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EM Task 12 - Laster Cleaning of Contaminated Painted Surfaces

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INTRODUCTION

Surface decontamination of concrete and steel surfaces in nuclear facilities provides cost savings during decommissioning operations by allowing recycling or reuse of concrete and steel structures. Separation of radionuclides and other contamination from the concrete or steel substrates also allows reduction in volume of hazardous materials during the D&D (decontamination and decommissioning) process, resulting in further cost savings.

Several techniques are available or under development for surface decontamination in nuclear facilities. Each technique has its merits; however, none of them is universally the best choice for all surface decontamination applications. Some issues which confront an organization selecting a surface decontamination technique for a particular application are as follows:

- Project scale
- Concrete or metal surfaces
- Contamination by radiological and other hazardous materials
- Stage of surface decontamination technology development (e.g., commercial, R&D)
- Equipment operating costs
- Collection of waste generated by surface decontamination
- Occupational health and safety requirements
- Utilities required for operations
- Real-time control of surface decontamination
- Recycling or reuse of decontaminated substrates
- Waste
  - Characterization
  - Classification
  - Transport
  - Storage
  - Treatment
  - Disposal
- D&D equipment decontamination

Because of the multitude of factors which influence the environmental and economic aspects of selecting a surface decontamination technique, it is difficult to select the best method in a given situation; an objective basis for comparing techniques is needed.

OBJECTIVES

The objective of this project is to develop a software tool for use by personnel selecting a surface decontamination technique. The software will incorporate performance data for available surface decontamination techniques. The major activities in the project are broken down as follows:

Task 1 – Complete decision tree development
Task 2 – Literature search for surface decontamination reports
Task 3 – Compilation of database from literature data
Task 4 – Sensitivity analysis and model design
Task 5 – Design of model data structures
Task 6 – PC software design and coding

ACCOMPLISHMENTS

Work during this reporting period completed Tasks 1, 2, 3, 5, and 6. Task 4 activities resulted in a prototype of the model design; sensitivity analysis and model modifications are in progress at the time of this report. Task 4 will be complete prior to the end of December 1997. A working prototype of the software implementation of the surface decontamination model and technology database has been completed. The program developed at the Energy & Environmental Research Center (EERC) called Surface Decontamination Assistant allows comparison of surface decontamination techniques for a user-defined application scenario.

Task 1 – Decision Tree Development

The decision tree developed over the course of this project was completed during this reporting period. Appendix A contains Figures A1 through A3, which depict the surface decontamination decision tree. The decision tree functions as a framework for design and implementation of the computer model, allowing comparison of surface decontamination technologies.

Task 2 – Literature Search for Surface Decontamination Reports

Literature pertaining to surface decontamination applied in D&D operations has been identified and acquired using a number of information resources, including the Remedial Action Program Information Center (RAPIC), the U.S. Department of Energy (DOE) Information Bridge, DIALOG database, Current Contents, and other traditional literature search tools. A complete list of the documents in the literature database for this work is given in Appendix B.

Task 3 – Compilation of Database from Literature Data

Available data on surface decontamination operations have been gleaned from available reports. Several articles [1, 2, 4–9] contain evaluations of surface decontamination techniques for specific cases. Data have been compiled from a number of articles and an attempt made to put the data into a form allowing technology comparisons to be made.

In addition to technology performance data gleaned from the literature, a survey of surface removal equipment vendors was completed to obtain additional information for the technology database. A listing of the database as incorporated into the computer model is given in Appendix C.

Some of the performance data in the database are vendor-supplied, and portions of the technology entries were extracted from data collected under less-than-optimal experimental conditions. Therefore, the program is designed to allow additional technologies to be added as well as modifications to the performance data for technologies already resident in the database. Modifications and additions to the database will maximize the utility of the Surface Decontamination Assistant model.

Task 4 – Sensitivity Analysis and Model Design

Sensitivity Analysis

Sensitivity analysis is being applied to evaluate the software implementation of the logic depicted in the flow charts of Figures A1 through A3 (see Appendix A). At the time of this report, the model is under evaluation. It is envisioned that adjustments to the software will be made in order to produce a model that ranks surface decontamination technologies for a user-supplied application scenario.

Model Design

The model is designed to provide an overall figure of merit for each applicable surface decontamination technique under a user-defined application scenario. The overall figure of merit is an aggregate value derived from intermediate figures of merit for the major aspects of the surface decontamination process. As defined in the Surface Decontamination Assistant model, intermediate figures of merit are computed for the following:

- Surface removal
- Waste transportation
- Waste disposal
- Amount of recyclable waste
- Environment, health, and safety (EH&S)
- Technology implementation, operation, and maintenance

A number of assumptions are built into the current form of the Surface Decontamination Assistant model. Assumptions intrinsic to the execution of the model at this time are as follows:

1. Types of surface contamination are known.
2. Surface coating composition and thickness are known.
3. Depth of surface contamination is known.
4. Technologies are capable of achieving 100% surface decontamination.

5. Operation costs are based on a vendor service cost, including technology deployment and transportation to the site of application.
6. Practitioners are willing to employ more than one technique to achieve 100% surface decontamination.
7. No transuranic waste (TRU) or spent nuclear fuel (SNF) are part of the surface decontamination waste stream.
8. Solid and liquid waste streams are separated.
9. Removed substrate waste remains in solid form.
10. On-site waste disposal will employ existing vehicles and personnel.
11. Radioactive waste for on-site disposal will be of the contact-handled (CH) type.
12. All waste shipments are full loads for the style of transport.

As described above, the model will provide a comparison of techniques based on a user-defined application scenario. The user inputs to the model are as follows:

1. Site name, location, substrate, and contamination descriptions
2. Surface type (e.g., floor, ceiling) and material (steel or concrete)
3. Surface area to be decontaminated, amount of surface that is hard to reach, coating thickness, and removal thickness
4. General categories of contamination (e.g., radionuclies)
5. Surface area that is contaminated in each category
6. Distance to off-site storage and disposal facilities
7. Surface decontamination technologies to be included in the analysis
8. Transportation and disposal costs
9. Priority ranking for EH&S; operational, maintenance, and reliability issues; surface removal costs; transportation costs; and disposal costs.
10. On-site disposal transportation distance
11. Distance from nonhazardous material deposit facility
12. Type of transportation for wastes (truck or rail)

Details of the Surface Decontamination Assistant model implementation are given in Appendix D.

Task 5 – Design of Model Data Structures

The Surface Decontamination Assistant software has as one of its key components an extensible database of surface decontamination technology performance data. The technology database is designed to incorporate all the information that is unique to each surface decontamination technique and necessary to application of the Surface Decontamination Assistant model. Each technology database record contains the following fields:

- Technology name
- Description, including type of process (e.g., physical, chemical, effects on the substrate)
- Applicable substrates (concrete, steel, or both)
- Aggressive surface removal capabilities
- Production rate
- Operating cost
- Volume, weight, phase (solid or liquid), and density of secondary waste
- Thickness of surface removal
- Number of passes needed to achieve 100% surface coating removal
- Vertical surface-cleaning ability
- Ability to clean hard-to-reach areas
- On-line analysis capabilities
- Utility costs
- EH&S factor
- Implementation state, operation, and maintenance factor
- Equipment design for decontamination factor
- Technology development stage
- Number of workers necessary for operation

Appendix C contains a listing of the technology database.

Task 6 – PC Software Design and Coding

The architecture of the Surface Decontamination Assistant software is based on the major subsections illustrated in Figure 1.

The user interacts with the Surface Decontamination Assistant software through a set of dialog boxes. The user is lead through a series of input dialogs where the following aspects of the user-defined application scenario are entered:

1. **Scenario summary description –** site name, location of site, general substrate description, general contamination description, site activation date, modification date.
2. **Detailed site description** – surface type, substrate material, total area of the surface, area of hard-to-reach portions of the surface, thickness of surface coating, total thickness of the surface to be removed.
3. **General contamination information** – generic types of contamination.
4. **Quantified contamination information –** area of recyclable surface, area of surface not contaminated by hazardous waste, area contaminated by CH waste for on-site disposal, area contaminated by CH waste for off-site disposal, area contaminated by RH waste.

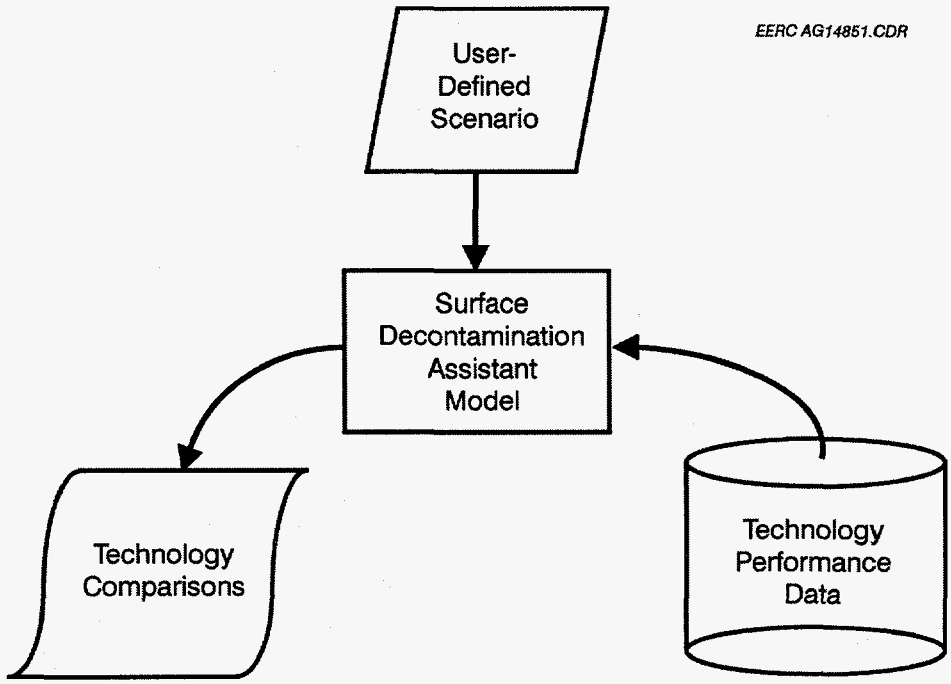

Figure 1. Surface Decontamination Assistant software architecture.

5. **Transportation information** – off-site transportation distance, on-site transportation distance, nonhazardous waste transportation distance, style of transport.
6. **Technology selection** – pick technologies to evaluate using the model.
7. **Setup inputs** – transportation fees, waste disposal fees, priority rankings.

A detailed description of the program structure and illustrations for each of the dialog boxes presented by the program are in Appendix E.

FUTURE WORK

Sensitivity analysis will be continued to evaluate the Surface Decontamination Assistant model, allowing optimization of the generated outputs to complete Task 4 of this project by December 31, 1997.

Work during the next year will involve distribution of the software to selected practitioners of surface decontamination within DOE and the U.S. Department of Defense. The software will be distributed with a questionnaire to allow user feedback on the software. At least one cycle of software distribution and modifications will be completed.

REFERENCES

1. Archibald, K.E. "Concrete Decontamination Scoping Tests," U.S. Department of Energy Idaho National Engineering Laboratory: Idaho Falls, ID, 1995; pp 1–19.

2. Ebadian, M.A.; Lagos, L.E.; Boudreaux, J.F.; Clark, T.R.; Miller, L.K. "Analysis of Potential Surface Blasting Decontamination Technologies for Structural Steel," Fernald Environmental Restoration Management Corporation: Cincinnati, OH, 1995; pp 1-41.

3. Feizollahi, F.; Shropshire, D.; Burton, D. "Waste Management Facilities Cost Information for Transportation of Radioactive and Hazardous Materials," DE96002295; U.S. Department of Energy: Idaho Falls, ID, 1995; pp 1–21.

4. Grieco, S.A.; Neubauer, E.D.; Rhea, J.R. "Removal and Treatment of Radioactive, Organochlorine, and Heavy Metal Contaminants from Solid Surfaces," In *Radioactive and Hazardous Surface Decontamination Utilizing Soda Blasting*; O'Brien and Gere Technical Services, Inc.: East Syracruse, NY, 1995; pp 1–10.

5. White, T. L.; Foster, D. Jr.; Wilson, C.T.; Schaich, C.R. "Phase 2 Microwave Concrete Decontamination Results," DE95010212CT; In *Waste Management '95: Working Towards a Cleaner Environment*; U.S. Department of Energy: Oak Ridge, TN, 1995.

6. Corleto, P.; Guidotti, M.; Ragazzo, G. "A Microwave System to Scarify Concrete Surfaces Upgrading and Testing," *In* Proceedings of the International Topical Meeting on Nuclear and Hazardous Waste Management Spectrum '94; U.S. Department of Energy American Nuclear Society, Inc.: La Grange Park, IL, 1994; pp 369–373.

7. Halter, J.M.; Sullivan, R.G. "Techniques for Removing Contaminated Concrete Surfaces," *Environmental Decontamination* **1979**, 185–194.

8. Halter, J.M.; Sullivan, R.G. "Contaminated Concrete Surface Layer Removal," EY-76-C-06-1830, Reprinted from *Surface Contamination*; Mittal, K.L., ed.; U.S. Department of Energy–Plenum Publishing Corp.: New York, NY, 1979; Vol. 1, pp 443–455.

9. Barbier, M.M.; Chester, C.V. "Decontamination of Large Horizontal Concrete Surfaces Outdoors," W-7405-eng-26; U.S. Department of Energy, pp 1–26.

APPENDIX A

SURFACE DECONTAMINATION DECISION TREE

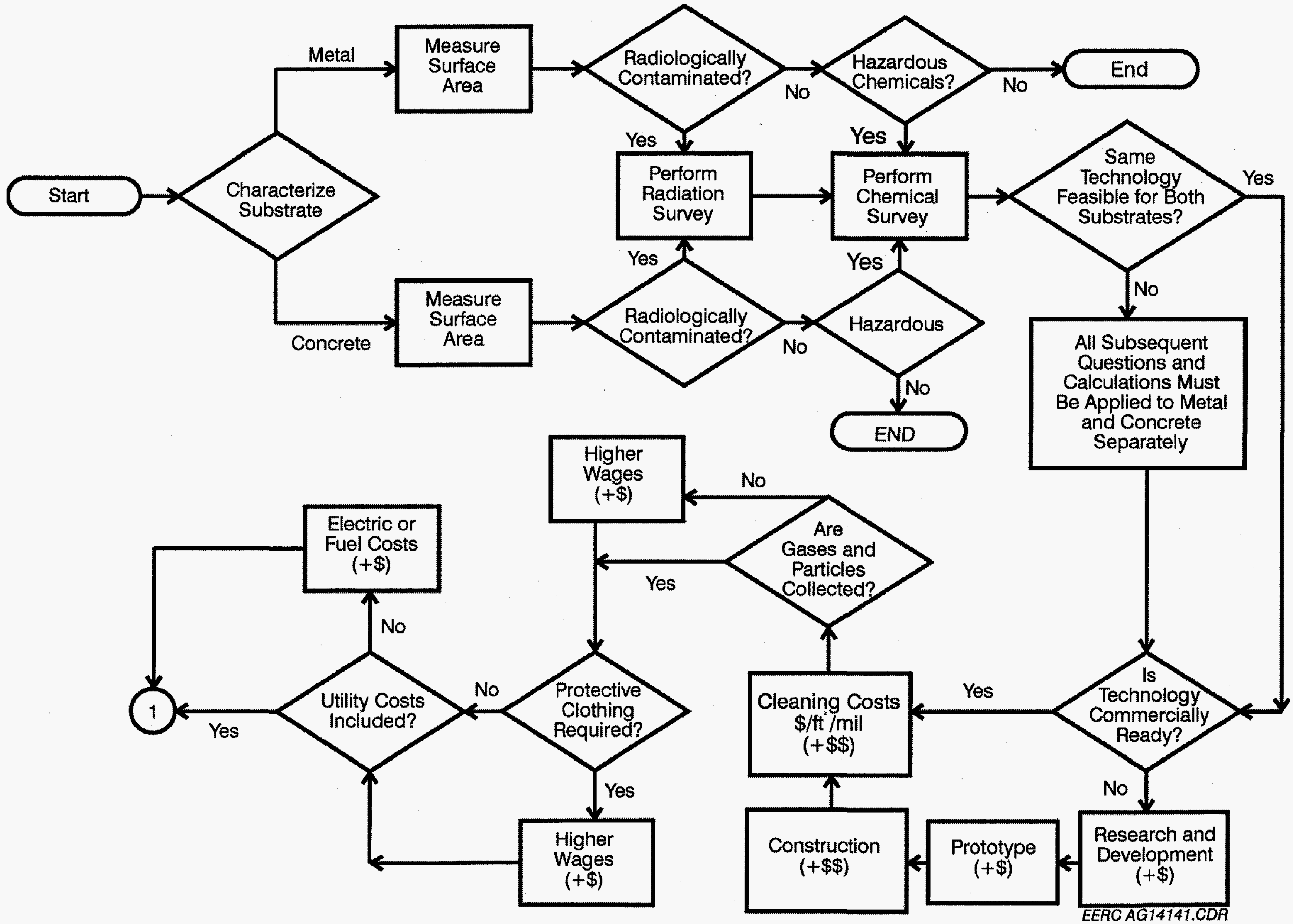

Figure A1. Surface decontamination decision tree, Sheet 1.

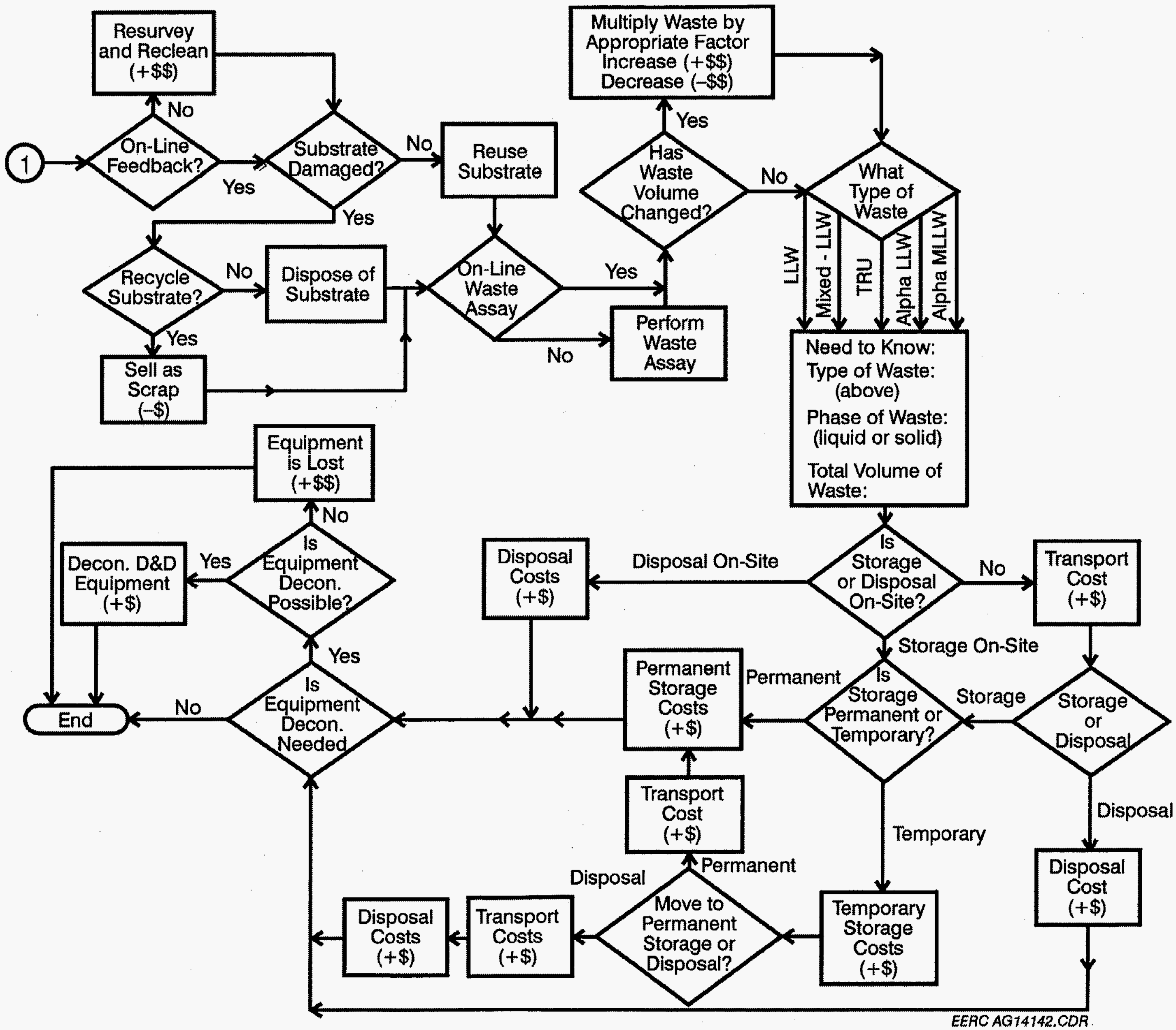

Figure A2. Surface decontamination decision tree, Sheet 2.

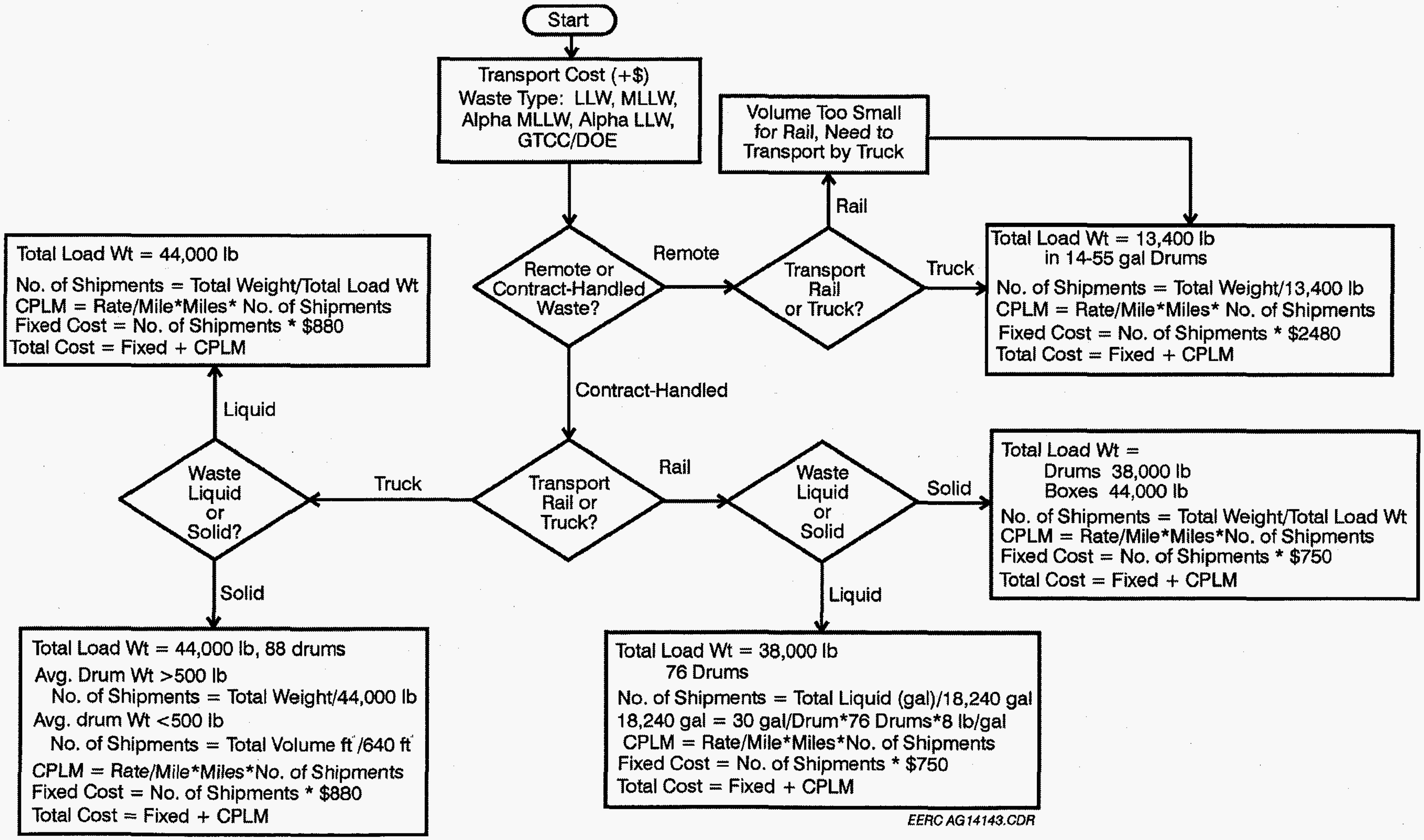

Figure A3. Surface decontamination decision tree, Sheet 3.

APPENDIX B

LITERATURE DATABASE

LITERATURE DATABASE

1. U.S. Department of Energy. "Mixed Waste Focus Area Integrated Technical Baseline Report Phase I," DOE/ID-10524; U.S. Department of Energy Idaho National Engineering Laboratory, 1996; Vol. 2, pp 1–384.

2. U.S. Department of Energy. "Technology Assessment: Laser Technologies for Decontamination and Decommissioning of Nuclear Facilities," Decontamination and Decommissioning Focus Area, Morgantown Energy Technology Center, 1996; pp 1–16.

3. Ayers, K.W.; Boren, J.K.; Stephen, A.; Parker, F.L. "Reuse of Concrete from Contaminated Structures. Part 1: Economic Analysis of the Feasibility of Recycling Contaminated Concrete," DE-FG05-94OR22343; Department of Civil and Environmental Engineering, Vanderbilt University: Nashville, TN, 1996; pp 14–21.

4. Bierschbach, M.C. "Estimating Boiling Water Reactor Decommissioning Costs," NUREG/CR-6270; U.S. NRC Pacific Northwest National Laboratory, 1996.

5. Darnell, G.R.; Larsen, M.M. "Existing LLW Treatment and Disposal Technology Offers 17-to-1 Volume Reduction and Advanced Disposal at Low Cost," DE-AC07-761D01570; U.S. Department of Energy Idaho National Engineering Laboratory: Idaho Falls, ID, 1996; pp 15–21.

6. U.S. Department of Energy. "Evaluation of Radioactive Scrap Metal Recycling," ANL/EAD/TM-50; Environmental Assessment Division, Argonne National Laboratory, 1996.

7. Swanston, S.R.; Davis, M.; Janke, R.J. "Unit Decontamination and Dismantlement (D&D) Costs," ANL/DIS/CP-87709; U.S. Department of Energy Argonne National Laboratory, 1996; pp 1–10.

8. Goodwill, M. E.; Lively, J. W.; Morris, R. L. "Radiological Decontamination, Survey, and Statistical Release Method for Vehicles," DE-AC04-86ID12584; U.S. Department of Energy, Grand Junction, CO, 1996; pp 1–12.

9. Kaelin, A.B. " Properly Engineer Lead Paint Removal Projects," *Chemical Engineering Progress* **1996**, 92 (1), 50–55.

10. S.A. SAIC. *Market Assessment Decontamination of Radioactivity – Contaminated Concrete*; 1996.

11. U.S. Department of Energy. "Draft Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and

Hazardous Waste," DOE/EIS-0200-D; Office of Environmental Management, 1995; Vol. 4, pp 1–469.

12. U.S. Department of Energy. "Commercial Environmental Cleanup – The Products and Services Directory," DOE/ID/12584-230; Grand Junction Projects Office, 1995; pp 1–1260.

13. Allen, L.; Pang, H.; Edelson, M.C. "Applications of Lasers to the Solution of Environmental Problems," IS-M840; U.S. Department of Energy Ames Laboratory, 1995; pp 1–8.

14. Archibald, K.E. "Concrete Decontamination Scoping Tests," U.S. Department of Energy. Idaho National Engineering Laboratory: Idaho Falls, ID, 1995; pp 1–19.

15. Benson, C.E.; Parfitt, J.E.; Patton, B.D. "Decontamination of Surfaces by Blasting with Crystals of H_2O and CO_2," DE-AC05-84OR21400; U.S. Department of Energy: Oak Ridge, TN, 1995; pp 1–63.

16. Bierschbach, M.C. "Estimating Pressurized Water Reactor Decommissioning Costs," NUREG/CR-6054; Pacific Northwest Laboratory: Richland, WA, 1995; pp 1–150.

17. Boudreaux, J.F. "Comparative Analysis of Surface Decontamination Technologies for Standard Steel Shapes," U.S. Department of Energy Office of Environmental Restoration, pp 751–995.

18. Byrd, J.S. "An Intelligent Inspection and Survey Robot," U.S. Department of Energy: Morgantown, WV, 1995; pp 299–304.

19. Conner, C.; Chamberlain, D.B.; Chen, L.; Vandegrift, G.F. "Equipment Decontamination: A Brief Survey of the DOE Complex," ANL-95/32; U.S. Department of Energy Argonne National Laboratory: Argonne, IL, 1995; pp 1–9.

20. Cook, E.; Quaranta, J. "Decontamination Systems Information and Research Program," U.S. Department of Energy: Morgantown, WV, 1995; pp 98–102.

21. Crystal, J.B. "Development Test Procedure for High Pressure Water Jet System," WHC-SD-SNF-TC-004 for U.S. Department of Energy; Westinghouse Hanford Co.: Richland, WA, 1995; p 1-C-1.

22. Dickerson, K.S.; Wilson-Nichols, M.J.; Morris, M.I. "Contaminated Concrete: Occurrence and Emerging Technologies for DOE Decontamination," DOE/ORO/2034; U.S. Department of Energy Oak Ridge National Laboratory, 1995; pp 1–352.

23. Dickerson, K.S.; Ally, M.R.; Brown, C.H.; Wilson-Nichols, M.J.; Morris, M.I. "Demonstration Recommendations for Accelerated Testing of Concrete Decontamination

Methods," ORNL/TM-13098, U.S. Department of Energy Oak Ridge National Laboratory, 1995; pp 1–70.

24. Ebadian, M.A.; Lagos, L.E.; Boudreaux, J.F.; Clark, T.R.; Miller, L.K. "Analysis of Potential Surface Blasting Decontamination Technologies for Structural Steel," Fernald Environmental Restoration Management Corporation: Cincinnati, OH, 1995; pp 1–4.

25. Edelson, M.C.; Pang, H.; Ferguson, R.L. "A Laser-Based Solution to Industrial Decontamination Problems," IS-M838; 1995; pp 1–10.

26. Feizollahi, F.; Shropshire, D.; Burton, D. "Waste Management Facilities Cost Information for Transportation of Radioactive and Hazardous Materials," DE96002295; U.S. Department of Energy: Idaho Falls, ID, 1995; pp 1–21.

27. Freiwald, J.G.; Freiwald, D.A. "Laser-Based Coatings Removal," U.S. Department of Energy: Morgantown, WV, 1995; pp 214–224.

28. Goldfarb, V.; Gannon, R. "Concrete Decontamination by Electro-Hydraulic Scabbling," U.S. Department of Energy: Morgantown, WV, 1995; pp 225–232.

29. Grieco, S.A.; Neubauer, E.D.; Rhea, J.R. "Removal and Treatment of Radioactive, Organochlorine, and Heavy Metal Contaminants from Solid Surfaces, " In *Radioactive and Hazardous Surface Decontamination Utilizing Soda* Blasting; O'Brien & Gere Technical Services, Inc.: East Syracuse, NY, 1995; pp 1–10.

30. Grieco, S.A.; Neubauer, E.D.; Rhea, J.R. "Removal and Treatment of Radioactive Contaminants," *Nuclear Plant Journal* **1995**, 13 *(4)*.

31. Griffin, T.P.; Johnston, J.E.; Payea, B.M.; Zeitoon, B.M. "Catalytic Extraction Processing of Contaminated Scrap Metal," U.S. Department of Energy: Morgantown, WV, 1995; pp 137–155.

32. Haines, J.R.; Fisher, P.W.; Foster, C.A. "Solvent-Free Cleaning Using a Centrifugal Cryogenic Pellet Accelerator," Martin Marietta Energy Systems, 9504123-1; Innovative Concepts Technology Fair, U.S. Department of Energy Oak Ridge National Laboratory: Denver, CO, 1995; pp 1–5,.

33. Hanulik, J., inventor; Deco-Hanulik, A.G., assignee. "Process for Decontaminating Radioactive Metal Surfaces," CAX No. 5 386 078, 1995; 1 882 503, 4 508 641, 4 587 043, 5 008 044, and 5 024 805.

34. Konzek, G.J.; Smith, R.I. Bierschback, M.C.; McDuffie, P.N. "Revised Analysis of Decommissioning for the Reference Pressurized Water Reactor Poser Station," NUREG/CR-5884 PNL-87, U.S. NRC Pacific Northwest Laboratory, 1995; pp 1–418.

35. Krupa, B. "Evaluation of Plant 7 Decontamination Methods," 1995.

36. Lomasney, H. "Electrokinetic Decontamination of Concrete," U.S. Department of Energy: Morgantown, WV, 1995; pp 18–21.

37. MacArthur, D. "Alpha Detection for Decontamination and Decommissioning: Results and Possibilities," 1205, Environmental Remediation. U.S. Department of Energy: Denver, CO, 1995.

38. Moore, T. "Rising to the Challenge in Military-Site Cleanups," *Environ. Eng. World* **1995**, 28–33.

39. Muth, T.R.; Shasteen, K.E.; Liby, A.L.; Mishra, B.; Olson, D.L.; Hradil, G. "Advanced Technologies for Decontamination and Conversion of Scrap Metal," U.S. Department of Energy: Morgantown, WV, 1995; pp 233–238.

40. Nichols, F. "Feasibility Analysis of Recycling Radioactive Scrap Steel," DOE/ID/12735-T38; U.S. Department of Energy Western Environmental Office, 1995; pp 1–191.

41. Nieves, L.A.; Chen, S.Y.; Kohout, E.J.; Nabelssi, B.; Tilbrook, R.W.; Wilson, S.E. "Evaluation of Radioactive Scrap Metal Recycling," ANL/EAD/TM-50; U.S. Department of Energy Argonne National Laboratory, 1995; pp 1–474.

42. O'Brien and Gere Technical Services. "Pilot-Scale Treatability Testing – Recycle, Reuse, and Disposal of Materials from Decontamination and Decommissioning Activities: Soda Blasting Demonstration," DOE/ORO-2032; U.S. Department of Energy Oak Ridge K-25 Site: Oak Ridge, TN, 1995.

43. Osborn, J. L.; Bares, C.; Thompson, B.R. "Mobile Worksystems for Decontamination and Dismantlement," U.S. Department of Energy: Morgantown, WV, 1995; pp 243–253.

44. Reisch, M.S. "Paints & Coatings," *C&EN* **1995**, 30–31.

45. Resnick, A.M. "Remote Operated Vehicle with Carbon Dioxide Blasting (ROVCO2),"U.S. Department of Energy: Morgantown, WV 1995; pp 239–242.

46. Russ, W.R.; Valentine, J.D.; Chung, W. "Radiological Contamination Penetration Depth in Fernald Transite Panels," FEMP/SUB-104 UC-271; U.S. Department of Energy Fernald Field Office: 1995; pp 1–8.

47. Shropshire, D.; Feizollahi, F. "Life Cycle Cost Estimation and Systems Analysis of Waste Management Facilities," DE96001615; U.S. Department of Energy: Idaho Falls, ID, 1995; pp 12.

48. Smith, M.; Harris, J.G.; Moore-Mayne, S.; Mayes, S.R.; Naretto, C. "Review of Private Sector Treatment, Storage, and Disposal Capacity for Radioactive Waste," INEL-95/0020; U.S. Department of Energy Idaho National Engineering Laboratory, 1995; pp 1–73.

49. Trovato, S.A.; Parry, J.O.; Monti, W.A.; Burger, J.M. "Decontaminating a Nuclear Power Plant," *Mechanical Engineering* **1995**, 76–78.

50. "Long-Term Decontamination Engineering Study," . WHC-SD-WM-ES-283; prepared for U.S. Department of Energy by Westinghouse Hanford Co.: Richland, WA; 1995; Vols. 1 2 pp A-1-B-147.

51. White, T.L.; Foster, D.C., Jr.; Wilson, T.; Schaich, C.R. "Phase 2 Microwave Concrete Decontamination Results," DE95010212CT; In *Waste Management '95: Working Towards a Cleaner Environment*; U.S. Department of Energy: Oak Ridge, TN, 1995.

52. Worchester, S.A.; Twidwell, L.G.; Paolini, D.J.; Weldon, T.A.; Mizia, R.E. "Decontamination of Metals by Melt Refining/Slagging, An Annotated Biblography: Updata on Stainless Steel and Steel," INEL-95/0123; U.S. Department of Energy Idaho National Engineering Laboratory, 1995; pp 1–97.

53. "Escalation of Decommissioning Waste Disposal Costs at Low-Level Waste Burial Facilities," NUREG-1307, Report on Waste Burial Charges; U.S. Nuclear Regulatory Commission: Washington, DC. 1994; pp 1.1–4.1.

54. Aldridge, T.L.; Aldrich, L.K. II; Bowman, E.V. "CO_2 Pellet Decontamination Technology at Westinghouse Hanford," WHC-SA-2435; prepared for U.S. Department of Energy by Westinghouse Hanford Co.: Richland, WA., 1994; pp 1–15.

55. Bonem, M.W. "Economical Decontamination of Concrete and Metal Using the TechXtract Process." *In* Proceedings of the International Topical Meeting on Nuclear and Hazardous Waste Management – Spectrum '94; U.S. Department of Energy–American Nuclear Society, Inc.: La Grange Park, IL, 1994; Vol. 3, pp 2434–2438.

56. Corleto, P.; Guidotti, M.; Ragazzo, G. "A Microwave System to Scarify Concrete Surfaces Upgrading and Testing," *In* Proceedings of the International Topical Meeting on Nuclear and Hazardous Waste Management – Spectrum '94; U.S. Department of Energy–American Nuclear Society, Inc.: La Grange Park, IL, 1994; pp 369–373.

57. Erickson; T.E.; Musich; M.A.; Sondreal, E.A.; et al. "Review of 'Reuse of Concrete from Contaminated Structures, Part 1: Economic Analysis of the Feasibility of Recycling Contaminated Concrete'," Prepared for Dr. Paul Hart, Decontamination & Decommissioning Area Leader, DOE Federal Energy Technology Center by Energy & Environmental Research Center, University of North Dakota, March 1995.

58. Demmer, R. "Testing and Evaluation of Eight Decontamination Chemicals," U.S. Department of Energy. WINCO-1228, Idaho National Engineering Laboratory. Westinghouse Idaho Nuclear Company, Inc.: Idaho Falls, Idaho, 1994; pp. 1–12.

59. Demmer, R.L.; Ferguson, R.L. "Testing and Evaluation of Light Ablation Decontamination," U.S. Department of Energy Idaho National Engineering Laboratory: Idaho Falls, ID, 1994; pp 1–27.

60. Demmer, R.L. "Development of Simulated Contamination (SIMCON) and Miscellaneous Decontamination Scoping Tests," DEAC0784ID12435; U.S. Department of Energy–Westinghouse Idaho Nuclear Company, Inc.: Idaho Falls, ID, 1994; pp. 1–13.

61. Feizollahi, F.; Shropshire, D.; Burton, D. "Waste Management Facilities Cost Information for Transportation of Radioactive and Hazardous Materials," Revision 1. DE95002022; U.S. Department of Energy: San Francisco, CA, 1994; 203 p.

62. Feizollahi F.; Shropshire, D. "Waste Management Facilities Cost Information for Mixed Low-Level Waste," interim report DE95009458; U.S. Department of Energy: Idaho Falls, ID, 1994; pp 1-1–29-6.

63. Feizollahi, F.; Quapp, W.J.; Hempill, H.G.; Groffie, F.J. "Integrated Thermal Treatment System Study–Phase 1 Results," DE-AC07-761D01570; U.S. Department of Energy, 1994; pp. 1–167.

64. Gillis, P.J., Jr. "Radwaste Cost Savings & Mixed Waste Volume Reduction Achieved with CO_2 Decontamination – Actual Utility History," In *Technology and Programs for Radioactive Waste Management and Environmental Restoration*; Post, R.G., Ed.; 1994; Vol. 3, pp 1647–1649.

65. Hanulik, J. "Decofor and Decoconcrete New Metal and Concrete Decontamination Processes for Decommissioning," 1994 International Symposium on Decontamination & Decommissioning.

66. Lomasney H.L.; Yachmenev, V. "Electrokinetic Decontamination of Concrete," *In* Proceedings of Opportunity '95–Environmental Technology Through Small Business; Kothari, V.P., Ed.; U.S. Department of Energy Morgantown Energy Technology Center: Morgantown, WV, 1994; pp 190–191.

67. Moorthy, P.N.; Rao, U.R.K.; Venkateswaran, G.; Gokhale, A.S.; Yuvaraju, B.; Vinaykumar, C.K.; Wagh, P.M.; Kansara, H.M. "Evaluation of Lomi and Citrate Formulations for the Decontamination of the Clean Up System Surfaces of Tarapur Atomic Power Station," 1994 International Symposium on Decontamination & Decommissioning; U.S. Department of Energy BWRS, 1994.

68. Simmons, M. "Decontamination of Radioactive Concrete: A Permanent Solution That's RCRA Friendly," *Radwaste Magazine* **1994** *1*, 25–29.

69. Tripp, J.L. "Criteria and Evaluation of Three Decontamination Techniques," WINCO-1187; prepared for U.S. Department of Energy by Westinghouse Idaho Nuclear Company Inc.: Idaho Falls, ID, 1994; pp. 1-A-12.

70. Tripp, J.L. "Criteria and Evaluation of Three Decontamination Techniques," DEAC0784lD12435; prepared for U.S. Department of Energy by Westinghouse Idaho Nuclear Company, Inc.: Idaho Falls, ID, 1994; pp 1–11.

71. *Radiological Control Manual*; DE93 013925, Lawrence Livermore Laboratory: Berkeley, CA, 1993; pp 1–21.

72. "Technology and Programs for Radioactive Waste Management and Environmental Restoration," In *WM'93, Waste Processing, Transportation, Storage and Disposal, Technical Programs and Public Education;* Post, R.G.; Wacks, M.E., Eds.; U.S. Department of Energy: Tucson, AZ, 1993; Vols.1 and 2.

73. Benda, G.A. "Commercial Experience in Treating U.S. Department of Energy Mixed Waste," In *High Level Radioactive Waste and Spent Fuel Management*; Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek. J., Eds.; The American Society of Mechanical Engineers: New York, NY, 1993; pp 385–390.

74. Berg H.P.; Debski, H.J. "Cost Analysis of German Waste Repositories," In *High Level Radioactive Waste and Spent Fuel Management*; Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek. J., Eds.; The American Society of Mechanical Engineers: New York, NY, 1993; pp 809–814.

75. Bonem, M.W.; Borah, R.E.; Rathke, S.E. "Extraction of Contaminants from Porous Surfaces – Case History," Meeting the Challenge – ER '93 Environmental Remediation Conference; U.S. Department of Energy, 1993; Vol. 2, pp 1009–1011.

76. Bossart, S.J.; Moore, J. "Innovative Technologies for Recycling Contaminated Concrete and Scrap Metal," Meeting the Challenge – ER '93 Environmental Remediation Conference; U.S. Department of Energy, 1993; Vol. 2, pp 335–338.

77. Cannon, N.S.; Flesher, D.J. "Lasers for the Radioactive Decontamination of Concrete," *In* Proceedings of the International Conference on Lasers and Applications; DE94003468 CT, U.S. Department of Energy: Richland, WA, 1993.

78. Christ B.G.; Wehner, E.L. "Project Specific Selection of Decommissioning Techniques," In *High Level Radioactive Waste and Spent Fuel Management;* Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek, J., Eds.; The American Society of Mechanical Engineers: New York, NY, 1993; pp 189–192.

79. Closs, J.W. "Decommissioning Experience: One-Piece Removal and Transport of a LWR Pressure Vessel and Internals," In *High Level Radioactive Waste and Spent Fuel Management;* Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek, J., Eds.; The American Society of Mechanical Engineers: New York, NY, 1993; pp 105–109.

80. Corleto, P.; Guidotti, M.; Petagna, E.; Ragazzo, G. "A Microwave System to Scarify Concrete Surfaces: Development and Testing," In *High Level Radioactive Waste and Spent Fuel Management;* Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek, J., Eds.; The American Society of Mechanical Engineers: New York, NY, 1993; pp 439–444.

81. Feizollahi F.; Shropshire, D. "Waste Management Facilities Cost Information Report for Greater-Than-Class C and DOE Equivalent Special Case Waste," DE94010770; U.S. Department of Energy: Idaho Falls, ID, 1993; pp 1–144.

82. Ferguson, R.L. "Liquid Abrasive Grit Blasting Literature Search and Decontamination Scoping Tests Report," WINCO-1163; U.S. Department of Energy Idaho National Engineering Laboratory and Westinghouse Idaho Nuclear Company, Inc.: Idaho Falls, Idaho, 1993; pp 1-A-7.

83. Foster, D. "U.S. DOE Researchers Demonstrate Use of Microwaves to Decontaminate Concrete," *D&D Technologies* **1993**; *1,* 15–16.

84. Fujiki K.; Nakamura, H. "Current Studies on the Decommissioning Materials Recycling at Japan Atomic Energy Research Institute," In *High Level Radioactive Waste and Spent Fuel Management;* Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek, J., Eds.; The American Society of Mechanical Engineers: New York, NY, 1993; pp 321–327.

85. Guthrie, W.S. "Foam Technology as a Decontamination/Waste Minimization Tool," (U) 1993; pp 243–248, DOE–Westinghouse.

86. Ishikura, T.; Onozawa, T.T.; Onozawa, H.; Ohtsuka, and K. Ishigure, "Development of Decontamination Techniques for Decommissioning Commercial Nuclear Power Plants," In Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek, J., eds., 2, High Level Radioactive Waste and Spent Fuel Management. The American Society of Mechanical Engineers: New York, NY, 1993; pp 295–300.

87. Johnso, S.V.; and Mayberry, J.J. "Management Approaches for Environmental Restoration at the U.S. Department of Energy Weapons Complex, Savannah River Site: A Case Study," In Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek, J. eds., 2, High Level Radioactive Waste and Spent Fuel Management. *The American Society of Mechanical Engineers*: New York, NY, 1993; pp 349–351.

88. Long, F.G.; Ward, R.D.; McNicholas, P.; Albers, R.W.; Zaccai, H.; Tsyplenkov, V. "Assessment and Comparison of Waste Management Costs for Nuclear and Fossil Energy Sources," In Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek. J., eds., 2, High Level

Radioactive Waste and Spent Fuel Management. The American Society of Mechanical Engineers: New York, NY, 1993; pp 815–823.

89. Majersky, D.; Solcanyi, M.; Prazska, M. "Recent Trends in the Area of the Decontamination of Nuclear Power Plants in the Slovak Republic and in the Czech Republic," In Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek, J., eds., 2, High Level Radioactive Waste and Spent Fuel Management. The American Society of Mechanical Engineers: New York, NY, 1993; pp 301–306.

90. Mantega, F.; Sanson, F.; Garofalo, A.; Vitiello, T., "Garitta Project: An Example of Conditioning of Large Dimensions Irradiated Components," In Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek, J., eds., 2, High Level Radioactive Waste and Spent Fuel Management. The American Society of Mechanical Engineers: New York, NY, 1993; pp 445-454.

91. Panciatici, G.; Belfiore, A.; Poggianti, M.; "Attapulgite, A Decontaminating Medium, Research Tool in the Radioprotection Field," In Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek, J., eds., 2, High Level Radioactive Waste and Spent Fuel Management. The American Society of Mechanical Engineers: New York, NY 1993; pp 313–320.

92. Pang, H.M.; Edelson, M.C.; Demmer, R. "Metal Decontamination Using High Power Lasers," 1 & 2, Meeting the Challenge-ER '93- Environmental Remediation Conference. DOE. 1993; Vol 2, pp 999–1004.

93. Pickett, J.B.; England, J.L.; Martin, H.L. "Life Cycle Cost Analysis Changes Mixed Waste Treatment Program at the Savannah River Site, " (U) Conf 9303105, DOE–Westinghouse Savannah River Co.: Aiken, SC, 1993.

94. Santiago J.L.; Sanchez, M. "Decommissioning and Waste Disposal Methods for an Uranium Mill Facility in Spain," In Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek J. eds., 2, High Level Radioactive Waste and Spent Fuel Management. The American Society of Mechanical Engineers: New York, NY, 1993; pp 193–197.

95. Sebastian R.L.; Beck, B.G. inventors. Coleman Research Co. assignee. "Integrated Apparatus for Mapping and Characterizing the Chemical Composition of Surfaces," VA. No. 5416321, 437220, 1993.

96. Sleeman, R.C. "Update of Lessons Learned from Cleanup Projects at Oak Ridge, P.E. Ahlstroem, C.C. Chapman, R. Kohout, and J. Marek. eds., 2, High Level Radioactive Waste and Spent Fuel Management. The American Society of Mechanical Engineers: New York, NY, 1993; pp 333–335.

97. Vovk, I.F.; Movchan, N.P.; Fedorenko, Y.G.; Shpigun, A.A.; Zlobenko, B.P. "Research on Cleanup of Buildings and Structures in Urban Areas of Ukraine Affected by the Accident at the Chernobyl NPP," In Ahlstroem, P.E. Chapman, C.C.; Kohout, R.; Marek, J. eds., 2,

High Level Radioactive Waste and Spent Fuel Management. The American Society of Mechanical Engineers: New York, NY, 1993; pp 225–227.

98. Wei, T.; Hsieh, J. "The Experiences of Using Ultrahigh-Pressure Waterjet to Decontaminate the Nuclear Facilities at Iner," In Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek, J., eds., 2, High Level Radioactive Waste and Spent Fuel Management. The American Society of Mechanical Engineers: New York, NY, 1993; pp 433–437.

99. Yanagihara, S.; Itoh, S.; Shiraishi, K. "Systems Engineering for Decommissioning the Japan Power Demonstration Reactor (JPDR)–A Study on Characteristics of Decommissioning Waste," In Ahlstroem, P.E.; Chapman, C.C.; Kohout, R.; Marek, J., eds., 2, High Level Radioactive Waste and Spent Fuel Management. The American Society of Mechanical Engineers: New York, NY, 1993; pp 423–431.

100. Feizollahi F.; Shropshire, D. "Waste Management Facilities Cost Information Estimating Data," U.S. DOE DE95009462, Idaho Falls, ID, 1992, 319 p.

101. Jennings, H.T. inventor. British Nuclear Fuels Plc, assignee. "Method of Decontaminating a Cementitious Surface," Warrington, GBX. No. 5414196, 9616632, 1992.

102. Schlueter R.; Schafer, J.J. "Low-Level and Transuranic Waste Transportation, Disposal, and Facility Decommissioning Cost Sensitivity Analysis," EGG-WTD--10092, U.S. DOE Idaho National Engineering Laboratory, Idaho Falls, ID, 1992; pp 1–23.

103. Angus, M.J.; Hunter, S.R.; Ketchen, J. "Classification of Contaminated and Neutron-Activated Concretes from Nuclear Facilities Prior to Their Decontamination or Decommissioning 2," 1990; Vol. 1, pp 229–234.

104. Bullard C.W.; Weger, H.T.; "LLRW Disposal: Economies of Scale and Waste-Type Segregation," *Energy Systems and Policy* **1990**, *14*, 227–236.

105. Gugan, M.A.; Sanders, M.J.; Collett, K.F. "Wet Abrasive Particle Impact Cleaning as a Nuclear Decontamination Technique," *In* Proceedings of the International Topical Meeting on Nuclear and Hazardous Waste Management Spectrum '90; American Nuclear Society, Inc.; La Grange Park, IL, 1990; pp 269–271.

106. Konzek, G.J.; Smith, R.I. "Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station–Comparison of Two Decommissioning Cost Estimates Developed for the Same Commercial Nuclear Reactor Power Station," NUREG/CR-0672, Pacific Northwest Laboratory, Richland, WA, 1990; pp 1–59.

107. Zaccai, H. "Evaluation of Storage and Disposal Costs for Conditioned Radioactive Waste in Several European Countries," EUR-12871, Commission of the European Communities, Luxembourg, 1990; pp 1–45.

108. Nuclear Waste–DOE's Method for Assigning Defense Waste Disposal Costs Complies with NWPA B-202377, 1989; pp 1–31.

109. *Analysis of the Total System Life Cycle Cost for the Civilian Radioactive Waste Management Program;* DOE/RW-0236, U.S. DOE Office of Civilian Radioactive Waste Management, Washington, DC, 1989; pp 1-1-9-7.

110. Bealby, J. "Optimization of Treatment, Storage and Disposal Strategies for (Unconditioned and Conditioned) Radioactive Waste," DOE-RW-89.063, DOE, London (UK), 1989; pp 1–27.

111. Chang S.Y.; Rivera, A.L. "Theory and Evidence of Economies of Scale in the Development of Waste Management Systems," Presented at the U.S. DOE Model Conference, Oak Ridge, TN, Oct. 2–6, 1989; 8910193--2, 1989; pp 1–52.

112. Morillon, C.; Routier, J.F.; Pilot, G. "Thermal Techniques for Surface Concrete Decontamination," *Decommissioning of Nuclear Installations*; Proceedings of the 1989 International Conference; Elsevier Applied Science: Barking, United Kingdom, 1989; pp 553–563.

113. Pick, M.E. "PWR Oxide Characterisation/Surface Finish Improvement and Development of Decontamination Processes for Gas and Water Cooled Reactors," Decontamination and Decommissioning of Nuclear Facilities–Results of a Co-ordinated Research Programme, Phase II: 1989–1993; IAEA, 1989; pp 185–192.

114. Collins H.E.; Leach, E.W. TAM-D3: Boiling Water Reactor Recirculation Pipe Replacement: Radiological Challenges, Innovative Solutions, and Long-Term Plant Impact," Thirty-Second Annual Meeting of the Health Physics Society, 1987; Vol. 52, Supplement 1.

115. Distenfeld, C.H.; Brosey, B.H.; Babel, P.J. "TAM-D4: A Collimated Surface Monitor for Estimating Activity Absorbed in Concrete Walls," Thirty-Second Annual Meeting of the Health Physics Society, 1987; Vol. 52, supplement 1.

116. Yasunaka, H.; Shibamoto, M.; Sukegawa, T.; Yamate, T.; Tanaka, M. "Microwave Decontaminator for Concrete Surface Decontamination in JPDR," In Tarcza, G.A. ed., 2, No. DE87012822, Proceedings of the 1987 International Decommissioning Symposium. DOE–Westinghouse Hanford Co.: Richland, WA., 1987; Vol 2, pp 109–116.

117. Elder, H.K. "Technology, Safety and Costs of Decommissioning Reference Nuclear Fuel Cycle Facilities," NUREG/CR-4519, Pacific Northwest Laboratory, Richland, WA, 1986; pp 1–22.

118. United States Accounting Office, Nuclear Waste–Cost of DOE's Proposed Monitored Retrievable Storage Facility B-202377, pp 1–31, 1986.

119. McIsaac, C.V.; Davis, C.M.; Horan, J.T.; Keefer, D.G. "Results of Surface Activity and Radiation Field Measurements Made During Surface Decontamination Experiments Conducted at TMI-2," In Huebner, M.F., ed.; Proceedings of the American Nuclear Society Meeting on Fission-Product Behavior and Source Term Research. DOE, 1985; pp 1–17.

120. Pavelek, II, M.D.; Carmel, P.G. "Volume Reduction of Contaminated Concrete Shield Slabs Through Surface Removal," In Post, R.G. ed.; 2, Waste Management '85–Waste Isolation in the U.S. Technical Programs and Public Education-Waste Policies and Programs, Low-Level Waste. DOE, 1985; Vol. 2, pp 303–307.

121. Kuriyama, O.; Koyama, T.; Kikuchi, M. "Decontamination of Radioactive Metal Surfaces by Plasma Arc Gouging," *Nuclear Technology* **1983**, *61*, 93–99.

122. Galecki, G.; Vickers, G.W. "The Development of Ice-Blasting for Surface Cleaning 6th International Symposium on Jet Cutting Technology," BHRA Fluid Engineering: Bedform, England, 1982; pp 59–79.

123. Halter, J.M.; Sullivan, R.G.; Bevan, J.L. "Surface Concrete Decontamination Equipment Developed by Pacific Northwest Laboratory," DEAC0676RL01830, U.S. DOE Pacific Northwest Laboratory, Richland, WA, 1982; pp 1-D.1.

124. McCoy, M.W.; Allen, R.P.; Fetrow, L.K.; Hazelton, R.F. "Vibratory Finishing for Decontamination- Pilot Scale Operation," In Blasewitz, A.G.; Davis, J.M.; Smith. M.R, eds.; *The Treatment and Handling of Radioactive Wastes*; Battelle Press & Springer/Verlag: Columbus & NY, 1982; pp 109–113.

125. Kennedy, Jr. W.E.; Watson, E.C.; Murphy, D.W.; Harrer, B.J.; Harty, R.; Aldrich, J.M. "A Review of Removable Surface Contamination on Radioactive Materials Transportation Containers," NUREG/CR-1858, Pacific Northwest Laboratory, Richland, WA, 1981; pp 1.1–6.2.

126. Cox E.J.; Garde, R. "Decontamination of Concrete Surfaces at the Los Alamos Scientific Laboratory," 1980.

127. Arrowsmith H.W.; Allen, R.P. "New Decontamination Techniques for Exposure Reduction 2," U.S. Department of Energy Environmental Control Symposium. DOE. 1979; Vol. 3, pp 183–206.

128. Clarke J.H.; Dippel, T. *Manual on Decontamination of Surfaces, Safety Series*; International Atomic Energy Agency: Vienna, Austria, 1979; Vol. 48, pp 1–44.

129. Halter J.M.; Sullivan, R.G. "Techniques for Removing Contaminated Concrete Surfaces," *Environmental Decontamination*; 1979; pp 185–194.

130. Halter J.M.; Sullivan, R.G. "Contaminated Concrete Surface Layer Removal," In Mittal, K.L., ed., EY-76-C-06-1830, Reprinted from: *Surface Contamination*, DOE–Plenum Publishing Corp.: New York, NY, 1979; Vol. 1, pp 443–455.

131. Kunze, S. "Waste-Compatible Cleansers for Elimination of Surface Contaminations," *Kerntechnik* **1979**, *34*, 147–150.

132. Barbier M.M.; Chester, C.V. "Decontamination of Large Horizontal Concrete Surfaces Outdoors," W-7405-eng-26 U.S. DOE, pp 1–26.

133. Benavides E.; Fajardo, M. "Closed Electropolishing System for Decontamination of Underwater Surfaces/Development of Vibratory Decontamination with Abrasive Media," In Pflugrad, K.; Bisci, R.; Huber, B.; Skupinski. E, eds.; *Decommissioning of Nuclear Installations*; Elsevier Applied Science: London & NY; pp 598–603.

134. Carson, D.R.; Shagula, B.P.; Moran, J.B. "Human Factors Assessments of Environmental Technologies," 95MC32260, U.S. DOE, Morgantown, WV, pp 1–11.

135. Mc Kernan M.L.; Schulmeister, A.R. "Surface Decontamination Utilizing Mechanical Vacuum Blasting Methods," SSDP-0035, U.S. DOE.

136. Pang, H.M.; Lipert, R.J.; Hamock, Y.M.; Bayrakal, S.; Gaul, K.; Davis, B.; Baldwin, D.P.; Edelson, M.C. "Laser Decontamination A New Strategy for Facility Decommissioning."

137. *Trends in Nuclear Decommissioning Costs*, 1997; http://www.tlgservices.com.corprate/trends.htm

APPENDIX C

TECHNOLOGY DATABASE

Technology Database

Technology Name	Description	Cleans Steel	Cleans Concrete	Process Type
Mechanical Scabbling	Physical/mechanical, destructive surface removal	No	Yes	Destructive
Milling	Physical/mechanical, destructive surface removal	No	Yes	Destructive
Drilling Spalling	Physical/mechanical, destructive surface removal	No	Yes	Destructive
Sand Blasting	Physical/mechanical, nondestructive	Yes	Yes	Nondestructive
Steel Grit	Physical/mechanical, nondestructive	Yes	Yes	Nondestructive
Plastic Blasting	Physical/mechanical, nondestructive	Yes	Yes	Nondestructive
Ultrahigh-Pressure Water	Physical/mechanical, nondestructive	Yes	Yes	Nondestructive
High-Pressure Water	Physical/mechanical, nondestructive	Yes	Yes	Nondestructive
Sponge Blasting	Physical/mechanical, nondestructive	Yes	Yes	Nondestructive
Soft-Media Blasting – Metal	Physical/mechanical, nondestructive	Yes	No	Nondestructive
Soft-Media Blasting – Concrete	Physical/mechanical, destructive	No	Yes	Destructive
Soda Blasting – Metal	Physical/mechanical, nondestructive	Yes	No	Nondestructive
Soda Blasting – Concrete	Physical/mechanical, nondestructive	No	Yes	Nondestructive
Shot Blasting	Physical/mechanical, destructive surface removal	Yes	Yes	Destructive
Scarification MOOSE	Physical/mechanical, destructive surface removal	No	Yes	Destructive
Squirrel Floor Scabbler and Corner Cutter	Physical/mechanical, destructive surface removal	No	Yes	Destructive
Microwave	Electrical/thermal/physical, destructive surface removal	No	Yes	Destructive
CO_2 Laser	Electrical/thermal, nondestructive	Yes	Yes	Nondestructive
Ice Blasting	Physical/mechanical, nondestructive	Yes	Yes	Nondestructive
Electrokinetic	Electrical/chemical/physical, nondestructive	No	Yes	Penetrating
Electrohydraulic Scabbling	Physical/mechanical, destructive surface removal	No	Yes	Destructive
TechXtract or Corpex Processes	Chemical, nondestructive	Yes	Yes	Nondestructive
Carbon Dioxide Blasting – Metal	Physical/mechanical, nondestructive	Yes	No	Nondestructive
Carbon Dioxide Blasting – Concrete	Physical/mechanical, nondestructive	No	Yes	Nondestructive

Technology Name	Production Rate $/ft^2	Operating Cost $/ft^2	Safety Factor	Reliability Factor	Volume Secondary Waste ft^3/hr	Secondary Waste Weight lb/hr	Cleaning Depth, in.	Number of Workers
Mechanical Scabbling	300	2.18	6.57	8.21	0	0	0.125	0
Milling	3	0.75	6.2	7.53	0	0	1	0
Drilling Spalling	6	12	6.13	7.8	0	0	1.5	0
Sand Blasting	47	7.5	5.53	8	0.03	1.8	0.125	3
Steel Grit	13.1	4.95	6.3	6.85	0.02	2.3	0.125	3
Plastic Blasting	5.15	4.8	6.23	5.88	0.22	13.1	0.0625	3
Ultrahigh-Pressure Water	59.75	0.87	6.23	7.55	32	1992	0.125	3
High-Pressure Water	11.6	4.8	5.67	7.88	112	6970	0.0625	3
Sponge Blasting	24.5	4.78	6.8	6.5	528	175	0.125	4
Soft-Media Blasting – Metal	90	11	6.8	5.09	0.2	20	0.125	4
Soft-Media Blasting – Concrete	90	11	6.8	5.09	0.2	20	0.125	4
Soda Blasting – Metal	24	4.17	5.77	6.85	5.8	361	0.0625	1
Soda Blasting – Concrete	100	5.1	5.77	6.85	5.8	361	0	1
Shot Blasting	1515	2.89	6.33	7.94	0	0	0.25	0
Scarification MOOSE	300	2.18	6.6	8.21	0.26	26.1	0.0625	0
Squirrel Floor Scabbler and Corner Cutter	25	2.18	6.6	7.58	0.26	26.1	0.0625	0
Microwave	40	2	7	5.26	0	0	2	0
CO_2 Laser	282	8.5	6.2	4.66	0.68	51.6	0.125	3
Ice Blasting	15	1.3	6.3	6.84	1.2	75.1	0.0625	3
Electrokinetic	132	0.42	6.3	4.13	4.66	290.7	3	0
Electrohydraulic Scabbling	30	1.23	6.3	5.76	300.8	18765	1	0
TechXtract or Corpex Processes	100	14.5	6.3	5.63	0.53	33.36	3	5
Carbon Dioxide Blasting – Metal	12.4	4.39	6.1	5.96	0.01	0.165	0.125	3
Carbon Dioxide Blasting – Concrete	15	1.75	6.1	5.96	0.01	0.165	0.0625	3

Technology Name	Stage of Technology	Waste Generation Type	Secondary Waste Solid, %	Number of Passes to Complete Cleaning	Cleans Floors	Cleans Walls	Cleans Ceilings	Handles Hard-to-Reach Areas	On-Line Analysis	Extra Utilities Req'd.
Mechanical Scabbling	Commercial	Solid	100	1	Yes	No	Yes	No	No	No
Milling	Commercial	Solid	100	1	Yes	No	Yes	No	No	No
Drilling Spalling	Commercial	Solid	100	1	Yes	No	Yes	No	No	No
Sand Blasting	Commercial	Solid	100	1	Yes	Yes	Yes	Yes	No	No
Steel Grit	Commercial	Solid	100	1	Yes	Yes	Yes	Yes	No	No
Plastic Blasting	Commercial	Solid	100	2	Yes	Yes	Yes	Yes	No	No
Ultrahigh-Pressure Water	Commercial	Liquid	0	2	Yes	Yes	Yes	Yes	No	Yes
High-Pressure Water	Commercial	Liquid	0	2	Yes	Yes	Yes	Yes	No	No
Sponge Blasting	Commercial	Solid	100	2	Yes	Yes	Yes	Yes	No	No
Soft-Media Blasting – Metal	Commercial	Solid	100	1	Yes	No	Yes	Yes	No	No
Soft-Media Blasting – Concrete	Commercial	Solid	100	1	Yes	Yes	Yes	Yes	No	No
Soda Blasting – Metal	Developmental	Liquid	50	2	Yes	Yes	Yes	Yes	No	No
Soda Blasting – Concrete	Developmental	Liquid	50	2	Yes	Yes	Yes	Yes	No	No
Shot Blasting	Commercial	Solid	100	1	Yes	Yes	Yes	Yes	No	No
Scarification MOOSE	Commercial	Solid	100	1	Yes	No	Yes	No	No	No
Squirrel Floor Scabbler and Corner Cutter	Commercial	Solid	100	1	Yes	Yes	Yes	Yes	No	No
Microwave	Commercial	Solid	100	1	Yes	Yes	Yes	Yes	No	Yes
CO_2 Laser	Developmental	Solid	100	1	Yes	Yes	Yes	Yes	Yes	Yes
Ice Blasting	Commercial	Liquid	0	1	Yes	Yes	Yes	Yes	No	No
Electrokinetic	Bench	Liquid	0	2	Yes	No	Yes	Yes	No	No
Electrohydraulic Scabbling	Developmental	Liquid	0	1	Yes	No	Yes	No	No	No
TechXtract or Corpex Processes	Commercial	Liquid	0	1	Yes	Yes	Yes	Yes	No	No
Carbon Dioxide Blasting – Metal	Commercial	Solid	100	2	Yes	Yes	Yes	Yes	No	Yes
Carbon Dioxide Blasting – Concrete	Commercial	Solid	100	2	Yes	Yes	Yes	Yes	No	Yes

APPENDIX D

SURFACE DECONTAMINATION ASSISTANT MODEL DESIGN

SURFACE DECONTAMINATION ASSISTANT
MODEL DESIGN

SURFACE CHARACTERISTICS AND WASTE DEFINITION

The model determines a performance index (PI) for decontamination of a metal or concrete surface using a user-defined scenario as input. The user-defined scenario can include various types of substrate material, amount of area to be removed/decontaminated, depth of removal, surface orientation (e.g., floor), type of contamination, type of transportation used for disposal, distance to disposal site, and fees charged for disposal. Outputs include the performance indices listed below, which together provide an overall PI for a decontamination technology:

- Surface removal
- Transportation
- Disposal
- Recyclability
- Environment, health, and safety
- Implementability, operation, and maintenance

Assumptions

- User knows types of contamination that occurred on site.
- User has knowledge of surfaces to be decontaminated.
- Depth of contamination is defined.

TECHNOLOGY SELECTION

Included within the model is a database of technologies that contains information on the operational aspects of each technology listed. The user can view this information while using the model to help determine which process is most applicable for the user's situation. Listed below are the fields within the database records that are based on the variables used in determining the overall PI for a technology:

- Destructive or nondestructive process
- Substrate cleaning ability – metal or concrete or both
- Surface-cleaning ability only
- Production rate
- Operating cost
- Volume, weight, phase, and density of secondary waste
- Depth of cleaning
- Number of passes needed to achieve 100% decontamination
- Ability to clean vertical surfaces

- Ability to clean hard-to-reach areas (corners, cracks, etc.)
- On-line analysis capabilities
- Usual utility costs
- Environment, health, and safety factors
- Implementability, operation, and maintenance
- Equipment decontamination necessary
- Stage of technology development
- Number of workers necessary to operate technology

Decontamination technologies are classified as either destructive or nondestructive processes. Destructive process are considered to have 100% effectiveness of decontamination due to the actual removal of the surface containing the contamination. For nondestructive processes, the model assumes that each technology has the ability to achieve complete removal of the contaminants even if the surface must be cleaned several times. Technologies that are not applicable to cleaning a particular substrate (concrete, metal) will not be selectable by the user for that particular application. For example, if the contaminant has seeped into a concrete floor, a surface-cleaning technology (nondestructive) will no longer be a viable selection. The model also asks the user the orientation of the contaminated surface, then excludes any technology from selection that is not able to clean surfaces of that orientation.

Assumptions

- All technologies are capable of 100% decontamination of the surface.
- Operation cost is a service cost, which includes deployment and transportation to site.

CALCULATION OF SURFACE REMOVAL FACTOR

This section describes how a PI of surface decontamination is determined. Variables used in the surface removal PI include operating cost, production rate, depth of removal, number of passes necessary for 100% cleaning, and area to be decontaminated/removed.

The model can determine several different contamination scenarios: 1) contamination that has seeped into the concrete below the surface coating, 2) decontamination of a room or building, and 3) easy- versus hard-to-reach areas to be decontaminated.

In Scenario 1, the contamination has seeped down into the concrete. There are two possible ways to achieve the objective of decontamination: 1) Removal of both the surface coating and the contaminated concrete with one technology. This technology would have to be a destructive process or a process that is capable of penetrating the contaminated concrete. 2) Performing two separate runs of the model using a nondestructive process to remove the surface coating and another to decontaminate the concrete. One reason for using two different technologies is to reduce secondary waste by using a nondestructive low-waste-producing technology to remove the surface coating.

Scenario 2 involves decontamination of rooms or buildings, which would include horizontal and vertical surfaces. Some technologies are not capable of cleaning vertical surfaces or ceilings. There are two possible ways to approach this scenario: 1) Enter the total surface area for the building/room and use one technology that is capable of cleaning all of the surfaces. 2) Use several technologies to decontaminate the building/room, and run the model a separate time for each technology and different surface orientation.

Scenario 3 involves areas that are hard to reach, defined as a deep crack or crease or an area within 6 inches of the corners of a room, versus areas that are easily cleaned. Several technologies are not capable of cleaning within 6 inches of a corner. 1) Select a technology that is capable of cleaning all of the contaminated surface. 2) Run the model twice, once using a technology to clean the easily accessible areas, but unable to reach into the corners, and a second time using a technology that is capable of cleaning in the corners.

Assumption

- User is willing to use one or more different technologies to decontaminate a site.

Algorithm Description

For the first step, the model determines the total number of passes needed to completely remove the contaminants using an equation based upon the depth of removal, the depth at which the technology can clean per pass, and the cleaning effectiveness of the technology (Ref. 22, Appendix B, pp 1–26).

A second equation determines the surface removal factor for a technology by multiplying the contaminated surface area by the technology operating cost and the number of passes needed by the process to complete the task. Floor surface is treated apart from vertical and ceiling surface areas because some technologies are able to decontaminate only floors (Ref. 22, Appendix B, pp 1–26).

The time needed to complete the user-defined decontamination task is provided in a third calculation. The parameters taken into consideration are the surface area to be cleaned, the production rate of a technology, the number of passes necessary, and the percent of the area that is hard to reach (as defined above). A compensation factor is included that determines the rate at which the total hours to decontaminate will increase because of areas that are more time-consuming to clean (hard-to-reach areas). The total hours will be used later to determine the amount of secondary waste produced by a technology.

CALCULATION OF WASTE VOLUMES AND WEIGHT

Two primary waste streams are produced during the decontamination process. One is surface debris, resulting from the actual removal of the contaminated surface, and the other is the secondary waste produced from the technology during the cleaning process. The secondary waste can be in liquid or solid phase, which is indicated in the technology database. For future definition of the types of waste to be disposed of at a storage or disposal site, the model tracks both weight and volume of the primary solid waste and secondary liquid and solid waste. Each phase of waste will be treated differently during transportation and disposal.

Assumptions

- No transuranic waste or spent nuclear fuel is being transported or disposed of.
- Technologies and site personnel are capable of removing one specific area, then another, without mixing the removed waste.
- Solid and liquid waste streams are kept separate.
- Primary substrate waste is always solid.
- On-site disposal will use existing trucks and personnel.
- No rail shipment of remote-handled waste.

Algorithm Description

The volume and weight of debris resulting from the removal of the contaminated surface are calculated by multiplying the surface area by the depth of removal and the solid surface volume by surface density, respectively.

Each technology produces a different amount and phase of secondary waste from the decontamination process (Ref. 1, Appendix B, pp 1–26). The total volume and weight of the secondary waste for both solid and liquid phase are determined by multiplying the volume and weight of waste produced by each technology per hour by the total number of hours.

The total volume amount of solid waste produced during the decontamination process is determined by adding the volume of surface debris and the volume of secondary waste. The amount of solid secondary waste is determined using the percentage of secondary waste that is solid from the technology database.

Waste Classification

Most U.S. Department of Energy (DOE) waste streams from decontamination processes fit one of the following categories: low-level waste (LLW), greater-than-Class C (GTCC) LLW and DOE equivalent waste, transuranic waste (TRU), spent nuclear fuel (SNF), and hazardous waste. (Ref. 26, Appendix B, p 1). These wastes streams are grouped together into three transportation categories:

- Contact-handled (<200 mrem/hr contact dose)

- Remote-handled (>200 mrem/hr contact dose)
- Hazardous waste

Most storage/disposal facilities accept LLW, MLLW, and TRU wastes (Refs. 26, 102, 137, Appendix B). For ease of use, the model classifies waste as contact-handled (CH) (<200 mrem/hr contact dose) or remote-handled (RH) (>200 mrem/hr contact dose) for transportation and disposal. Solid CH waste can be disposed of on-site, thus lowering disposal costs. All liquid CH waste is assumed to be disposed of at a DOE or commercial disposal facility.

For on-site CH disposal, the travel distances are assumed to be under 30 miles and existing trucks and personnel are assumed to be used for transportation, resulting in a cost of $\$1/ft^3$ based on Idaho National Engineering Laboratory (INEL) experience (Ref.102, Appendix B, p 5). Other types of waste produced during the decontamination process are recyclable aggregate, recyclable scrap metal, and general construction and disposal (C&D) waste. Uncontaminated concrete can be disposed of in a C&D landfill at a default charge of $\$7/yd^3$ (Ref. 3, Appendix B). Recycled aggregate is assumed to fetch 80% of the value of virgin aggregate, $6.67/ton (=$8.45 * 0.80) (*Engineering News Report* 1996).

Only concrete is considered recyclable, since it is in the waste stream during the decontamination process. Being able to recycle concrete will lower disposal costs. Concrete in the waste is removable from the structure during the process when steel is never in the actual waste stream and is still attached after decontamination. The value of recyclability would be the same for all metal decontamination processes. One technology will not produce more or less metal that is suitable for resale or recyclable after the cleaning process than another.

CALCULATION OF TRANSPORTATION COSTS

Waste is classified for shipping as either contact- or remote-handled. Waste also can be transported by either truck or rail with specific weight restrictions and container device restrictions. As noted in a DOE technology assessment, "The volume of remote-handled waste is very small and does not warrant an estimate of rail costs in addition to truck costs" (Ref. 2, Appendix B, p 9). Also, the standard remote-handled containers are not designed for rail shipment. For this reason the model does not consider rail shipment of remote-handled waste.

Transportation costs are determined in the form of cost-per-loaded-mile (CPLM) format. Most transportation is by truck, but rail can be used where practical. The CPLM unit rate is a variable cost dependent on the distance traveled. It has two subcomponents:

- Carrier cost – covers the variable costs associated with the cargo carrier. The carrier is the entity that takes title to the waste from the shipper during transportation, i.e., the trucking or railroad company.

- Hardware costs – the variable costs associated with procuring and maintaining the special hardware used during the transportation of waste. Special hardware consists mainly of trailers and railroad cars equipped with special tight-sealing enclosures or shielded casks.

Fixed costs generally consist of demurrage cost of the carrier and the hardware used in the shipment, which are independent of the distance traveled. Fixed costs are incurred during loading and unloading operations.

Guidelines for liquid waste shipments by truck or rail differ from those for solid shipments because of the need to provide secondary containment of spills that might occur in transit. Liquid components will only be 50% of the shipment volume. A common method used for packaging liquids is to place the liquid waste in a 30-gal closed-top drum, which is then placed in a 55-gal open-head drum. Absorbent is placed between the two containers, allowing the absorbent to remain noncontaminated, not adding to the disposal costs (Ref. 26, Appendix B).

Assumptions

- On-site disposal will be solid CH waste only.
- All loads are full shipments.

Algorithm Description

Truck – Contact-Handled Waste

- 48-ft-long unshielded truck trailers
- Solid type of waste: LLW, MLLW, alpha LLW, alpha MLLW
- Solid load: 44,000 lb per shipment – 88 drums @ 500 lb
- Liquid type of waste: LLW, MLLW
- Liquid load: Type A container, 44,000 lb per shipment – 88 drums @ 500 lb

A calculation is done to determine the number of truckloads necessary to transport the waste to a DOE storage/disposal facility. The number of trucks needed are rounded up to the nearest full load. 2600 gallons is the estimated amount of liquid per shipment. Multiplying 2600 gallons by the density of water equals 21,688 lb/shipment (Ref. 26, Appendix B). Another computation determines the cost of transportation by multiplying the number of loads by the one-way distance traveled to a disposal facility and charge per mile. For the cost per mile, all distances traveled to DOE storage/facility sites are considered to be over 300 miles.

The fixed costs are multiplied by the number of loads and added to the total cost. The format is the same: 1) determine the number of loads necessary to remove waste, and 2) calculate the transportation cost for rail CH, truck RH, CH on-site disposal, and C&D disposal costs.

Rail – Contact-Handled Waste

- 40-ft-long intermodel (sea–land) containers

- Solid type of waste: LLW, MLLW
- Liquid load: Type B container, 38,000 lb per container – 76 drums @ 500 lb
- Load: 44,000 lb per container – 11 boxes @ 3945 lb
  or 38,000 lb per container – 76 drums @ 500 lb
- Liquids – number of shipments = total quantity of liquid gal/18240 lb

Truck – Remote-Handled Waste

- Type of Waste: LLW, MLLW, alpha LLW, alpha MLLW, GTCC/DOE equivalent waste
- Load: 13,400 lb per shipment – 14–55 gallon drums per shipment
- Liquids – number of shipments = total quantity of liquid gal/6422 lb

Truck – On-Site Disposal

- Mass of solid waste
- Number of truckloads at 44,000 lb per truckload
- Fixed costs for loading/unloading and other costs associated with the use of trucks (fuel, etc.)

CALCULATION OF DISPOSAL FEES AND RECYCLE CREDITS

The fees charged by DOE and commercial storage/disposal facilities vary greatly from location to location (Refs. 3, 102, 137, Appendix B). The model uses an average for the different types of waste, which is considered fair, because the fee is the same for each technology. If the user wishes to change or knows the fee charged by a particular facility, that number can be entered instead.

- Contact-handled waste, off-site – High $300/ft^3$ (Ref. 137, Appendix B), medium $150/ft^3$ (Ref. 102, Appendix B,), low $100/ft^3$ (Ref. 57, Appendix B)
- Contact-handled waste, on-site – $60/ft^3$ (Ref. 26, Appendix B)
- Remote-handled waste – High $740/ft^3$, medium $300/ft^3$, low $150/ft^3$ (Ref. 102, Appendix B)
- Construction and disposal waste – $0.26/ft^3$ (Ref. 3, Appendix B)
- Aggregate resale – $6.76/ft^3$ (*Engineering News Report* 1996)

Assumptions

- User can use default values or will enter local disposal and recycle values.

Algorithm Description

The disposal and recycle values are determined by dividing the amount of material to be disposed or recycled by the material density and multiplying by the appropriate fee.

CALCULATION OF TECHNOLOGY PERFORMANCE INDICES

A PI is computed for each technology when it is selected. PIs can be compared against those for another technology if the decontamination scenario input values are identical. The higher the PI for a technology, the better the technology did decontaminating that scenario. The overall PI is composed of six different factors: surface removal, transport, disposal, recyclability, safety, and maintenance. To determine the safety and maintenance factors, performance scores were given each of the cleanup technologies in the areas of operation, maintenance, implementability, and environment, health, and safety (Ref. 57, Appendix B). The technologies were assigned nominal performance scores on a scale of 1 to 10, with 10 being the best. The criteria used were as follows:

- Implementability
  - Availability of the technology
  - Previous use of the technology
  - State of development of environmental management (EM) applications
  - Flexibility and adaptability

- Operation and maintenance
  - Setup
  - Cleaning operations
  - Equipment cleanup after shutdown
  - Equipment maintenance

- Environment, health, and safety
  - Regulatory compliance
  - Emissions of toxic gases, vapors, and dust
  - Worker exposure

The performance scores were independently assigned to the criteria by three raters: a senior chemical engineer with process experience, a research engineer, and a senior research chemist with recent background in developing a computer model for evaluating alternative surface-cleaning methods (Ref. 57, Appendix B).

Algorithm Description

Surface removal, transport, disposal, and recyclability were determined by summing all of the costs for each individual factor together and dividing by the total surface area removed. For example, all of the different types of waste disposal costs are added together (CH on-site, CH off-site, RH off-site, and C&D) then divided by the total surface area input by the user.

Disposal, surface removal, and transportation are all costs, with a lower cost meaning savings. To obtain an index number that gets larger to indicate a greater value, these variables are divided into a factor. The user has the ability to give one factor of merit more weight, or importance, than another factor by giving each factor a priority ranking. Each factor is assigned a priority rank with a value of 1–10, with 10 being the best. The program takes each PI and multiplies each value by the priority ranking given by the user, then sums together the six PIs and divides by the sum of the priority rankings.

APPENDIX E

SURFACE DECONTAMINATION ASSISTANT SOFTWARE DESIGN

SURFACE DECONTAMINATION ASSISTANT SOFTWARE DESIGN

As described in the body of the report, the program applies the Surface Decontamination Assistant algorithm, taking its inputs from a user-defined application scenario and the database of technology performance data, resulting in technology comparisons.

User-Defined Application Scenario

Upon program execution, the user is presented with the main screen dialog, shown in Figure E1.

Interaction between the user and the software model is done via a series of input dialogs. Once the Run Complete Scenario button shown in Figure E1 is pressed, the user is led through a series of inputs defining the application scenario. The inputs requested of the user by each dialog are listed below.

First, a summary description of the site is entered as listed below and illustrated in Figure E2:

i. Site name
ii. Location of site
iii. General substrate description
iv. General contamination description
v. Scenario (site) activation date
vi. Scenario modification date

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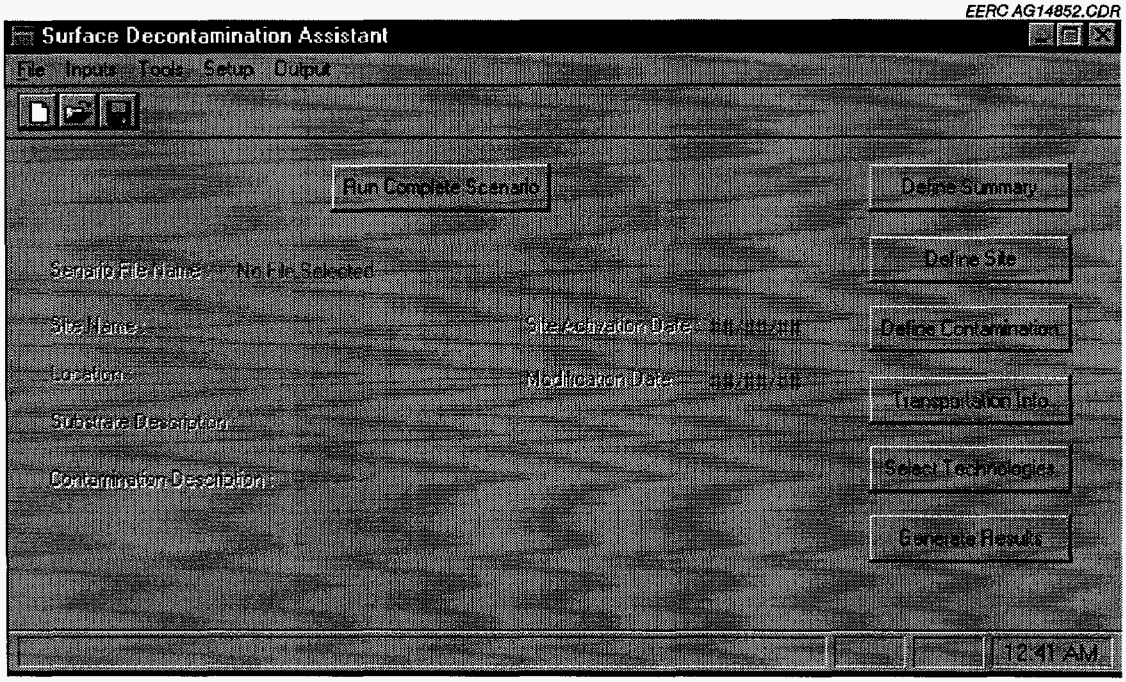

Figure E1. Surface Decontamination Assistant main dialog.

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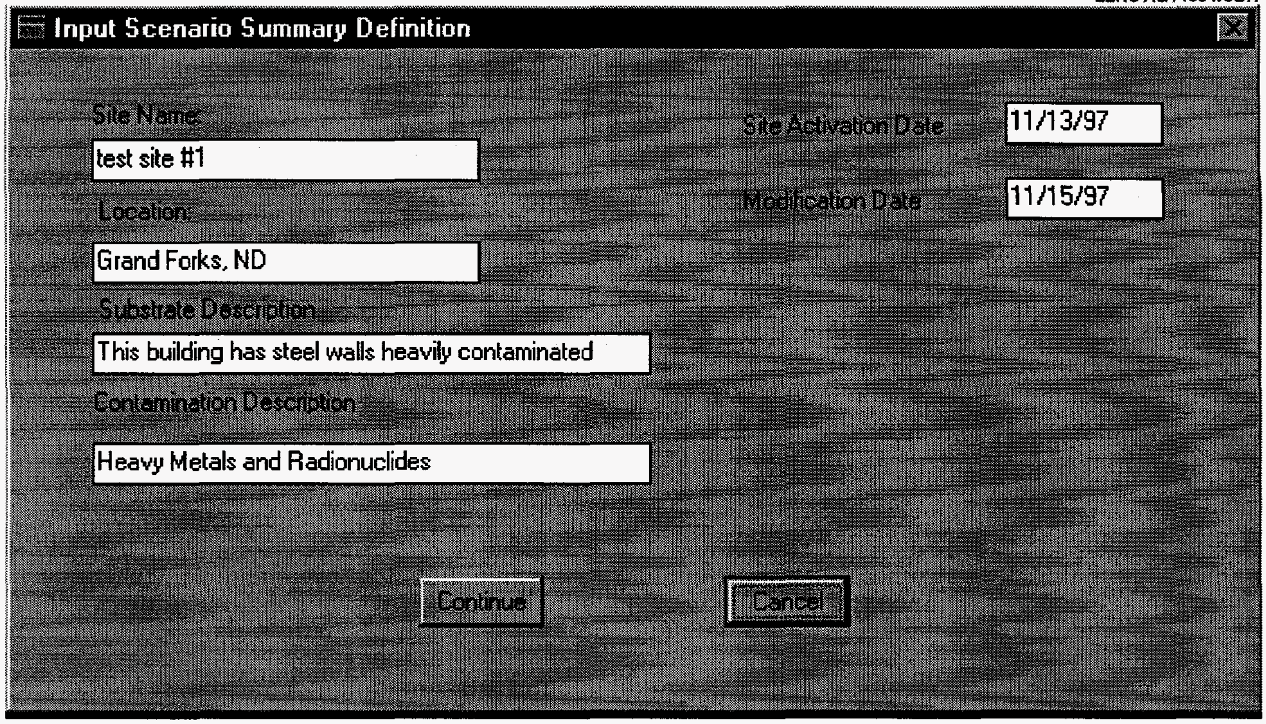


Figure E2. Input scenario summary description dialog.

Upon pressing the Continue button shown in Figure E2, the user is prompted for more detailed site information as listed below and shown in Figure E3.

i. Surface type
ii. Substrate material
iii. Total area of the surface
iv. Area of hard to reach portions to be decontaminated
v. Thickness of surface coating
vi. Total thickness of surface to be removed

Next, when the Continue button depicted in Figure E3 is pressed, the user can select general categories, as shown in Figure E4.

As before, pressing the Continue button illustrated in Figure E4 brings the user to the input dialog shown in Figure E5, Quantified Contamination Definitions. The inputs needed are estimated surface areas of the following waste categories:

i. Recyclable
ii. Construction and disposal (can be sent to a landfill)
iii. Contact-handled (<200 mrem/hr) for off-site storage
iv. Contact-handled (<200 mrem/hr) for on-site storage
v. Remote-handled (>200 mrem/hr)

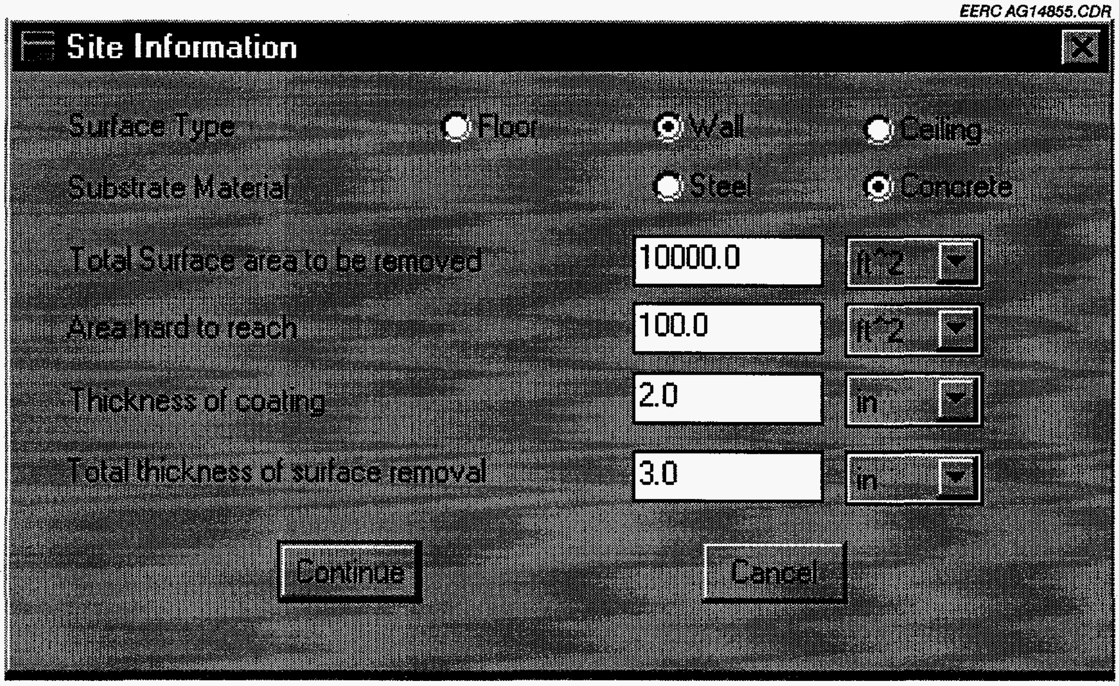


Figure E3. Site Information dialog.

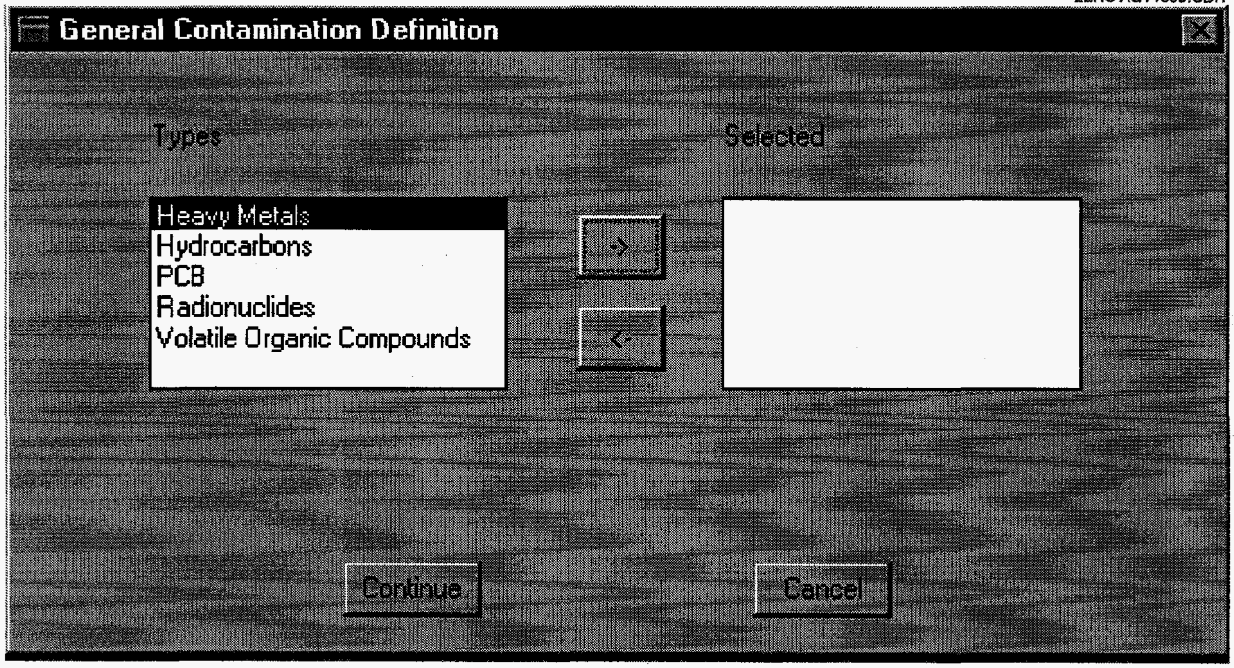


Figure E4. General Contamination Definition dialog.

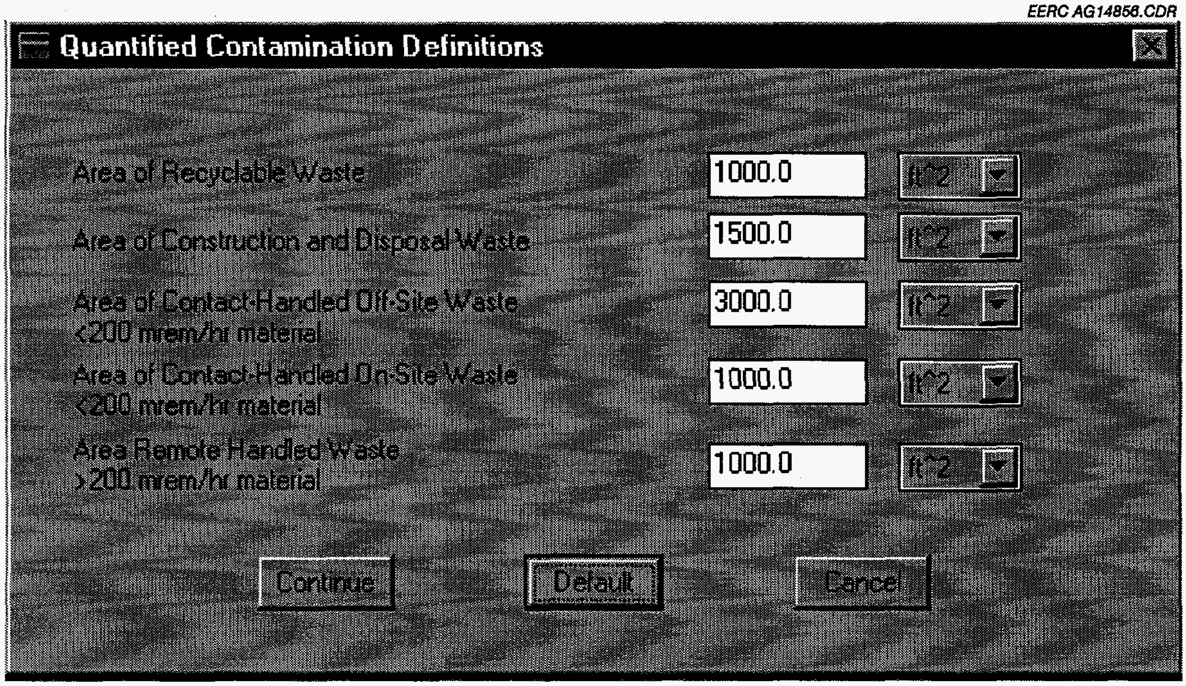


Figure E5. Quantified Contamination Definitions input dialog.

Once the contamination input dialog is completed by pressing the Continue button, the user is prompted for information on the details of transportation to remove waste from the decontamination site. Listed below are the inputs, and the dialog is illustrated in Figure E6.

i. Distance to off-site waste storage
ii. Distance to on-site waste storage
iii. Distance to landfill disposal site
iv. Style of waste transport

Pressing the Continue button shown in Figure E6 brings the user to the surface decontamination Technology Selection dialog depicted in Figure E7.

Pressing the Continue button shown in Figure E7 will initiate a dialog box prompting the user to name and save the application scenario. After the application scenario data are saved, program control is returned to the output viewer shown in Figure E8.

Pressing the Cancel button illustrated in Figure E8 will return program control to the main input screen shown in Figure E1.

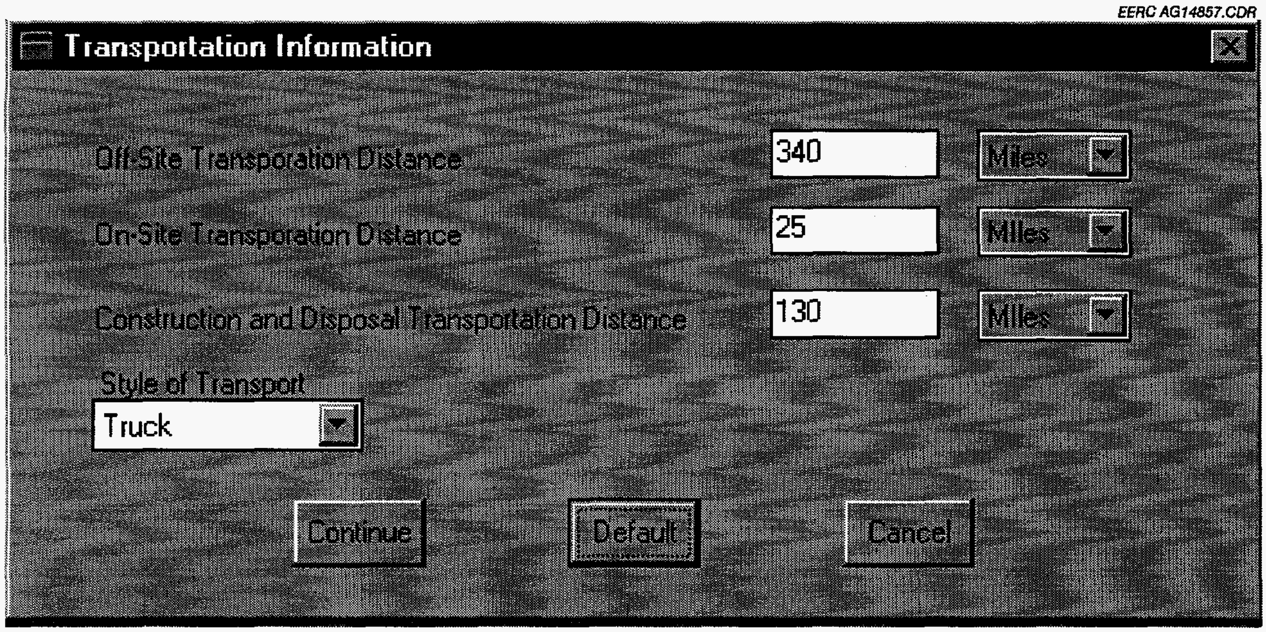


Figure E6. Waste transportation input dialog.

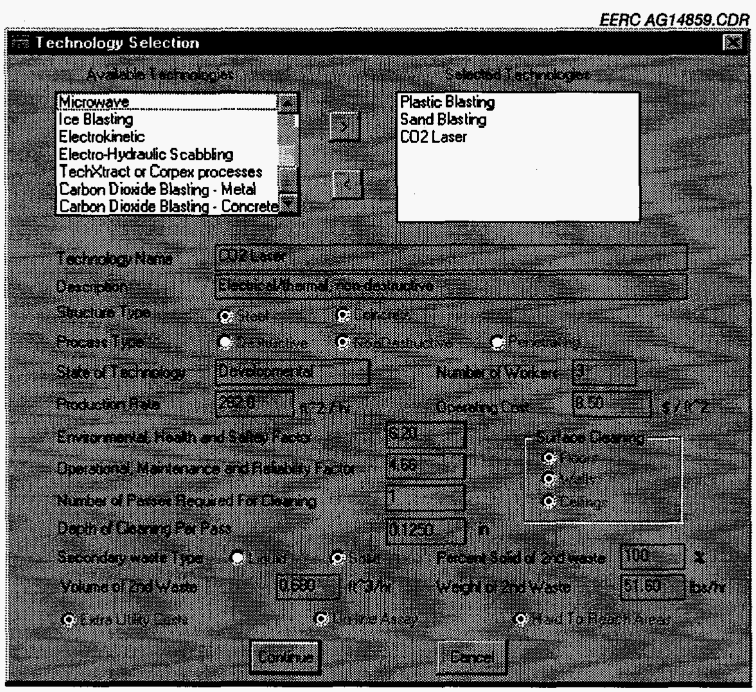
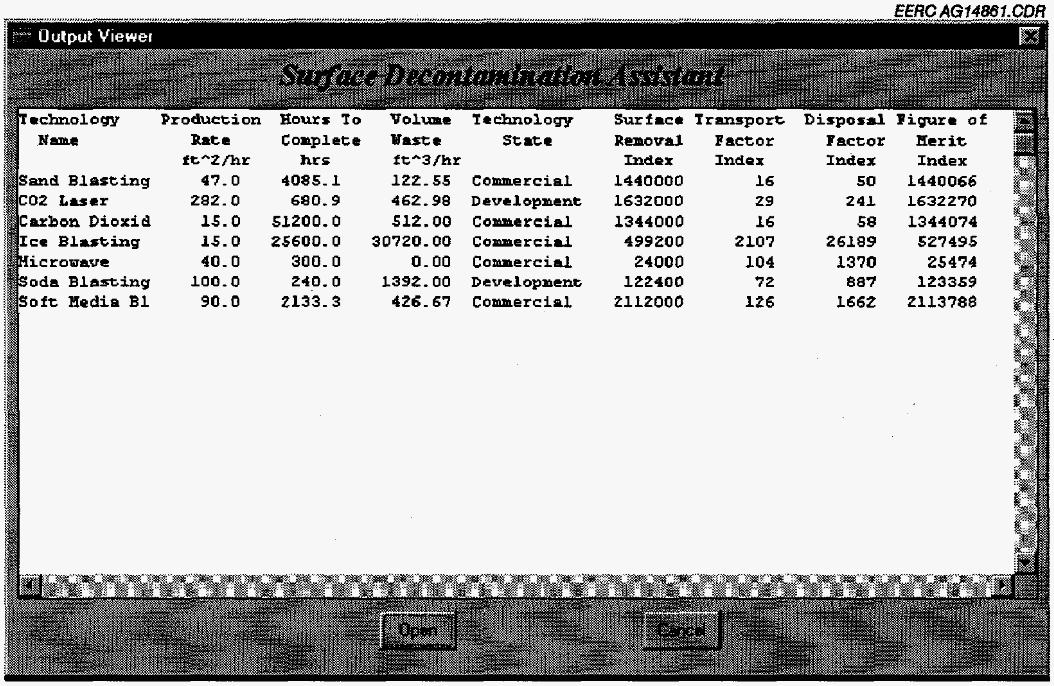


Figure E7. Surface decontamination Technology Selection dialog.



Technology Name	Production Rate ft^2/hr	Hours To Complete hrs	Volume Waste ft^3/hr	Technology State	Surface Removal Index	Transport Factor Index	Disposal Factor Index	Figure of Merit Index
Sand Blasting	47.0	4085.1	122.55	Commercial	1440000	16	50	1440066
CO2 Laser	282.0	680.9	462.98	Development	1632000	29	241	1632270
Carbon Dioxid	15.0	51200.0	512.00	Commercial	1344000	16	58	1344074
Ice Blasting	15.0	25600.0	30720.00	Commercial	499200	2107	26189	527495
Microwave	40.0	300.0	0.00	Commercial	24000	104	1370	25474
Soda Blasting	100.0	240.0	1392.00	Development	122400	72	887	123359
Soft Media Bl	90.0	2133.3	426.67	Commercial	2112000	126	1662	2113788

Figure E8. Model results output viewer.

Technology Comparisons

Technology comparison outputs are obtained by pressing the Generate Results button shown in Figure E1. The Surface Decontamination Assistant program outputs take three forms. Upon completion of a program run, the user is presented with a tabular output containing a summary of the technology comparisons, as shown in Figure E8.

Another type of output produced by the program is a series of bar graphs showing the indices (surface removal, figure of merit, etc.) computed by the program. An example of the figure-of-merit bar graph is shown in Figure E9.

Finally, the program generates a table containing all user-defined inputs and model results in a comma-delimited ASCII file formatted to allow reading the data into other programs such as spreadsheets, graphics programs, and other data analysis packages.

Setup Inputs for Fixed Site-Specific Information

Some user inputs not contained in the normal input sequence are accessed via the Setup menu. Selections available under this menu are described below.

A dialog is provided to allow the user to specify transportation and disposal costs (Figure E10). The inputs available are included on the following page:

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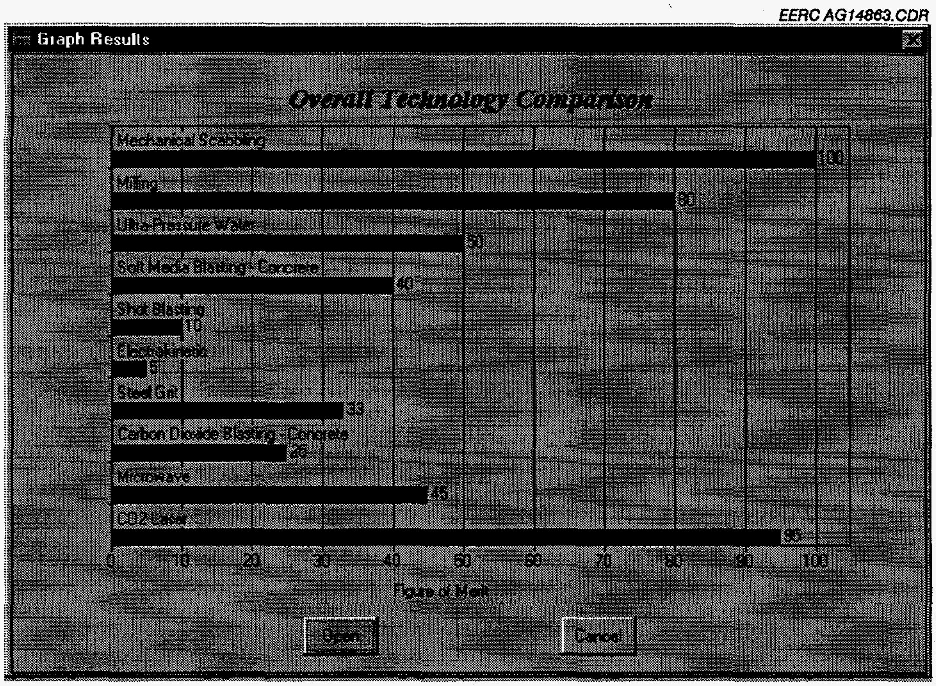

Figure E9. Technology comparison bar graph output.

1. Transportation fees
   i. Off-site truck contact-handled (CH) waste fee
   ii. Off-site rail CH waste fee
   iii. Off-site truck remote-handled (RH) waste fee
   iv. On-site CH waste fee
   v. Construction (nonhazardous) waste fee
2. Waste disposal fees
   i. CH waste on-site fee
   ii. CH waste off-site fee
   iii. RH waste off-site fee
   iv. Construction (nonhazardous) waste fee
   v. Aggregate income (recycle concrete)
   vi. Scrap metal income (recycle metals)

The user is also allowed to give priority to specific aspects of the surface decontamination process by adjusting the ranking of the categories listed on the dialog box shown in Figure E11. This allows the user to calibrate the model to individual preferences.

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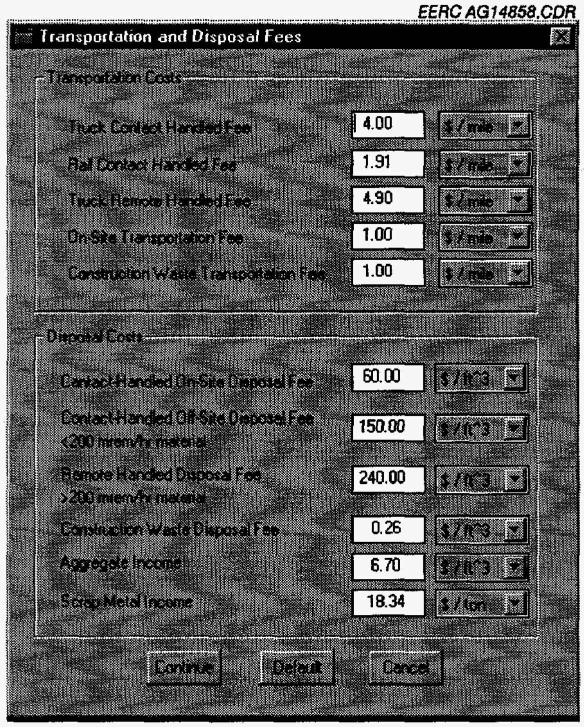

Figure E10. Transportation and Disposal Fees.

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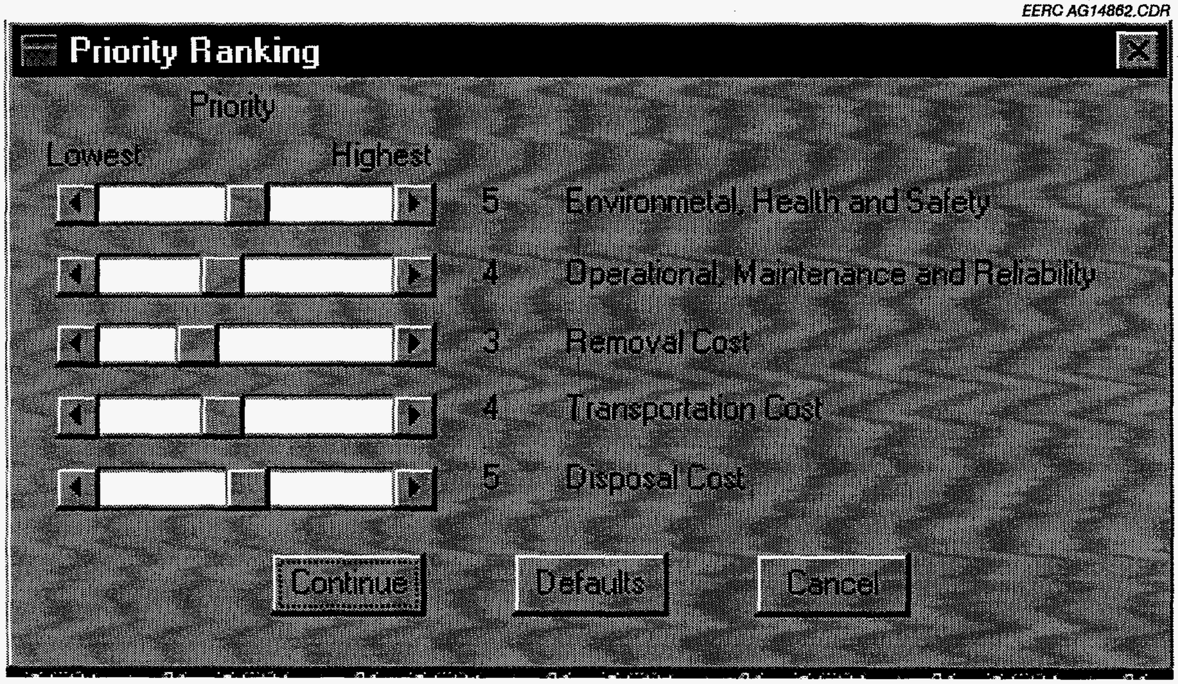

Figure E11. Priority Ranking user input.