may be necessary to protect human health and the environment, to control transporters of hazardous waste-derived fuels. In developing standards, EPA may require transporters to meet the requirements contained in Section 3003(a), but may vary these requirements, or adopt different ones, as may be necessary to protect human health and the environment.

Utility and Mining Wastes.—Section 6(g) provides that "nothing in this subsection shall be construed to affect or impair the provisions of section 3001(b)(3)." That section, added to RCRA in 1980, provides that specified utility and mining wastes [2] should not be subject to regulation under subtitle C until at least six months after EPA submitted studies of those wastes to Congress. The section then specified that the Administrator could request, gather, and make public, information about the generation, handling, and disposal of those waste materials.

Reference to Section 3001(b)(3) in this bill has one specific purpose. We are reaffirming our intent that substantive regulation of the specified wastes must await completion of the relevant studies. It should be clear, however, that that deferment is limited to the wastes specified in 3001(b)(3); it does not include solvents, degreasers, pesticides, smelting or other wastes generated independently of the processes listed in 3001(b)(3). Thus, facilities burning or blending those other wastes are not exempt from the provisions of this bill. Furthermore, we reaffirm the intent of the 1980 Act that the Administrator has the duty and the authority to gather and

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(i) Fly ash waste, bottom ash waste, slag waste, and flue gas emission control waste generated primarily from the combustion of coal or other fossil fuels, (ii) solid waste from the extraction, benefication, and processing of ores and minerals, including phosphate rock and overburden from the mining of uranium ore; and (iii) cement kiln dust waste

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