LA-UR-98-2245

Title: Uncertainty and Approximate Reasoning in Waste Pretreatment Planning

Author(s): Stephen F. Agnew, CST

Stephen W. Eisenhawer, TSA

Terrence F. Bott, TSA

Submitted to: Lockheed/Martin Hanford, DOE Richland, and Pacific Northwest National Laboratory

Los Alamos
NATIONAL LABORATORY

DISCLAIMER

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

UNCERTAINTY AND APPROXIMATE REASONING IN WASTE PRETREATMENT PLANNING

Stephen F. Agnew
Chemical Science and Technology Division
Mail Stop J586
Los Alamos National Laboratory
Los Alamos, NM 87545
505 665 1764

Stephen W. Eisenhawer
Technology and Safety Assessment Division
Mail Stop K557
Los Alamos National Laboratory
Los Alamos, NM 87545
505 667 2420

Terrence F. Bott
Technology and Safety Analysis Division
Mail Stop K557
Los Alamos National Laboratory
Los Alamos, NM 87545
505 667 9207

ABSTRACT

Waste pretreatment process planning within the DOE complex must consider many different outcomes in order to perform the tradeoffs necessary to accomplish this important national mission. One of the difficulties encountered by many who assess these tradeoffs is that the complexity of this problem taxes the abilities of any single person or small group of individuals. For example, uncertainties in waste composition as well as process efficiency are well known yet incompletely considered in the search for optimum solutions.

This paper describes a tool, the pre-treatment Process Analysis Tool (PAT), for evaluating tank waste pre-treatment options at Hanford, Oak Ridge, Idaho National Environmental and Engineering Laboratory, and Savannah River Sites. The PAT propagates uncertainty in both tank waste composition and process partitioning into a set of ten outcomes. These outcomes are, for example, total cost, Cs-137 in iLAW, iHLW MT, and so on. Tradeoffs among outcomes are evaluated or scored by means of an approximate reasoning module that uses linguistic bases to evaluate tradeoffs for each process based on user valuations of outcomes.

I. INTRODUCTION AND DESCRIPTION

The Process Analysis Tool (PAT) will provide Tanks Focus Area (TFA) decision makers, researchers, and site users with a capability to evaluate alternative waste pretreatment processes, system configurations, processing conditions, and operational scenarios across the complex. Performance and cost tools for pretreatment processing are needed by users for developing process flow sheets and by DOE for evaluation of proposals as privatization proceeds. Performance data (chemical, physical, and cost) needs to be compiled and presented in a common format. In this way, the significant amount of chemical processing (leaching /dissolution) experimental data being obtained throughout the DOE complex on the of tank sludges will be readily accessible. New data and technology models must be accessible as they are developed by the TFA, other DOE programs, and private industry.

Approximate reasoning has been applied to other high level waste problems.[1] In addition, various levels of decision analysis have been and are being applied to tank waste pretreatment planning at Hanford and SRS.[2,3,4,5,6]

The three analysis modules as well as site-specific databases are accessed via a Graphical User Interface (GUI) that is based mainly on Decisioneering's Analytica™. The user selects inventory from a tank or set of tanks, specifies chemicals added, defines species transformations, and provides species, volume, and solids partitions to each of two waste streams: Low Activity Waste (LAW) and High Level Waste (HLW). Each pretreatment option can be combined with a variety of retrieval and final product options.

For a user specified tank inventory and set of pretreatment process options, the PAT derives an output for each of ten outcomes:

- overall costs
- HLW MT
- LAW MT
- HLW / LAW wt / wt ratio
- Cs-137 Ci/L in LAW
- Sr-90 Ci/L in LAW
- TRU μCi/g in LAW
- processing rate or schedule

HLW wt% oxides
LAW wt% oxides

These outcomes are more than single numbers—they are probability distributions that reflect the uncertainties present in processes partitions and tank waste compositions. The PAT performs a series of Monte-Carlo or Latin Hypercube trials to propagate uncertainties to each of ten outcomes.

The key in any process evaluation is the assessment of tradeoffs among the various outcomes. The approximate reasoning evaluation module provides a means to score outcomes and thereby produce three intermediate results as Acceptabilities of Cost, Decontamination, and Waste Loading. These three intermediate results are then combined into an Overall Acceptability, with each level of tradeoff scoring open to examination and alteration by the user.

II. RESULTS

A. Processing module

Chemical processing in the PAT will be performed as a steady-state approximation. Dynamic information such as processing rate will be included for cost and schedule determinations, but the PAT is not meant to be a dynamic simulation model for process planning.

A waste type selection by the user provides the waste input for the processing module. These waste inventories are those readily available from each Site[7,8,9] and are selected within the Tank Waste module as shown in Fig. 1. The user must then supply added chemical and partitioning for each species as well as for solids and volume within the Pretreatment module as shown in Fig. 2. There will be certain dependencies in the processing that must also be specified. For example, tetraphenylborate added during In-Tank Processing at SRS is at 1.1 equivalents of potassium in the feed.

Any unit processing beyond that specified within the PAT must be combined by the user as an effective single unit. For example, recycle streams must be incorporated into the process description. The outputs of the process module are LAW and HLW (see Fig. 1). The LAW will be processed into saltstone at SRS and glass or grout at Hanford. The costs and volume increases will therefore be built into those parts of the PAT.

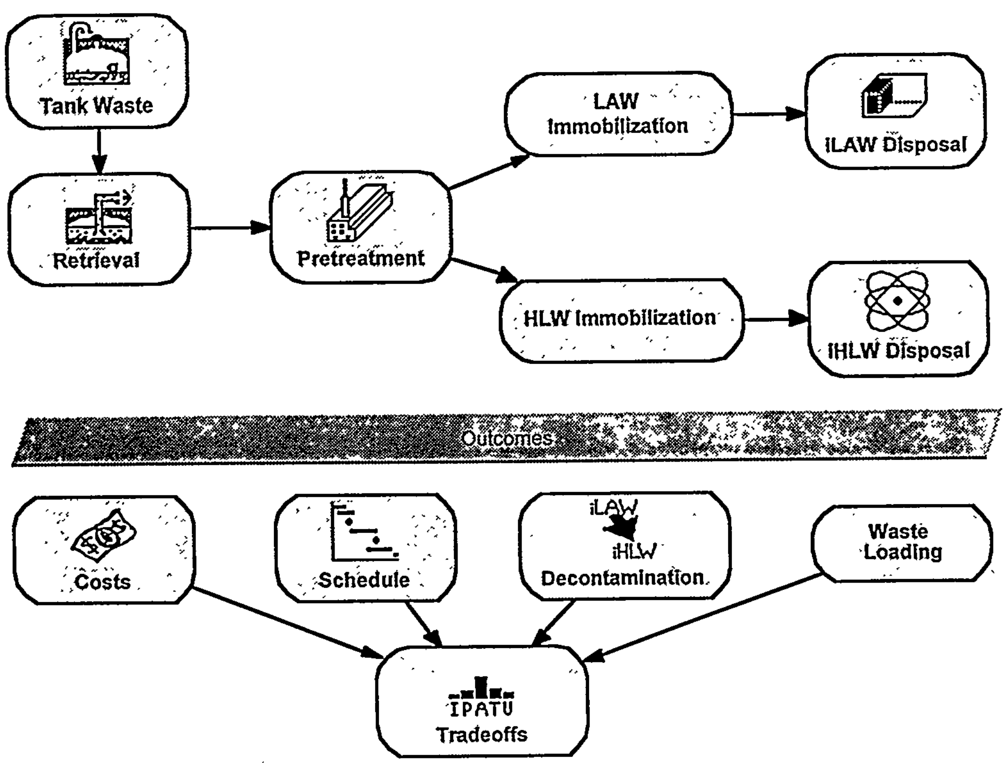

Fig. 1. Whiteboard shows overall structure of PAT. Tank inventories reside in Tank Waste module and are selected in Retrieval, and partitioned in Pretreatment modules.

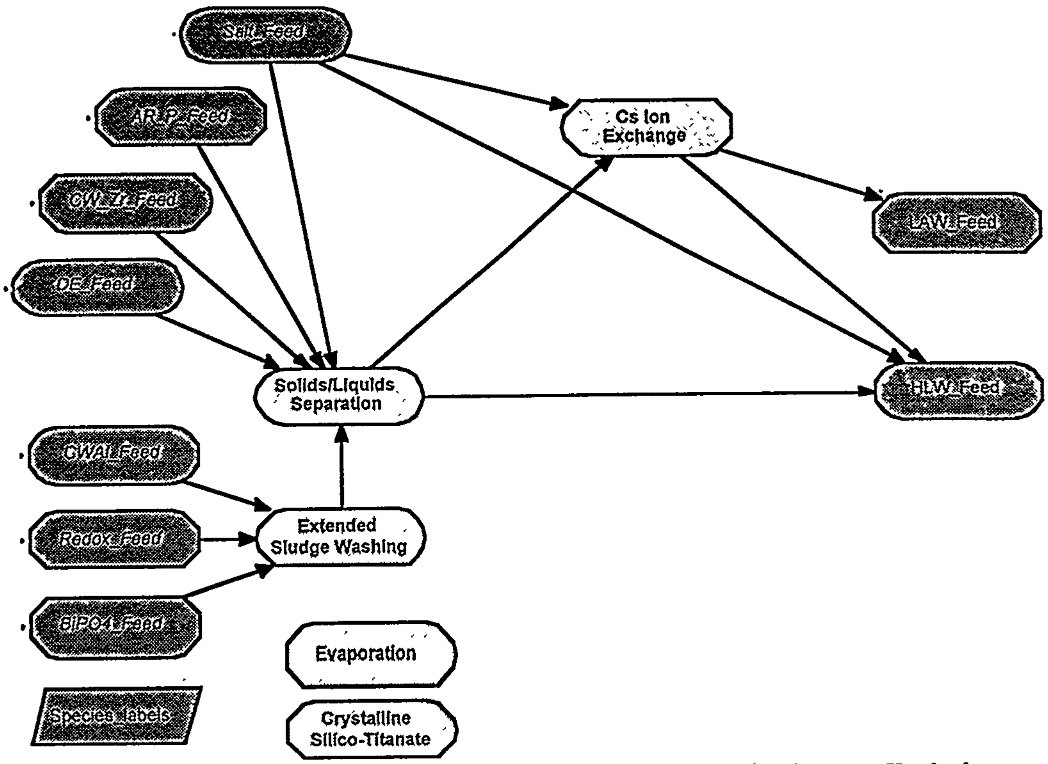

Fig. 2. Opening the Pretreatment module in Fig. 1 shows this white board. The seven Hanford waste types comprise inputs for a particular process.

B. Specifications for processing module

The PAT processing options are sludge washing, solids/liquids separation, and column extraction or precipitation extraction of Cs-137. Each of these options will affect the partition of the waste stream as specified by input data for those processes.

Input data for each process is as follows:

species short list-Na, Al, Cr, Cs-137, Sr-90, total Pu and Am-241

mass balance list-H_2O, NO_3^-, NO_2^-, PO_4^{3-}, SiO_2, FeOOH, K^+

others important for mass balance-$Ca(OH)_2$, TOC^-, SO_4^{2-}, CO_3^{2-}, Cl^-

processing steps--sludge washing, solids/liquids separation, column extraction, and vitrification

representation of distribution functions for parameters

TFA HLW process specification (to become a library)

—process name
—chemicals added per unit volume treated with dependencies
—balanced species transformations
—volume added
—volume partition with dependencies
—species partition with dependencies
—solids partition with dependencies
—fixed costs with dependencies
—incremental costs with dependencies
—volumetric processing rate

C. Approximate reasoning evaluation module

For a given pretreatment process specification, the PAT performs a series of Monte-Carlo or Latin Hypercube trials to derive probability density functions for key outcomes such as HLW MT, Cs-137 in LAW, and cost. Uncertainties in the information input are represented as probability distributions and as a result each outcome is a probability distribution as well.

Although each outcome is presented as a numerical distribution function, some kind of scoring or ranking must occur to evaluate tradeoffs among process options. The evaluation module performs tradeoffs among the ten outcomes and allows the user to score or value each outcome as membership in a linguistic set {Ideal, Preferred, Acceptable, Tolerable, Unacceptable}. Translating outcomes into membership in a linguistic set provides a means of comparing the relative value of two very different outcomes.

Outcomes are traded off against each other to produce three intermediate results:

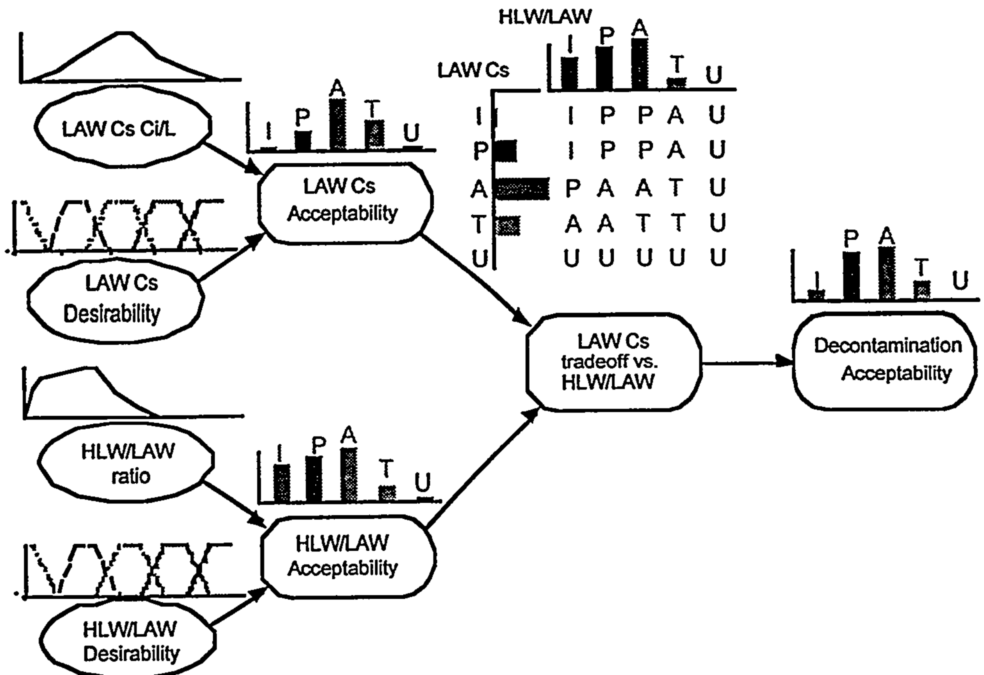

Fig. 3. Structure of binary decision tree for two outcomes shown. Bar charts show degrees of membership in linguistic set {Ideal, Preferred, Acceptable, Tolerable, Unacceptable}.

Acceptability of Costs (Costs vs. other nine combined)

Acceptability of Decontamination (Cs, Sr, TRU each vs. iHLW/iLAW)

Acceptability of Waste Loading

(iHLW wt% vs. iHLW MT and iLAW wt% vs. iLAW MT)

The user provides rule tables to evaluate tradeoffs for each pair of outcomes. For example, as shown in Fig. 3 overall cost versus LAW Cs-137 is a tradeoff that results in membership in an linguistic set {Ideal, Preferred, Acceptable, Tolerable, Unacceptable} that is combined with LAW Sr and LAW TRU tradeoffs against HLW/LAW ratio into an Acceptability of Cost output. These three Acceptabilities, Cost, Decontamination, and Waste Loading, are then traded off one against the other to produce a final Overall Acceptability.

There is an underlying binary decision tree that processes pairs of outcomes by means of decision rule tables that are required from the user for each of these nodes. For example, the user is required to provide evaluations of the tradeoff between LAW Cs-137 and HLW/LAW ratio in terms of a linguistic set {Ideal, Preferred, Acceptable, Tolerable, Unacceptable}. This is shown in Fig. 3. A {Preferred} LAW Cs-137 and a {Preferred} HLW/LAW might have an {Preferred} result, whereas a {Preferred} Cs-137 and a {Tolerable} HLW/LAW might only get an {Acceptable} rating. Clearly, either a {Unacceptable} LAW Cs-137 or{Unacceptable} HLW/LAW would be {Unacceptable}.

III. CONCLUSION AND DISCUSSION

The particular results that we present here are merely representative of the potential applications of this tool. The validity of any tool and therefore its usefulness really ultimately depends on both the validity of its logic as well as the validity of its input parameters. The PAT potentially provides a common platform upon which limited comparisons and evaluations can be performed across the entire DOE complex. It then allows extensive valuation of different outcomes in order to use decision analysis to rank various processes.

We have attempted to develop a tool that requires fairly straightforward input from a user. However, the PAT does not pretend to take the place of more elaborate development tools for process flowsheet development. It rather compliments existing capability and allows explicit inclusion of waste composition and process uncertainties, as well as site-specific valuation of outcomes.

NOMENCLATURE

DOE	Department of Energy
SRS	Savannah River Site
LAW	Low Activity Waste
iLAW	immobilized LAW

HLW High Level Waste
iHLW immobilized HLW
ITP In-Tank Process
PAT Process Analysis Tool
IPATU {Ideal, Preferred, Acceptable, Tolerable, Unacceptable}
TFA Tanks Focus Area
GUI Graphical User Interface
Cs Cesium
Sr Strontium
TRU Transuranic
MT metric tonnes
Ci Curie
L liter

ACKNOWLEDGMENTS

This work was performed under the auspices of the Department of Energy and was funded by DOE Office of Science and Technology, EM-50, Tanks Focus Area, Pretreatment Processing.

REFERENCES

1. Eisenhawer, S.W.; Bott, T.F.; Smith, R.E. "An Approximate Reasoning-Based Method for Screening Flammable Gas Tanks," LA-UR-96-XXXX, September 1996.

2 Davis, N.R.; Wells, M.N. "High-Level Waste System Plan Rev. 7 (U)," HLW-OVP-96-0083, October 1996.

3. DeMuth, S.F. "Cost Benefit Analysis for Separation of Cesium from Liquid Radioactive Waste by Crystalline Silico-Titanate Ion Exchange Resin," LA-UR-96-966, March 1996.

4. d'Entremont, P.D.; Jacobs, R.A.; Fowler, J.R.; Brown, D.F.; McCabe, D.J.; Walker, D.D.; Gillam, J.M. "High-Level Waste System Process Interface Description," WSRC-TR-94-0442, March 1995.

5. McConnville, C.M.; Johnson, M.E.; Derby, S.L. "Decision Analysis Model for Assessment of Tank Waste Remediation System Waste Treatment Strategies," WHC-EP-0874, December 1995.

6. Orme, R.A. et al. "TWRS Operation and Utilization Plan," HNF-SD-WM-SP012, Rev. 0 Draft, August 1997.

7. Agnew, S.F.; Boyer, J.; Corbin, R.A.; Duran, T.B.; FitzPatrick, J.R.; Jurgensen, K.A.; Ortiz, T.P.; Young, B.L. "Hanford Tank Chemical and Radionuclide Inventories: HDW Model Rev. 4," LA-UR-96-3860, January 1997.

8. Hester, J.R. "High Level Waste Characterization System (WCS)," WSRC-TR-96-0264, Rev. 0, December 1996.

9. Kupfer, et al. "Standard Inventories of Chemicals and Radionuclides in Hanford Site Tank Wastes," HNF-SD-WM-TI-740, Rev. E, April 1997.