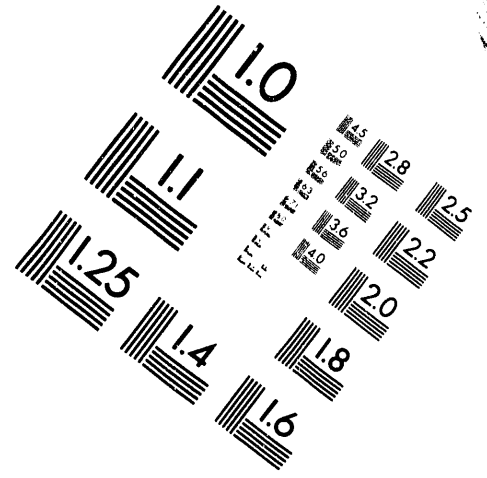
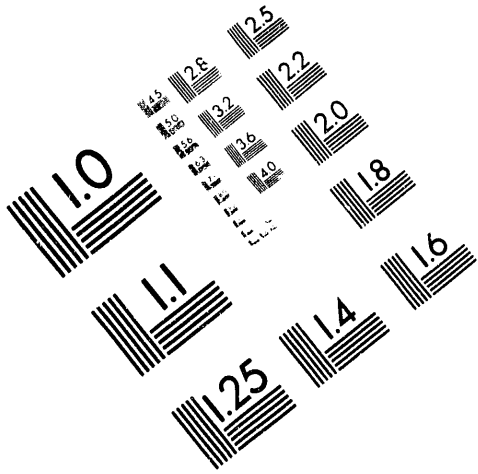




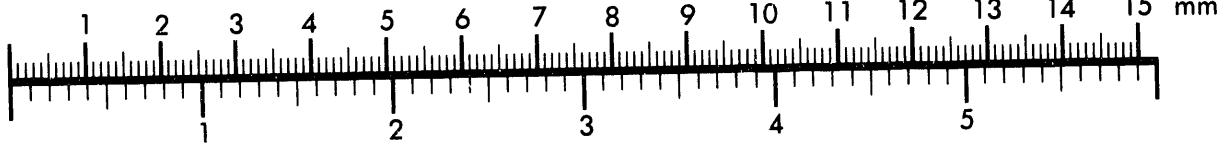
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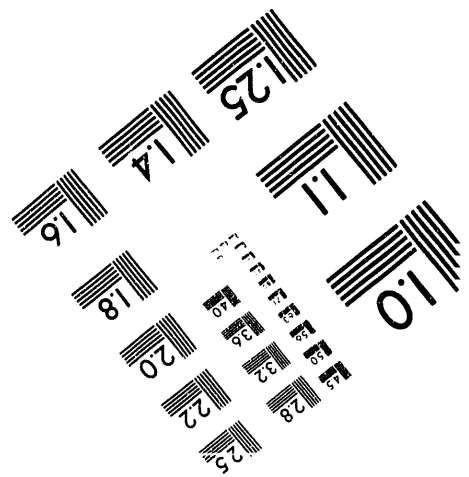
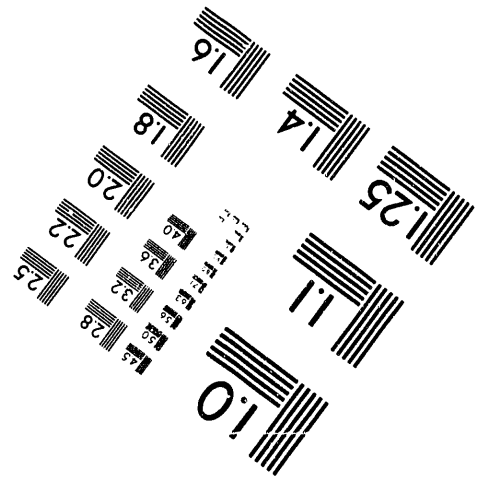
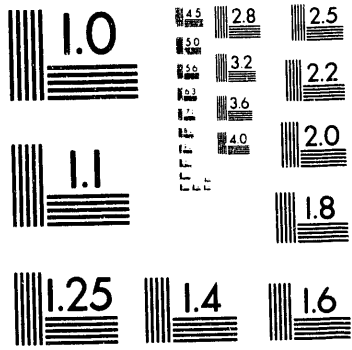
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An Innovative Approach to Multimedia Waste Reduction Measuring Performance for Environmental Cleanup Programs

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ABSTRACT

One of the greatest challenges we now face in environmental clean up is measuring the progress of minimizing multimedia transfer releases and achieving waste reduction. Briefly, multimedia transfer refers to the air, land, and water where pollution is not just controlled, concentrated, and moved from one media to another. An example of multimedia transfer would be heavy metals in waste water sludges moved from water to land disposal. Over two billion dollars has been budgeted for environmental restoration site cleanups by the Department of Energy for fiscal year 1994. Unless we reduce the huge waste volumes projected to be generated in the near future, then we will devote more and more resources to manage and dispose of these wastes.

To minimize multimedia transfers and reduce waste for significant amounts of contaminated soil, sediments, and groundwater, two things have to happen:

1. We need to develop a better understanding of how to collect good trend data from various phase projects that reduce waste and releases.
2. We also need to evaluate how successful the trend data is by some quantitative measurement of each generator's ability to prevent or minimize waste thus establishing performance measures.

Reliable data that exhibits where and how much waste is reduced would aid the cause for pollution prevention. It would provide trend data to show generators, managers, and regulators where promotion of pollution prevention is needed most. It would show where to focus our efforts, taking into consideration factors such as potential exposure and public concerns. It would identify successful pollution prevention projects that would be prioritized for technology transfer. The data will establish the basis for establishing performance measures for individual generators and programs.

Unfortunately, there are several constraints in collecting good data for environmental clean up programs. Some of the reasons for the lack of good data are:

1. Many environmental clean up programs are in the start-up to infancy stages.
2. Published sources of information on source reduction and recycling technologies for remediation programs are limited. Source reduction is hard to quantify, because when you stop generating waste, it isn't around to measure.
3. The ability to quantify pollution prevention is simpler with facility manufacturing with a product than for the decontamination of a manufacturing facility with a history of several waste streams. No historical rate production data can be applied.
4. There are multiple sites, multiple programs, and many players. Project schedules and targets are uncertain which makes it difficult to project a waste baseline.
5. Published guidance from the Department of Energy (i.e. goal setting, waste assessments) was not designed for remediation implementation.

When you combine these constraints to getting good data with the Environmental Protection Agency enforcement measures of multimedia specific requirements via the integrated permit, waste reduction becomes a monumental task. An integrated permit coordinates various media specific requirements for releases to air, water, and land to minimize cross medial transfers of pollutants. Such a permit would be based on an assessment of all releases from that plant. It becomes apparent that environmental clean up activities have a high potential for varied releases from all media placing even more emphasis on collecting good trend data.

To meet this challenge, Martin Marietta Energy Systems Oak Ridge Environmental Restoration (ER) Program has explored the value of a multimedia approach by designing an innovative Pollution Prevention Life Cycle Model. The model consists of several fundamental elements (Figure 1) and addresses the two major objectives of data gathering and establishing performance measures. Since the majority of projects are in the Remedial Investigation

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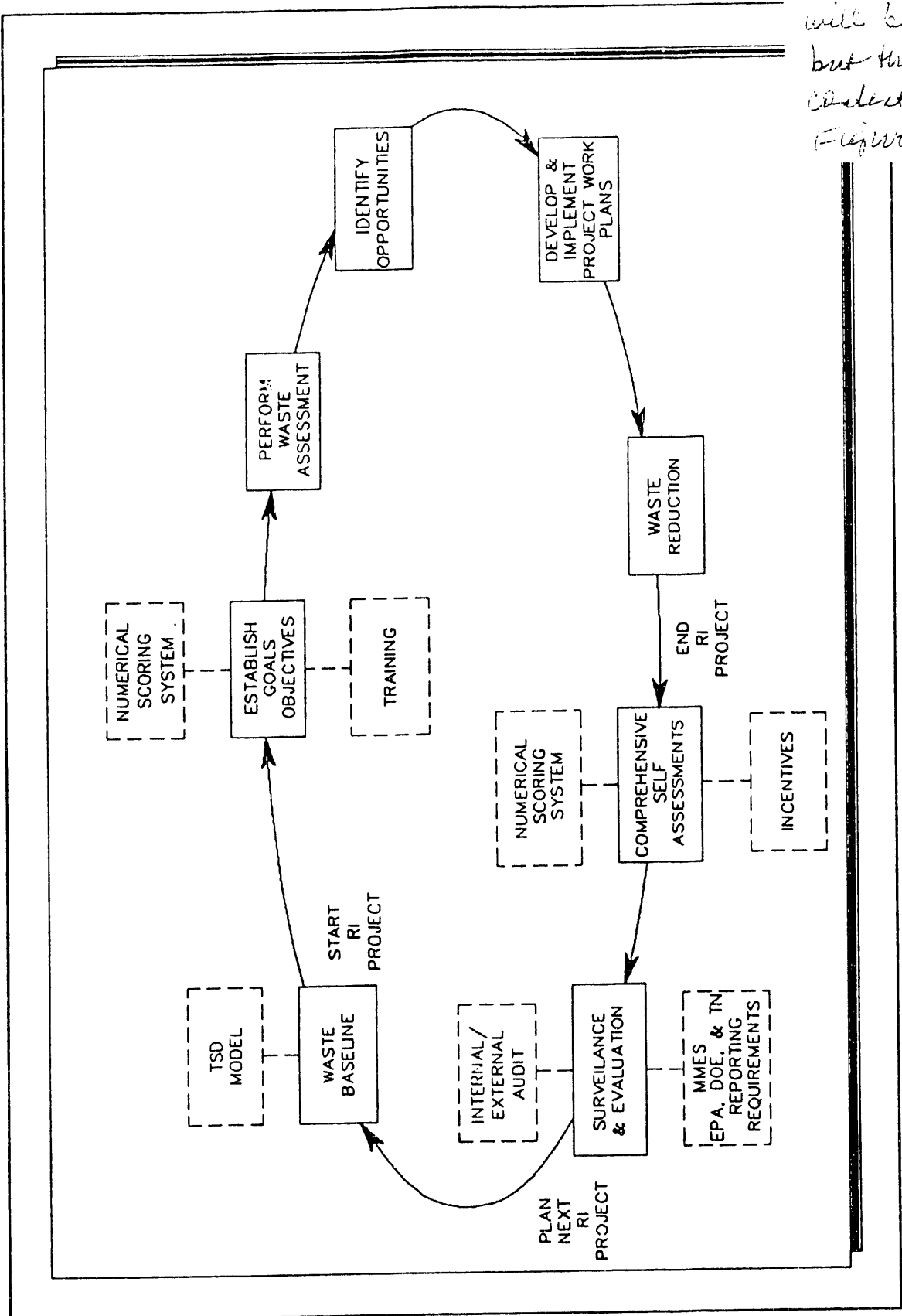


Figure ES-1 Pollution Prevention Life Cycle Model

phase the focus is on the prevention of unnecessary generation of Investigation Derived Waste and multimedia transfers at the source. A state-of-the-art tool developed to support the life cycle model for meeting these objectives is the Numerical Scoring System which is a computerized, user friendly information management data base system designed to measure the effectiveness of the pollution prevention activities in each phase of the Environmental Restoration Program.

The paper discusses the development of the Pollution Prevention Program Life Cycle Model and the role the Numerical Scoring System will play in the pollution prevention programs in the remedial investigation phase of the Environmental Restoration program at Martin Marietta Energy Systems facilities.

INTRODUCTION

The Martin Marietta Energy Systems Oak Ridge Environmental Restoration (ER) program located at Oak Ridge, Tennessee, Paducah, Kentucky, and Piketon, Ohio is conducting remedial action and decommissioning and decontamination activities. Among the ER Program activities that will generate wastes are site characterization studies, removal of contaminated soil, sediments, and structures, groundwater remediation, and treatability studies. In general, the magnitude of expected ER Program waste-generation activities is enormous, with over 1.1 billion cubic feet of waste estimated over the lifetime of the ER Program. Both the solid and liquid waste totals represent waste management activities equivalent to or greater than the existing operating plants' waste management programs. The most significant contributing factors to this large volume of waste are the assumed use of groundwater collection and treatment options and the expected demand for excavation of contaminated soils and sediments from a number of large area sites/projects. Therefore, the benefits that can be derived from implementation of an effective pollution prevention program early in the process are obvious.

In response to the regulatory issues and economic considerations, ER management wishes to be proactive in the performance of pollution prevention policies in the Energy Systems programs to decontaminate former waste sites, manage wastes generated, and minimize the risk to human health and the environment. The ER Program established a formal pollution prevention program in March 1991. The program mission is to implement and integrate pollution prevention into the Remedial Action (RA) and Decontamination & Decommission (D&D) site program activities. Success of the mission will result in the reduction of volume and/or hazard level of the waste generated.

BACKGROUND

Clearly, to understand and appreciate innovation in multimedia waste reduction performance measurement for site cleanups, we need to determine what, if any, pollution prevention techniques were in use throughout the Department of Energy including private industry.

The ER Program performed a literature search to determine what performance measurement techniques for pollution prevention are being used in the United States and their potential application to ER activities at Oak Ridge. Sites from Department of Energy (DOE) Complex along with Private Vendors were contacted and solicited for information about their pollution prevention measurement techniques. Various other sources were also contacted for any information that they may have had on this subject.

It was determined that there are, on average, three common methods to measure pollution prevention: comparison of volume produced to a baseline established or previous volume produced; comparison of the weight of the waste to an established baseline or previous weight measured; and a measure of the cost benefit that the pollution prevention has produced. Both in the literature search performed, and in the numerous telephone contacts conducted, it was found that well established performance measures, for pollution prevention in the ER activities, are very hard to find. Major obstacles for developing ER Program pollution prevention performance measures include: variability and uncertainty in waste generation data, numerous and varying waste streams, and a lack of life cycle cost data.

Due to the obstacles found in implementing the three common performance measurements identified in this report, it was recommended that the ER Program establish a performance measure which is not solely dependant upon volume, weight, or cost since these common measures have significant variance and uncertainty in remedial actions and decontamination and decommissioning activities.

The Pollution Prevention Performance Measure Project was undertaken to examine pollution prevention programs across the United States and determine if an accurate and feasible method for measuring pollution prevention existed that would be applicable to the ER Program at Oak Ridge. The scope of this project included site in the DOE complex and conventional hazardous waste generators in the private vending sector.

In order to become more familiar with the subject of pollution prevention, materials from the Oak Ridge National Laboratory (ORNL) library were accumulated and reviewed. A list of Waste Minimization contacts for the DOE Complex was obtained from the Hazards Waste Remedial Action Program (HAZWRAP) and a list of private vendors was acquired from the EPA. After these materials were analyzed, a comprehensive effort was taken to contact as many people, in the six week time-frame, as possible.

In preparation for this project, much material was gathered that contained listings of various contacts both in the DOE Complex and the private vending sector. Table 1 presents in a matrical listing the sites contacted and the information acquired.

Some of the problems associated with the measurement of pollution prevention will be listed and discussed. This list is by no means comprehensive, but it does give a good picture of the general problems facing the pollution prevention measurement area.

- Lack of available data. There is not a system for measurement of pollution prevention for those generators that have sporadic generation rates. Strictly volume and weight measurement yield unreliable results.
- Lack of Motivation or Incentive. Some people do not understand the necessity of quantifying pollution prevention. Those facilities that have highly motivated people in the waste minimization area are experiencing favorable results, and are more likely to develop new technology for measuring pollution prevention.
- Very small quantities. Some of the labs contacted expressed this particular problem. It's hard to minimize something that's already small, and sometimes in the process of trying to minimize the waste to avoid pollution, more waste is generated.
- Very large quantities. The Praair Company that was contacted expressed this problem. In large waste treatment systems, there are chemical reactions and evaporation of constituents which in turn make it difficult to account for the pollution prevented.
- A large number of waste streams. With a large number of waste streams, the time and effort involved must be divided between the wastes. Therefore, some waste streams will go unminimized and unmeasured.
- Inadequate funding. In order for a waste minimization plan to be successful, adequate funding must be provided. With the funds being divided among different projects, it is difficult to be able to afford to accurately measure pollution prevention.
- Unknown quantity of originating material. This was another problem of the labs. With poor procurement strategies and inventory control, the amount of incoming material cannot accurately be accounted for. Therefore, the waste that is minimized cannot be precisely measured.
- Lack of life cycle cost data. In general, DOE facilities have not established life cycle cost data for their waste streams, which inhibits the development of a cost benefit related performance measure.

The Oak Ridge ER Program is designing an innovative Pollution Prevention Program Life Cycle Model for measuring the effectiveness of management and implementation of site-wide pollution prevention programs. The model consists of several fundamental elements (Figure 1) and addresses two major objectives. The first objective is to develop pollution prevention/waste minimization techniques that focus on Investigative Derived Wastes (IDW) from Remedial Investigation (RI) activities. To meet this objective, data is collected to determine what deficiencies

Table 1 Sites Contacted

DOE Sites and Private Vendors	Measure by Volume	Measure by Weight	Other Method of Measurement
<u>ALBUQUERQUE FIELD OFFICE</u>			
Kansas City Plant	Yes	No	No
Pantex Plant	Yes	Yes	No
Sandia National Lab. Livermore	Yes	Yes	No
<u>CHICAGO FIELD OFFICE</u>			
Battelle Columbus Laboratories	Yes	No	No
Combined Laboratories	*	*	*
<u>FERNALD SITE OFFICE</u>			
Feed Materials Production Center	Yes	No	No
<u>IDAHO FIELD OFFICE</u>			
Grand Junction Project Office	Yes	No	No
Idaho National Engineering Lab.	Yes	Yes	No
West Valley Demonstration Project Office	Yes	Yes	No
<u>NEVADA FIELD OFFICE</u>			
Nevada Test Site	Yes	Yes	Yes. A cost benefit is sometimes used.
<u>OAK RIDGE FIELD OFFICE</u>			
K-25 Site	Yes	Yes	Yes. A cost benefit and a cost avoidance are sometimes used.
Oak Ridge National Lab.	Yes	Yes	Yes. A cost benefit and cost avoidance are sometimes used.
Y-12 Plant	Yes	Yes	No
<u>RICHLAND FIELD OFFICE</u>			
Hanford Site Office	Yes	Yes	Yes. Sometimes a cost benefit and cost avoidance are used.
<u>ROCKY FLATS FIELD OFFICE</u>			
Rocky Flats Site Office	Yes	No	No

Table 1 Sites Contacted (contd.)

SAN FRANCISCO FIELD OFFICE

Stanford Linear Accelerator Center	No	Yes	No
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SAVANNAH RIVER FIELD OFFICE

Savannah River Site Office	Yes	Yes	Yes. Sometimes a cost benefit and cost avoidance are used.
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PRIVATE VENDORS

International Remediation Corporation	*	*	*
Groundwater Technology Inc.	*	*	*
Geo-Microbial Technologies, Inc.	Yes	Yes	Yes. Sometimes a cost benefit analysis is used.
3-M Corporation	Yes	No	No
Remediation Technologies	*	*	*
Biogee International, Inc.	No	No	Yes. Levels of contamination before and after treatment.
Ensite, Inc.	*	*	*
CTC	Yes	No	No
Bryson Industrial Services	*	*	*
OHM Corporation	Yes	No	Yes. Sometimes a cost benefit analysis is used.
Riedel Environmental Technologies	*	*	*
Dix & Associated Hazardous Materials Corp.	*	*	*
Delta Environmental	*	*	*
Praxair	No	No	Yes. Calculations regarding evaporated waste are used.
Horsehead Resource & Development Co., Inc.	No	Yes	No

NOTE: Vendors and site that have the "*" symbol in all categories do not prescribe to either volume or weight, but establish their measurement plan according to each site's specifics.

exist in the pollution prevention/waste minimization program, and guidelines are introduced in the form of a checklist to the generators so the concept of pollution prevention will originate during the planning stages of the RI. The second objective would then be to evaluate the success of implementing pollution prevention techniques early in the RI phase by some quantitative measurement of each generator's ability to prevent and/or minimize IDW. Comparisons could then be made throughout the various ER program sites, and incentive awards given to those with the highest scores during self assessment. A state-of-the-art tool developed for meeting these objectives is a Numerical Scoring System (NSS) which is a computerized, user-friendly information management database system designed to measure the effectiveness of the pollution prevention activities in each phase of the ER program. The NSS will enable waste generators to establish performance measures and set numerical goals for pollution prevention; and will provide the waste generator/manager a guide for implementation for pollution prevention techniques for all projects. The NSS is a checklist approach to the development and integration of all the elements in the Program Prevention Life Cycle model. When incorporated in the planning stage of a project, will become a powerful tool in the prevention of unnecessary IDW at the generation source as well as minimizing multimedia transfers.

POLLUTION PREVENTION LIFE CYCLE MODEL

The pollution prevention program is a cyclic process with the objective to continue to improve on previous results. The initial stage in the pollution prevention program requires assurances that pollution prevention plans are in place and that the development of a waste stream baseline has been initiated. The waste stream baseline involves determinations of types of waste, volumes, toxicity, and other information for the various waste streams that will be generated. The establishment of the waste stream baseline is usually supported by a computer data base. In the early stages of the model, a life cycle approach has been integrated in the planning stages. By life cycle costs, we mean all costs associated with managing, treating, and disposing of any wastes or contaminants. These life cycle costs are housed in a computer data base. By utilizing the NSS, waste generators train themselves in what pollution prevention techniques to use as well as establishing goals and objectives. Next, opportunities identified during the waste assessment are then documented in the RI work plan. This is a very important step in the life cycle because it is the only mechanism to assure that subcontractors performing RI work implement waste reduction techniques. The NSS is then utilized again to establish opportunities to minimize waste generation. Examples of opportunities for waste minimization during the typical RI include:

- obtaining information through non-invasive techniques;
- reducing the number and size of bore holes;
- recycling decontamination water;
- reusing personal protective equipment (PPE);
- optimizing monitor well locations; and
- implementing groundwater sampling procedures which minimize the volume of purge water.

The strengths and weaknesses of a pollution program are identified during the waste assessment stage. Strengths can include a well conceived pollution prevention plan and a strong management commitment to minimize waste production, thereby reducing the volume of waste generated during site investigations. Weaknesses may include insufficient attention to planning and failure to effectively implement the pollution prevention techniques in the field. The RI work plan is then compared to a generator checklist to make sure D&D pollution prevention techniques are listed. The work plan is then implemented in the field by the subcontractor. After the RI project has been completed, the self-assessment program will determine whether the reduction techniques employed are sufficient to meet the program goals by confirming actual versus planned estimates of production. These estimates can be further verified by program audits. This information can be used to update the waste baseline. This life cycle of self-assessment and baseline updating is shown in Figure 1 for those generators with the highest scores. A formal, documented assessment program to monitor the pollution prevention activities is considered an essential element of a successful pollution prevention program.

The assessment system developed to support the waste minimization program for the ER program is the NSS. The NSS can be effectively used to establish goals and objectives. The NSS also monitors and ranks the pollution prevention activities.

NUMERICAL SCORING SYSTEM

The NSS is a computerized user-friendly information management system consisting of two tiers. The first tier is the database portion of the system, which is designed to maintain baseline data for the pollution prevention program. The data is collected from input from waste generators. The database contains the facility-specific information and lists the waste generating activities. The facility-specific information includes hazard characterization, regulatory status, volume, and project management costs for the various wastes at the subject facility. The waste generating activities information includes the type and volume of wastes from these activities, the distribution of these wastes by regulatory status, and total costs.

The second tier includes the system of algorithms for computation of the individual indices, and the composite indices for all the waste streams. These indices are designed to measure the effectiveness of different areas in the ER program such as pollution prevention general practice, waste volume reduction, cost and pollution prevention hierarchy. The system design allows revision of the algorithm parameters as data is assembled from implementation of pollution prevention techniques developed in the ER program. The input information tier consists of specific waste streams, waste minimization techniques implemented, volumetric reductions achieved, and cost information. The output from this tier consists of the generator evaluation score (GES), a volume reduction index, a cost/benefit index, and a relative ranking index.

Development for Pollution Prevention Techniques on IDW for RI

A planning checklist was developed to identify elements which should be considered for pollution prevention in the ER Program. The checklist questions are divided into two sections. The first section consists of general questions that apply to every phase of the program. These questions will be developed from the combination of the required elements in the pollution prevention program and the elements of the Nuclear Quality Assurance (NQA-1) that are relevant to waste minimization.

- Does the waste generator have a pollution prevention plan incorporated in the RI work plan?
- Is the Area of Contamination (AOC) clearly defined?
- Are the contaminants identified?
- What are the levels of contaminants?
- What waste streams will be generated?

After completing the assembly of general information, the waste generator is presented a set of examples of remediation initiatives from which the waste generator picks the example that best illustrates the project of interest. The waste generator is then asked a series of yes or no questions dealing with specific elements of their pollution prevention program.

The second set of questions are phase specific and are developed from waste reduction techniques for specific waste streams associated with the RI phase. These streams include soils, sediments, sludges, groundwater, decon liquids, and personal protective equipment (PPE). These questions are primarily used to collect waste stream data, and will be used to determine the total numerical score for the waste generator. The main purpose for these questions is to encourage the waste generator to use the checklist to properly plan the project, and to select appropriate pollution prevention techniques during the planning effort.

The waste stream questions were put into the EPA Data Quality Objectives (DQO) format to facilitate compliance with regulatory reporting requirements.

Development of Pollution Prevention Techniques on IDW for FS, D&D, and S&M

As has been done previously for the RI phase, NSS questions will also be developed to evaluate the pollution prevention plans for ER Program Feasibility Study (FS), D&D, and Surveillance & Maintenance (S&M) activities.

Questions in these new checklists will be divided into two sections. The first section will consist of general questions that apply to all phases of the ER program. These questions will be based on the required elements in the ER pollution prevention program, and those elements of (NQA-1) that are relevant to pollution prevention. The second section will be the phase-waste stream specific section. These set of questions will be developed from the from waste reduction techniques specifically used for different types of waste streams, and will be specifically designed specifically for FS, S&M, and D&D program activities.

Evaluation of the Effectiveness of Pollution Prevention Activities

Presently, the evaluation of the pollution prevention activities for the ER program is focused only on the RI projects in fiscal years 1993-1994 at the following DOE facilities: the Y-12 Plant, the K-25 Site, the Oak Ridge National Laboratory, the Paducah Gaseous Diffusion Plant, and the Portsmouth Gaseous Diffusion Plant.

Generator Evaluation Scores (GES), Volume Reduction Indices, Cost/Benefit Indices, and Relative Ranking Indices, as described in the following sections, are being used to evaluate various aspects of pollution prevention activities specific to the RI projects at these facilities.

Generator Evaluation Score (GES)

The GES component of the NSS system is an interactive, screen-based questionnaire derived from applicable NQA-1 elements, DQO's, and successful pollution prevention programs. The questionnaire is designed to provide guidance to the user concerning incorporation of the necessary waste reduction elements during the implementation of projects. This component of the system will consist of a set of inquiries derived from the 18 elements of NQA-1 and EPA's eight elements. Figure 2 is an illustration of the correlation of waste minimization program requirements and those NQA-1 elements applicable to the ER Program phases.

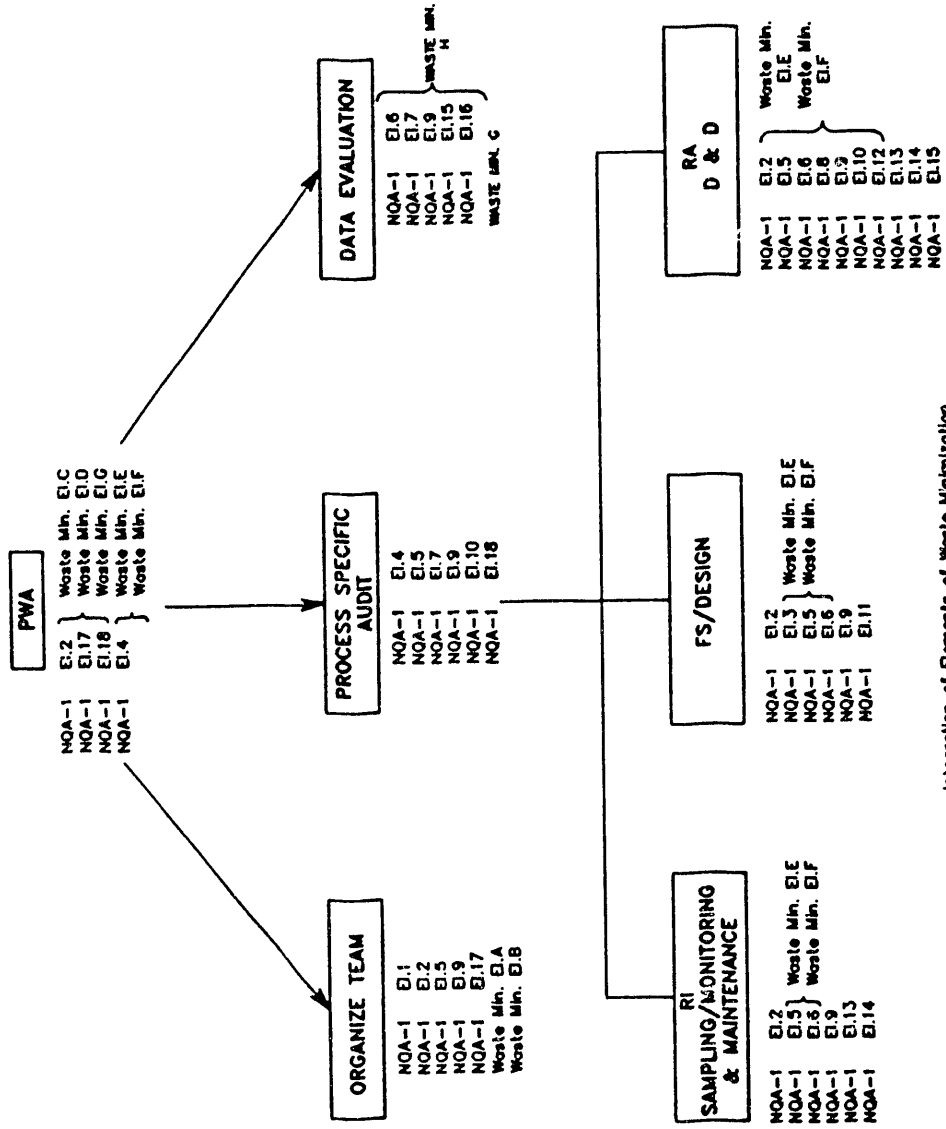
Volume Reduction Index

The volume reduction index is intended to measure the effectiveness of the waste generator's efforts to achieve significant volume reduction. A numerical index "S" is defined as the effectiveness of the pollution prevention efforts for volume reduction. The value of S is determined through a comparison of the actual volume reduction achieved to the potential reduction that could be achieved. For a given waste stream j, the mathematical representation of S_j is:

$$S_j = \frac{A_j}{R_j} \quad (1)$$

S_j is a numerical index that measures the effectiveness of waste minimization effort as related to volume reduction for waste stream j. A_j is the actual volume reduction index for waste stream j (details of this index will be described in later sections). R_j is the potential reduction index for waste stream j (details of this index will be described in later sections).

It is likely that, during early implementation of the NSS, cases will occur in which the value of the ratio will exceed 1.0 due to techniques or gains not considered in the initial development stage. Therefore, data concerning these situations will be used to interactively refine the parameters used to calculate the potential reduction index.



Integration of Elements of Waste Minimization and NOA-1 Elements into the PWA Activities

Elements of Waste Minimization

- A. Top Management Support
- B. Waste Minimization and Pollution Prevention Awareness
- C. Explicit Program Scope, Objectives and Numerical Goals
- D. Periodic Waste Minimization Assessments/Audits
- E. Accurate Cost Accounting
- F. Accurate Waste Accounting
- G. Technology Transfer
- H. Program Evaluation

NOA-1 Requirements

- 1. Organization
- 2. Quality Assurance Program
- 3. Design Control
- 4. Procurement Document Control
- 5. Instructions, Procedures, and Drawings
- 6. Document Control
- 7. Control of Purchased Items and Services
- 8. Identification and Control of Items
- 9. Control of Process
- 10. Inspection
- 11. Test Control
- 12. Control of Measuring and Test Equipment
- 13. Handling, Storage, and Shipping
- 14. Inspection, Test, and Operating Status
- 15. Control of Nonconforming Items
- 16. Corrective Action
- 17. Quality Assurance Records
- 18. Audits

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Fig. 2.2. Relationship of NOA-1 and PWA Elements Used as Organization Basis for GES Dev

The actual volume reduction index, A_j , is the ratio of the actual volume reduction achieved by the implementation of waste minimization techniques to the total volume that would have resulted without waste minimization efforts. This is mathematically represented as follows:

$$A_j = 10 \times \frac{(V_{jp} - V_{ja})}{V_{jp}} \quad (2)$$

V_{jp} is the volume of waste stream j that would be generated without implementing any waste minimization techniques. V_{ja} is the volume of waste with the implementation of waste minimization efforts. A_j is the volume reduction index for waste stream j , which would have a value in the range of 0 to 10.

The potential reduction index, R_j is designed to measure the theoretical volume or toxicity reduction achieved by a given waste minimization technique. The potential reduction index, r_{ij} , for a waste stream j and reduction technique i is:

$$r_{ij} = \frac{e_{ij} \times P_{ij}}{10} \quad (3)$$

r_{ij} is the reduction index for waste stream j using the reduction technique i (maximum value of 10). The value e_{ij} is the effectiveness of reduction technique i on waste stream j (range of 0 to 10). P_{ij} is an adjusted value of the probability of reduction technique i being implemented for waste stream j (range of 0 to 10).

Estimation of the effectiveness and probability parameters will be developed for each target waste stream and reduction technique by a combination of literature search and best engineering judgment.

After determination of the potential reduction index for each waste stream and reduction technique combination, the composite potential reduction index, R_j for waste stream j will be calculated. It is considered unlikely that the entire range of reduction techniques could be applied to a given waste stream. Therefore, the composite reduction index for the waste stream will be based on only those techniques that are considered to be most favorable.

Cost Benefit Index

The cost benefit index provides a cost benefit factor that will enable the waste generator to assess the economic effectiveness of a particular waste minimization technique. The cost benefit index is the ratio of overall cost saving from implementation of waste minimization to the overall cost of managing the waste without minimization efforts. This cost benefit index for a waste stream j can be represented as follows:

$$C_{ja} = \frac{C_j - C_{jm}}{C_j} \quad (4)$$

C_{ja} is the cost benefit index for waste stream j (maximum value of 1). C_j is the overall cost of managing the waste without waste minimization. C_{jm} is the cost of managing the waste with minimization of waste stream j .

Equation (4) above is the fundamental equation of the cost benefit index. The actual cost benefit index equations which have been expanded from equation (4) to include all cost factors that are relevant to the pollution prevention activities are too complex to present in this paper.

Relative Ranking Index

The relative ranking index is a measure of the desirability of the implemented minimization efforts relative to the pollution prevention hierarchy. The relative ranking index for a given technique and waste stream may be defined by the pollution prevention hierarchy (Z_{ij}) factor in conjunction with the effectiveness factor (e_{ij}) as represented by the following equation:

$$h_{ij} = \frac{e_{ij} Z_{ij}}{10} \quad (5)$$

The value e_{ij} is the effectiveness of reduction technique i on waste stream j (maximum value of 10). Z_{ij} is the pollution prevention hierarchy of reduction technique i being implemented for waste stream j (value range from 0 to 10). The parameter h_{ij} is the relative ranking index of reduction technique i on waste stream j (value range from 0 to 10).

The pollution prevention hierarchy, Z_{ij} will be developed for each target waste stream and reduction technique by using best engineering judgment coupled with a relative ranking of the waste minimization technique. The pollution prevention hierarchy may generally be assigned in the following order:

- procedural alterations,
- material substitutions,
- process elimination,
- technology alteration,
- direct reuse,
- reclamation, and
- end of pipe treatment.

The composite relative ranking index for each target waste stream, H_j will be defined as the sum of the equation (5) products of the effectiveness and position parameters for each of the reduction techniques.

Future Scoring Mechanism

A periodic re-evaluation of the pollution prevention activities in the ER Program will be very beneficial. It will not only give a better picture of how well each individual generator and the overall program are doing but will also facilitate the feedback of the necessary information to the NSS which is, by nature, a dynamic process.

Some indices, such as Volume Reduction Index and Relative Ranking Index, will greatly benefit from a frequent reevaluation, since these indices are designed for a long term self-refinement. Parameters used in the calculations will need a series of iterations to improve accuracy. The cost benefit evaluation will also improve with the maturity of the pollution prevention activities in the ER Program. The break down in cost accounting will get better, and in turn, more detailed cost information will become available. This will result in a more accurate definition of the cost benefit index.

The waste generator will also be provided with outputs for documentation of all performance indices that include their GES answers, volume, cost benefit, and relative ranking.

Scoring for FS, D&D, and S&M Phase

The initial stage of development of the FS, D&D, and S&M checklist questionnaires has just begun. The preliminary questionnaires will serve as the pilot stage of the evaluation of the pollution prevention activities in the FS, D&D, and S&M phases. Eventually, a full scale scoring mechanism will be developed to serve as an evaluation tool for waste generators in these phases. It is likely that the scoring mechanism and index already developed for

the RI phase in the NSS, with some adjustment to accommodate the different nature of FS, D&D, and S&M phases, will be used as an evaluation tool for these three phases.

RECOMMENDATIONS AND CONCLUSIONS

After reviewing the above information obtained in this project, it can be concluded that the area of multimedia waste reduction performance measurement is very complex. In observing sites in the DOE and various private vendors, it was discovered that most generators are trying to measure their waste reduction after the generation of the waste. This method could be called the "Norm" in the measurement of waste minimization, although it does not give accurate results in all cases, especially for remedial or restoration type activities.

Until accurate waste generation and life cycle cost data is available, it is concluded that use of common pollution prevention measures such as percentage goals for ER would not yield meaningful results. Since pollution prevention is a high priority due to regulatory drivers and costs benefits, it is logical to apply meaningful performance measures.

Therefore, in conclusion, a multimedia approach performance measures which accurately reflects pollution prevention to minimize multimedia transfers and reduce waste is essential to the ER program. One of the first steps in this approach is the application of the Pollution Prevention Life Cycle Model. The model which is based on a cyclic process, with the objective to collect trend data from the various phase projects to be measured. The next step is to utilize the NSS that scores a waste generator on how well they are implementing the best available methods to maximize their pollution prevention is recommended.

Although the NSS is in the premature stages of development, Energy Systems as well as other environmental cleanup sites will be able to realize the benefits of pollution prevention in every aspect of remedial action planning and project implementation. The benefits are as follows:

- Limited dollars will be needed to implement since personal computers are readily available,
- Performance indices for pollution prevention activities will be established,
- Cost savings result as waste generators train and assess themselves eliminating expensive PWAs and audit teams,
- Consistency and communication will be improved between top management, technical support, and waste generators,
- Reporting requirements are improved since all pollution prevention activities are documented by the NSS, and
- Healthy competition between site programs will be promoted as top performers are recognized through incentive programs.

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