WASTE MINIMIZATION IMPROVEMENTS ACHIEVED THROUGH SIX SIGMA ANALYSIS RESULT IN SIGNIFICANT COST SAVINGS

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ABSTRACT

Improved waste minimization practices at the Department of Energy's (DOE) Idaho National Engineering and Environmental Laboratory (INEEL) are leading to a 15% reduction in the generation of hazardous and radioactive waste. Bechtel, BWXT Idaho, LLC (BBWI), the prime management and operations contractor at the INEEL, applied the Six Sigma improvement process to the INEEL Waste Minimization Program to review existing processes and define opportunities for improvement. Our Six Sigma analysis team: composed of an executive champion, process owner, a black belt and yellow belt, and technical and business team members used this statistical based process approach to analyze work processes and produced ten recommendations for improvement. Recommendations ranged from waste generator financial accountability for newly generated waste to enhanced employee recognition programs for waste minimization efforts. These improvements have now been implemented to reduce waste generation rates and are producing positive results.

INTRODUCTION

The objective of this paper is to present how we applied the Six Sigma process to waste minimization at the INEEL, describe the specific recommendations for improvement, and review results to date. The information gained from our Six Sigma process improvement project can be used by both government and nongovernment waste generators to increase waste minimization effectiveness and reduce overall waste management costs.

NEED

Waste is defined as an error or defect and is a result of inefficiency. The more inefficient a process, the more waste it will produce; conversely, a highly efficient process will produce no waste at all. An integrated waste minimization program will be aligned with both the work planning and work execution processes to minimize inefficiencies and the associated waste generating processes, while presenting other alternatives for excess materials produced. Even in the DOE cleanup effort, where much of the waste was previously generated, waste minimization tools can be used to reduce final waste disposition toxicity and volume amounts.

Waste minimization is an important element to both the DOE Integrated Safety Management System (ISMS) and the International Standards Organization (ISO) 14001 Standard at the INEEL. The INEEL Environmental Management System (EMS) is designed to integrate waste minimization processes with environmental protection, environmental compliance, and continual improvement activities throughout all INEEL work areas. In 2001, BBWI implemented the Six Sigma process at the INEEL. To support this implementation, we completed a review of the five primary areas of the INEEL EMS to identify targets for improvement. The five primary areas included: (1) policy and requirements flow down, (2) waste minimization, (3) packaging and transportation, (4) environmental services, and (5) assessments, reporting, and certification. A fishbone diagram was used to capture the work elements in each of these areas, and is shown in Figure 1.

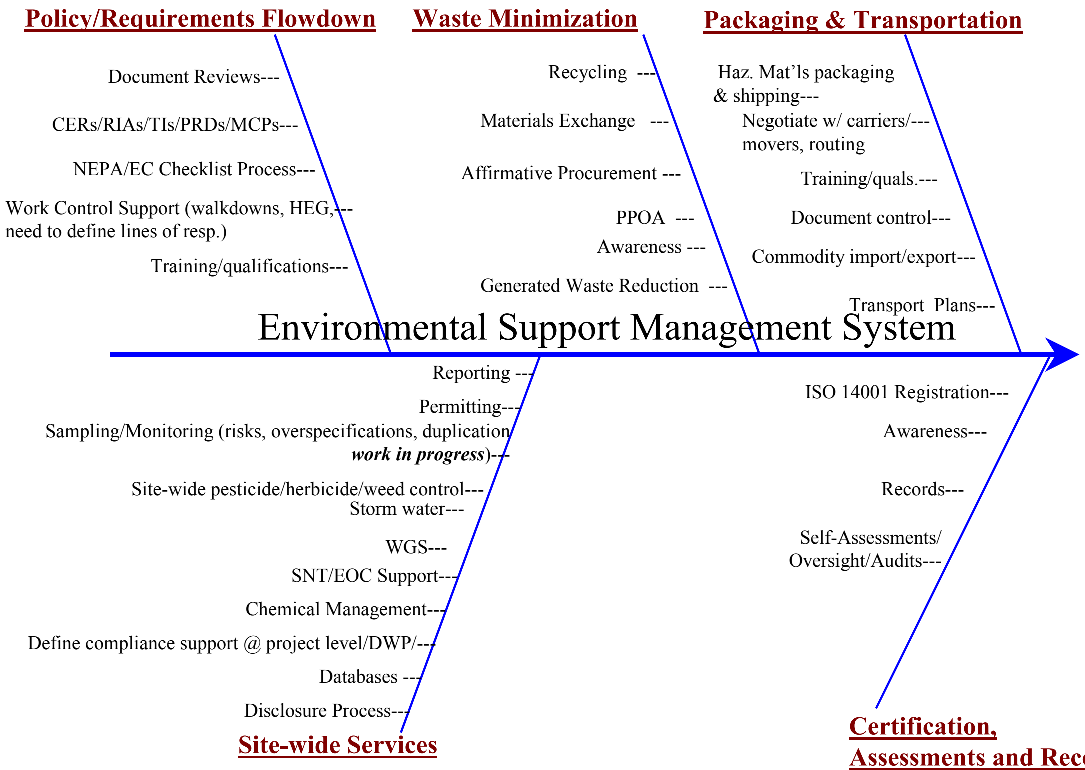

Fig. 1. Areas of INEEL EMS reviewed for improvement.

Our initial review of the waste minimization area determined that although some excellent elements existed; a fully integrated waste minimization program that focused on the reduction of newly generated waste did not appear to be in place. Due to the lack of an integrated program, waste generation rates and costs for characterizing, storing, treating, and disposing newly generated wastes were higher than necessary. Our analysis showed that in 2001, the INEEL generated approximately 186,900 cubic feet of hazardous, radioactive, and mixed waste costing approximately $8.2 million to disposition. This volume of waste and the resulting cost to disposition was estimated to be high based upon the INEEL waste types and Environmental Protection Agency and industry studies of waste minimization programs. Also missing were incentives for generators to reduce waste and waste generation feedback mechanisms including waste cost information that were not available to field personnel. Based upon this, a 15% waste generation reduction target was set. This established a reasonable objective for an enhanced waste minimization program at the INEEL.

The opportunity for significant costs savings combined with the strong ISMS and the ISO 14001 waste minimization objectives justified further review of the existing INEEL Waste Minimization Program and processes for other improvements using the Six Sigma process analysis tool.

SIX SIGMA ANALYSIS

The Six Sigma process, developed by the Motorola Corporation in 1986, has been used throughout the Bechtel Corporation as a process analysis and improvement tool. Six Sigma employs a standardized, statistical based, improvement approach to enhance work processes, eliminate product defects and errors, and increase overall product quality. The Six Sigma process is divided into five phases: (1) define, (2) measure, (3) analyze, (4) improve, and (5) control. It is important that these phases are properly sequenced to ensure that the process under review is fully understood prior to working on improvements. Six Sigma uses process flow mapping tools combined with statistical analysis methods to determine primary areas of inefficiencies and defects. For our process analysis, standard Six Sigma evaluation tools included the fishbone diagram, the "as-is" process flow diagram, X/Y input/output analysis, failure modes and effects analysis, primary and secondary metrics, and lastly, the "improved" process flow diagram.

Using the Six Sigma process, we first developed the fishbone diagram to identify the major activities associated with waste minimization discussed previously. From this we developed the as-is process flow diagram that mapped the existing waste minimization process from DOE authorization, to goal setting, through implementation, and concluding with monitoring and reporting. Ten primary waste minimization elements were identified are:

- Waste minimization goals
- Performance measurement
- Waste minimization reporting and feedback
- Pollution Prevention Opportunity Assessments
- Generate waste
- Waste minimization technical training
- Employee awareness programs
- Materials exchange for reuse
- Affirmative procurement
- Recycling and reuse.

Using the as-is flow diagram, key inputs and outputs were identified as part of an X/Y input/output analysis. For each of the functional inputs, the importance of the output is evaluated. This output is ranked with the other functional outputs, providing a tool to evaluate which inputs are the most important narrowing areas for additional review. Results of the X/Y analysis are shown in Figure 2.

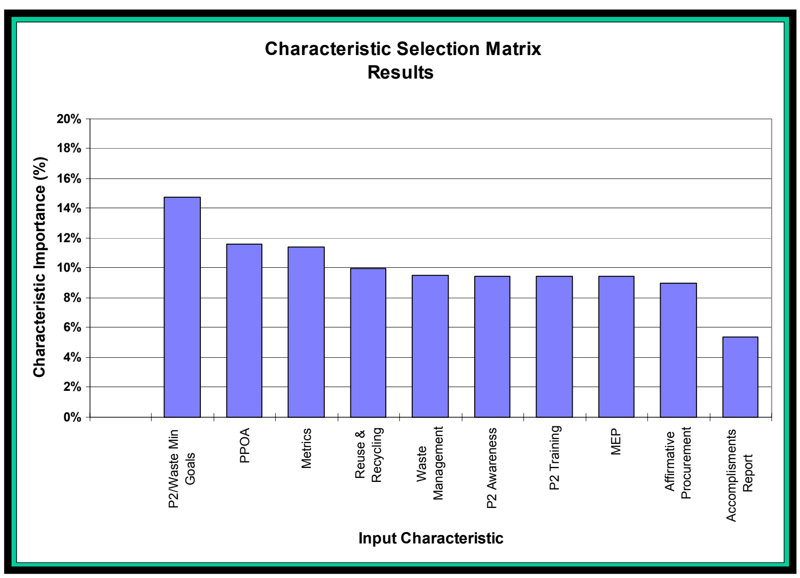

Fig. 2. X/Y input/output analysis used to determine area importance.

Although all of the input characteristics were evaluated for process deficiencies, we selected four process areas on which to perform a more complete failure mode effects analysis (FMEA). FMEA is a process used to determine the severity of consequences of failure. A portion of the FEMA analysis sheet is shown in Figure 3.

#	Process Function (Step)	Potential Failure Modes (process defects)	Potential Failure Effects (Y's)	SEV	Clas	Potential Causes of Failure (X's)	OCC	Current Process Controls	DET	RPN	Recommend Actions	Responsible Person & Target Date	Taken Actions	SEV	OCC	DET	RPN
1	Identify & select PPOA waste stream	select low value PPOA	no cost benefit	5		unclear selection criteria	9	none	10	450	develop & formalize selection criteria						
				5		poor understanding of WM cost	8	none	10	400	develop standard WM costs						
				5		selection team is inadequate	9	none	8	360	formalize evaluation board						
				5		focus is on completing PPOA--not reduce waste	8	none	9	360	change goal to waste reduced &/or $saved; change reporting to PPOA implemented						
				5		lack of generator awareness of PPOA process	5	none	9	225	N/A						
				5		tendency to focus on easy opportunities	9	none	10	450	change goal to waste reduced &/or $saved;change reporting to PPOA implemented						
###			missed opportunities	6		unclear selection criteria	9	none	10	540	develop & formalize selection criteria						
###				6		poor understanding of WM costs	9	none	10	540	develop standard WM costs						
				6		selection doesn't consider P2 goals	9	none	8	432	develop & formalize selection criteria						
				6		selection doesn't consider planned operations	9	EC	9	486	incorporate planned operations in P2 Plan & include in selection criteria						
				6		tendency to focus on easy opportunities	10	none	10	600	change goal to waste reduced &/or $saved;change reporting to PPOA implemented						
###		not implementable	wasted resources	7		no $s to implement	6	none	10	420	evaluate funding at front end of process;						
###				7		programmatic changing priorities	5	none	10	350	P2 plan & goals need to be revised to reflect current priorities						
###				7		cost/benefit doesn't pan out	4	none	10	280	N/A						
###				7		regulatory & procedural	4	none	10	280	N/A						
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Fig 3. FMEA used to determine failure consequence.

Process areas selected included: (1) waste minimization goals, (2) performance measurement, (3) pollution prevention opportunity assessments (PPOAs), and (4) material exchange. With the exception of material exchange, these had all been identified as the top areas in the X/Y analysis. Material exchange was selected because team members believed it to be dysfunctional. Overall FMEA scores ranged from a high of 630 to a low of 140. A high score indicates more severe consequences of failure. The first line in Figure 3, would be read as:

> *Because of unclear selection criteria for pollution prevention opportunity assessments, we have a risk of selecting low-value waste minimization opportunities with little cost benefit. We have no controls in place to prevent this, and to correct we need to develop and formalize selection criteria and perform selection through a more diverse committee.*

We performed this analysis for each failure mode for the process step.

From our failure mode effects analysis significant deficiencies were found. The following is a summary of our investigation results for each of the ten primary waste minimization elements.

1. Establish Goals and Targets – These are established by the Department of Energy, and are neither realistic nor relative to current INEEL cleanup operations. For instance, no consideration is provided for changes in work volume or for cleanup activities in meeting these goals. While environmental targets are established at the INEEL, waste minimization targets are not established at the facility or project level, and consequently, are meaningless to facility and project personnel who ultimately have the ability to meet the objectives. Waste reduction objectives are not prioritized; therefore, actions to reduce industrial waste become as important as actions to reduce mixed radioactive waste.

2. Performance Metrics – Metrics do not provide meaningful feedback to the facility working level. Waste generators do not have sufficient information on the types and volumes of wastes produced and the costs associated with the disposition of such waste.

3. Waste Minimization Accomplishments Reporting – Although reporting meets DOE-HQ customer needs, meaningful reporting is not provided to appropriate INEEL personnel (e.g., waste generators).

4. Identify Pollution Prevention Opportunity Assessments (PPOA) – Two problem areas were identified. First, the selection process for PPOAs is not lined up with waste minimization objectives. Second, once PPOAs are performed the waste generator is responsible to implement the solution within their budget. Often times there is no budget available for implementation.

5. Waste Generation – Because waste treatment and disposal costs for low-level and mixed waste are program funded through the Environmental Management's Waste Management Program at the INEEL, the waste generator has little financial incentive to reduce generation rates. Financial burden for waste disposition was a major driver in the Environmental Protection Agency's development of its waste minimization program. It was also noted that waste stream planning for effective waste minimization practices needs additional emphasis.

6. P2/Waste Min Training - Current employee training was judged as good.

7. P2/Waste Min Awareness – INEEL P2/Waste Min awareness activities for the most part go unnoticed.

8. Materials Exchange Program (MEP) - The INEEL MEP is difficult to use to obtain needed chemicals or dispose of excess chemicals. In addition, it is not mandatory to use the MEP prior to procuring new chemicals. The MEP has limited success in chemical turn-around and most materials are ultimately dispositioned as waste. Materials with higher volumes have a greater chance of use. The MEP is not tied to the INEEL chemical management system, and carries items other than chemicals and chemical products.

9. Affirmative Procurement – Affirmative procurement program was judged as good.

10. Reuse and Recycling – The INEEL has a strong recycling program, although the DOE Metal Recycling Moratorium limitations on metal recycling create a greater volume of waste at the INEEL.

In addition to the INEEL processes review, we performed a review of the best practices from waste minimization programs at several other DOE sites. DOE sites reviewed included Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), Lawrence Berkley Laboratory (LBL), and the Savannah River Site (SRS). Best practices were identified and were included as improvements in the FMEA and the Improved Process Flow Diagrams. Best practices identified are summarized as follows:

- Waste Minimization Investment Fee – Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL) and Los Alamos National Laboratory (LANL) established a tax on waste generation that was collected to fund waste minimization implementation activities such as PPOA recommendations and recycling initiatives. This was focused on the problem that generators may not have funds available to implement waste minimization field changes. This tax was approximately 5% of the waste servicing cost.

- Success Stories – Most sites reviewed kept a well written log of waste minimization success stories easily available to all employees through their website. This included results of PPOAs, and included volumes of waste reduced and costs saved. SRS, PNNL, and LANL did the best job of putting this information together. Some awards programs also had involvement from regulatory agencies.

- Waste Performance Reporting – Both LANL and the LBL had developed excellent waste volume reporting metrics. The metrics for LANL were by waste type and reported directly against goals. Goals were clearly stated for each stream. This information was available to all employees through the website. LBNL did a good job in reporting waste volumes by waste type per year measured against Department of Energy goals.

- Waste Minimization Committee - Most of the sites had an established waste minimization committee that led the direction and implementation of waste minimization initiatives. These committees were made up of organizations involved in waste generation and disposition. These committees managed the set-aside funds, awards programs, objectives, PPOAs, and technology transfer, and basically oversaw the waste minimization program at the site.

- Awards Programs –Several sites had waste minimization awards programs. LANL has an annual ceremony honoring both outstanding individual and team successes. SRS has a program where it selects a "pollution prevention hero" each quarter. These efforts are well publicized. Awards programs such as these provided not only recognition of significant contribution, but also provided incentive for others and demonstrated strong management commitment.

RECOMMENDATIONS FOR IMPROVEMENT

Based upon the Six Sigma analysis, we recommended ten specific improvements. These improvements ranged from establishing facility based waste generation objectives and measurement metrics to implementing waste generator financial accountability for all newly generated waste. The improvements recommended were:

1. Develop Facility-specific Waste Reduction Goals - Revise the INEEL waste minimization goals to be INEEL facility specific by waste type. The Waste Minimization Steering Committee shall review and approve goals. This shall then be incorporated into the BBWI detailed work plan.

2. Implement Waste Generator Financial Accountability - Implement a system whereby each INEEL waste generator will be responsible for the costs of waste characterization including sampling and analysis, packaging and transportation, temporary storage, waste treatment, and waste disposal for newly generated waste. Primary changes from the current system include waste generator financial accountability for the treatment and disposal of low-level waste and for treatment and disposal of mixed low-level waste. The INEEL will be one of the first sites in the DOE complex to employ a uniform financial accountability system for all newly generated hazardous and radioactive waste. Under this system, the waste generator has a strong financial incentive to reduce waste toxicity and volumes.

3. Establish Steering Committee - Charter a company integrated waste minimization steering committee to oversee waste minimization activities.

4. Establish Performance Measures - Provide volume metrics against the waste minimization goals, and provide facility-specific cost metrics based upon waste disposition costs. Have metrics easily available to all, not just management and the DOE customer.

5. Enhance PPOA Process - Formalize pollution prevention opportunity assessment selection criteria tied to goals and manage it under the waste minimization committee.

6. PPOA Fee Pool - Establish a waste minimization fee pool to support implementing pollution prevention opportunity assessment recommendations.

7. Performance Incentives - Establish stronger company performance incentives for waste reduction.

8. Realign Organization - Relocate the waste minimization function from environmental affairs to waste management to better align with waste generating processes.

9. Improve Materials Exchange – The materials exchange system must be reviewed prior to chemical or chemical product purchase. Also materials exchange should be integrated with the INEEL chemical management system. In addition, the materials exchange should be limited to chemicals and chemical products.

10. Enhance Employee Recognition - Reenergize pollution prevention/waste minimization employee awareness and recognition.

METRICS

Using the Six Sigma process, it is important to establish primary metrics to measure improved performance. These must be established prior to implementing improvements. We established two primary performance metrics and one secondary metric. These are summarized below.

- Primary Metric #1 – Newly generated waste volume broken down by waste type (hazardous, low-level, mixed, and industrial) will be measured. This measurement will be divided to INEEL site areas, and shall be collected for process waste and for clean-up waste. The INEEL Integrated Waste Tracking System will be used as the source data for these measures. This measurement system has been established.

- Primary Metric #2 – The cost per unit volume per for each waste type has been developed and validated through this evaluation effort and will be applied to waste volumes to measure total costs. Unit costs shall be revalidated annually.

- Secondary Metric #1 – The total INEEL budget shall be used for comparison against total waste disposition costs.

IMPLEMENTATION

We began implementing the Six Sigma recommendations for improvement in October of 2001. A schedule for implementation was established, and by October 2002 all recommendations were implemented with the exception of the PPOA opportunity fee pool; which was delayed until 2003 due to the other substantial financial changes being made. Waste generation results for fiscal year 2002 show decreases in all three categories of hazardous and radioactive waste. A comparison of the 2001 and 2002 waste generation volumes is provided in Table I. These decreases result in a cost savings of almost $1.5M exceeding initial projections. Additional performance data from FY2003 will better substantiate whether such savings can be achieved over the long run.

Table I. Comparison of 2001 and 2002 waste generation rates shows improvement.

Waste Type	FY2001	FY2002	%Reduction	Estimated Cost Saved
Low-level waste	4378 m3	3988 m3	8.90%	$106K
Hazardous Waste	411m3	250m3	39.20%	$387K
Mixed Waste	471m3	406m3	13.80%	$986K
				$1479K

CONCLUSIONS

Applying the Six Sigma process to the INEEL waste minimization process has yielded substantial recommendations for improvement. Six Sigma provided a standardized, systematic process to analyze our waste minimization process, and provided the analysis tools to quantitatively evaluate critical process areas. Recommendations resulting from the Six Sigma analysis have been implemented, and metrics are in place to measure their improvement.

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