INNOVATIVE TECHNOLOGY

Summary Report

DOE/EM-0596

Lumi-Scint Liquid Scintillation Counter

Deactivation and Decommissioning
Focus Area

Prepared for

U.S. Department of Energy
Office of Environmental Management
Office of Science and Technology

July 2001

INNOVATIVE TECHNOLOGY

Summary Report

Lumi-Scint Liquid Scintillation Counter

OST/TMS ID 2311

Deactivation and Decommissioning
Focus Area

Demonstrated at
Miamisburg Environmental Management Project
Miamisburg, Ohio

INNOVATIVE TECHNOLOGY
Summary Report

Purpose of this document

Innovative Technology Summary Reports are designed to provide potential users with the information they need to quickly determine if a technology would apply to a particular environmental management problem. They are also designed for readers who may recommend that a technology be considered by prospective users.

Each report describes a technology, system, or process that has been developed and tested with funding from DOE's Office of Science and Technology (OST). A report presents the full range of problems that a technology, system, or process will address and its advantages to the DOE cleanup in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. Innovative Technology Summary Reports are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

All published Innovative Technology Summary Reports are available on the OST website at www.em.doe.gov/ost under "Publications."

TABLE OF CONTENTS

SECTION 1
SUMMARY

Executive Summary

The conventional baseline methodology for analyzing swipes involves (a) taking the swipes in the field and (b) transporting the swipes to a centralized laboratory for counting. In many instances, the results of the analysis may take a considerable number of hours or even days depending on the workload on the laboratory technician and the number of samples already waiting to be analyzed.

The purpose of this demonstration was to determine if the centralized laboratory liquid scintillation counter (LSC) could be supplemented by the use of the portable Lumi-Scint LSC to provide a rapid quantitative tool for the field analysis of swipes. The Lumi-Scint 1000 LSC is a portable instrument designed for the rapid qualitative analysis of low-energy beta-emitting radionuclides. It has been proved accurate for counting swipes for tritium activity over a large range, starting at about 1000 dpm. The Lumi-Scint LSC eliminates the need for carrying samples to a centralized laboratory for counting because it can be carried to the area where the samples are being collected. Although the technology is not being recommended as a replacement to the existing baseline, the demonstration results show that the Lumi-Scint is cost-effective and faster for quick field swipe analysis. The Lumi-Scint has a capital cost of $7,930, and a unit cost (life-cycle) of $4.17/sample; whereas the baseline LSC has a capital cost of $35,000 and a unit cost (life-cycle) of $4.14/sample. A major benefit of this innovative technology is that results can be obtained at the work site without the necessity of transporting the collected swipes to a centralized laboratory for analysis.

Introduction

The United States Department of Energy (DOE) continually seeks safer and more cost-effective technologies for use in decontamination and decommissioning (D&D) of nuclear facilities. To this end, the Deactivation and Decommissioning Focus Area (DDFA) of the DOE's Office of Science and Technology (OST) sponsors Large-Scale Demonstration and Deployment Projects (LSDDPs). These LSDDPs are managed by DOE's National Energy Technology Laboratory (NETL). At these LSDDPs developers and vendors of improved or innovative technologies showcase products that are potentially beneficial to the DOE's projects and to others in the D&D community. Benefits sought include decreased health and safety risks to personnel and the environment, increased productivity, and decreased cost of operation.

The Miamisburg Environmental Management Project (MEMP) site is undergoing a transition from a DOE site to an industrial park. The site has many tritium-contaminated facilities to be decontaminated. There are high levels of tritium in process piping, equipment, and tanks; lower levels exist in gloveboxes and buildings and in contaminated soil and ground water under and around the buildings. A large number of tritium survey samples will be taken to ascertain contamination levels of building and equipment surfaces during this transition.

This report provides a comparative analysis of the cost and performance of the Lumi-Scint portable liquid scintillation counter (LSC) and the standard laboratory-based LSC (baseline technology). The Lumi-Scint LSC technology was demonstrated to determine if it can be used to supplement the baseline technology as a faster quantitative tool for the analysis of swipes by minimizing the need for transporting swipes to a centralized laboratory for analysis. Although this technology cannot replace the existing baseline, it can provide a time-efficient tool for field measurement.

Technology Summary

Baseline Technology Description

In the baseline laboratory LSC, the Radiological Control Technician (RCT) takes a paper swipe of a 100 square centimeter area and places this into a coin envelope. The sample number is recorded, and the sample is transported to a centralized laboratory for counting. In the laboratory, the technician counts the sample in a gas-proportional counter for alpha and beta activity. Upon completion, the swipes are then loaded into 7-milliliter vials in which 5 milliliters of a liquid scintillation cocktail is added. These vials are then loaded into the liquid scintillation counters for tritium analysis. When the sample count is completed, the RCT is contacted to return to the laboratory to review the results. After reviewing and documenting the results, the RCT contacts the appropriate project personnel for whom the samples were taken.

Lumi-Scint Technology Description

Unlike the baseline technology where the samples must be taken to the laboratory for analysis, the Lumi-Scint technology permits samples to be counted at the location where they are collected because the entire system is portable. The swipe collection methodology is identical to that of the baseline technology. The Lumi-Scint is capable of counting samples with activities up to 20,000,000 counts per minute (cpm). This capability is a result of optimization of the electronics to handle much higher counting rates.

In the Lumi-Scint LSC, a pulse train detected by the photo-multiplier tube (PMT) is transferred to the microprocessor, which controls all counting, logic, and computational processes. The manually operated sample chamber assembly can hold one vial at a time. Two interchangeable sample holders are provided with the unit.

RCTs collect swipes as in the baseline method. The swipe is put into a sample vial, and then scintillation cocktail is added to the vial. The tritium beta particles produce light photons in the scintillation cocktail. These light photons are converted into electrical pulses by the PMT in the LSC. These electrical pulses are registered as “counts” by the instrument. The number of light photons produced, and thus the resulting number of counts, is proportional to the tritium activity in the sample. The number of counts recorded by the LSC is converted to disintegrations per minute per 100 cm^2 for comparison to free release limits for equipment and areas. The authorized limit for free release of materials at Mound is 10,000 dpm/100 cm^2.

The Lumi-Scint LSC combines state-of-the-art luminescence counting with LSC counting in a compact instrument that provides quantitative information. It is designed to give accurate information in both LSC "mini-vial” and test tube formats and requires less than 1 square foot of bench space. With the optional battery pack, it can be carried into the field to provide on-site data.

Demonstration Summary

The demonstration was conducted from March through May 1999 in three phases. Each phase was conducted to collect data for analyzing its performance and cost-saving possibilities against the baseline technology. Each phase of the demonstration was successful in collecting sufficient data for comparing the results. Additional analytical procedures were added in order to determine hold times for each sample, consistency in measurement results, and acquiring additional data to reinforce the accuracy of performance.

The technology demonstration focused on three separate phases in order to test for accuracy in measurements, time required for swipe analysis, and practical use in a typical environment. Swipes were taken in the T-Building of the Mound complex. Phase 1 samples were collected in a contaminated area; Phase 2, in various routine survey locations; and Phase 3, in an uncontaminated room to simulate a free release survey. These buildings contain laboratory and process areas that handled tritium. Some of the process equipment was exposed to relatively pure tritium and is highly contaminated. This equipment is housed in secondary containment consisting of gloveboxes and fumehoods. These gloveboxes and fumehoods are installed in individual rooms within the buildings. In order to provide the proper room radiological postings and access requirements, the contamination levels must be quantified. These rooms are routinely monitored for tritium contamination through the use of field swipes and LSC analysis.

The objective of the Lumi-Scint demonstration was to identify if the technology could serve as a suitable supplement to the baseline technology with respect to speed in the analysis of swipes, cost-effectiveness, and efficiency in performance. Because the baseline LSC is located in a centralized laboratory, samples have to be transported from the field to be analyzed. The time of transporting samples to a centralized laboratory can be avoided by using the Lumi-Scint technology. The Lumi-Scint can be a useful tool for a quick field measurement of low-energy beta contamination.

Upon analysis of the performance data collected during the demonstration at Mound, it was found to be inconclusive and unreliable due to human errors in recording and tabulation of data. To mitigate this, additional samples were collected and analyzed using the baseline and innovative technologies at Princeton Plasma Physics Laboratory (PPPL) in September 2000. The performance data reported in this ITSR is from the data collected at PPPL, whereas the cost analysis is based on the data collected during the demonstration at Mound.

Key Results

The key results of the demonstration are as follow:

- The demonstration revealed that the Lumi-Scint LSC technology is useful for providing fast turn-around on a small number of samples.
- Because the Lumi-Scint is portable, it can provide low-energy beta measurements for the samples immediately after they are taken in the field since it can be taken to the location where the swipes are being collected. Under these conditions, the Lumi-Scint can prove to be a cost-effective, safe, and timesaving tool.
- Lumi-Scint has proved comparable to a laboratory LSC for counting tritium beta activity over a large count range. Activity was counted from 1,000 to 320,000 dpm as measured by Lumi-Scint.
- Although a supplement to the existing baseline, the Lumi-Scint is a cost-effective tool for low-energy beta field measurements. With a technology cost of $7,930 and a demonstration cost of $4.17/sample, the innovative is cheaper than the baseline's $35,000 technology cost and demonstration cost of $4.14/sample.
- The Lumi-Scint, like all field instruments, is sensitive to background radiation. This is avoided in laboratory analysis where the surrounding environment has been configured to have little effect on the integrity of the results.

Contacts

Vendor

Seth Schulman
Bio Scan
MacArthur Blvd.
Washington, D.C. 20007
(800) 255-7226

Technology Demonstration

Travis Finch
Project Engineer
Lawrence Livermore National Laboratories
7000 East Ave.
Livermore, CA 94550
(925) 422-5215
finch3@llnl.gov

Jeff Van Patten
Project Engineer
BWXT Services, Inc.
P.O. Box 11165
Lynchburg, VA 24506
(804) 522-6757
jeff.van-patten@mcdermott.com

Mound Tritium D&D Large-Scale Demonstration and Deployment Project

Don Krause
Project Manager
BWXT Services, Inc.
P.O. Box 3030
Miamisburg, OH 45342
(937) 865-4501
kraudr@doe-md.gov

J. Mark Mintz
Principal Investigator
Lawrence Livermore National Laboratory
7000 East Ave.
Livermore, CA 94550
(925) 422-8394
mintz1@llnl.gov

Cost Analysis

Tim Lamb
United States Army Corps of Engineers
600 Dr. M.L. King Jr. Place
Louisville, KY 40201
(502) 625-7338
timothy.lamb@usace.army.mil

Management

Harold Shoemaker, U.S. DOE
Project Manager
NETL
P.O. Box 880
Morgantown, WV 26507
(304) 285-4715
Harold.Shoemaker@netl.doe.gov

James Johnson, U.S. DOE
Project Manager
Miamisburg Environmental Management Project
P. O. Box 66
Miamisburg, OH 45343
(937) 847-5234
James.O.Johnson@ohio.doe.gov

Licensing

No special regulatory considerations were required to demonstrate or implement this technology.

Permitting

No special regulatory permits were required to demonstrate or implement this technology.

Website

The Mound Tritium LSDDP website address is http://www.doe-md.gov/lsdd/lsd.htm

Other

All published Innovative Technology Summary Reports are available on the OST website at www.em.doe.gov/ost under "Publications." The Technology Management System (TMS), also available through the OST website, provides information about OST programs, technologies, and problems. The OST/TMS ID for the Lumi-Scint Liquid Scintillation Counter is 2311.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

Demonstration Goals and Objectives

The goal of this demonstration was to determine if the centralized laboratory LSC could be supplemented by the use of the portable Lumi-Scint to provide a rapid quantitative tool for the analysis of swipes. The objectives of the demonstration were to collect valid operational data so that a legitimate comparison could be made between the Lumi-Scint technology and the baseline technology in the following areas:

- Cost
- Performance
- Ease of use
- Limitations and benefits.

Technology Description – Baseline

As the safe shutdown at the Mound facility continues along its course, one of the main concerns during the process is to protect personnel, the environment, and surrounding communities from the possible spread of radiological hazards. The Radiation Safety Department at Mound adheres to the established processes to ensure the continued safety of all those involved in the safe shutdown. One of the responsibilities of an RCT is to perform contamination surveys by taking swipes, as needed, of a 100 square centimeter area of equipment, rooms, material, etc. These swipes are taken with dry filter paper and transported to a centralized counting laboratory to be counted on an LSC for tritium. Before the swipe is counted on the LSC, it is first counted on a gas-proportional counter to check for alpha and high-energy beta radiation. As it is possible for a large number of samples to accumulate at the laboratory in any given time, and as it is required to transport these samples from the field, the turnaround time required for a sample can be from several hours to a few days.

The LSC detection method is the same as the innovative Lumi-Scint technology. Radiation emitted by the sample interacts with the scintillation cocktail to produce light. The light is then transformed into minute electrical signals by the PMT. The preamplifier and amplifier circuits in the instrument further amplify the signals. Noise, inherent in the PMT and generated by other sources, is rejected by the threshold circuitry, and a pulse or count is produced for each valid pulse of light detected.

A typical process consists of the RCT taking a swipe of a 100 square centimeter area and placing this swipe into a coin envelope. The sample's identification is recorded, and the samples are transported to the centralized counting laboratory. A laboratory technician takes custody of the samples and counts them for alpha and high-energy beta activity in a gas flow proportional counter. Upon completion of the count for alpha and high-energy betas, the sample is removed and placed into a 7-milliliter vial. This vial is filled with 5 milliliters of a liquid scintillation cocktail solution. Each "string" of samples brought from a particular project are loaded into the LSC behind a source and a background vial. The source calibrates the machine each time for the string of samples (requires 120-second count time). Next, the background is counted for automatic subtraction from the samples (requires 600-second count time). Upon completion of the sample count, the RCT is contacted, and he/she returns to the laboratory to review the results. The total time required to perform this activity was documented in the data package for the demonstration and nominally ran about 3 minutes per swipe. After reviewing and documenting the results, the RCT contacts the appropriate personnel. The workload in the laboratory is highly variable, that is, at the time of delivery of the samples, there may be few samples to be analyzed or there may be many samples to be analyzed. Consequently, the laboratory may be able to almost immediately begin preparing the delivered samples, or the laboratory may have several hundred samples in line ahead of the delivered samples. The number of samples in the queue determines the wait time before sample processing. Whether the wait time is 20 minutes or 2 days, it does not change the analytical costs. However, if the activity for which the measurements are needed is on the critical path and work has to stop until the results are available, significant project costs can be accrued waiting for the results (schedule delay, lost productivity, etc.). Therefore, very short turnaround contributes to significant project cost savings.

Technology Description – Innovative

The basic detection mechanism for the Lumi-Scint is the same as the baseline LSC. Radiation emitted by the sample interacts with the scintillation cocktail to produce light. The light is then transformed into minute electrical signals by the PMT. The preamplifier and amplifier circuits in the instrument further amplify the signals. Noise, inherent in the PMT and generated by other sources, is rejected by the threshold circuitry, and a pulse is produced for each valid pulse of light detected.

The Lumi-Scint's optimum count-time for this demonstration was determined to be two minutes. The Lumi-Scint has the ability to count test tubes, 7-ml vials, and 20-ml vials. The manufacturer will provide the appropriate drawer upon request. The Lumi-Scint has memory for approximately 200 samples. It has outputs for an external computer and a printer. Some of the programmable options are time, count-time, CPM or DPM, calibration, isotope (H3, C14, P32), delay time, and memory clear. The instrument weighs approximately 5 pounds with dimensions of 12 inches (in length) by 6 inches (in width).

Lumi-Scint operation is controlled with an 8-bit microprocessor, and all factory set functions are stored in Erasable Programmable Read Only Memory (EPROM), while user-defined protocols are stored in battery-backed Random Access Memory (RAM). The pulse train detected by the PMT is transferred to the microprocessor, which controls all counting, logic, and computational processes.

A printer can be connected to the parallel printer port, and results may be printed in real-time. However, if the printer is not connected (as in field use), the results are stored in battery-backed memory for later printing.

The instrument is operated on 12-Volt DC. The transformer/charger can be set for use with any AC power source at 120 or 240 VAC and will supply the necessary 12-Volt DC to run the instrument and to charge the optional battery. Because other adapters may not have adequate filtering, it is recommended that the Lumi-Scint be operated only with the 12-Volt DC transformer/charger supplied.

Prior to the use of the Lumi-Scint for swipe analysis, a calibration must be performed to establish measurement efficiency for the instrument. To insure accurate results, calibrations must be performed using standards with the same volume and quench characteristics as the unknown samples that will be counted. Sealed standards are available commercially for unquenched tritium. However, if there are some materials present on the swipes that quench or reduce light output, then calibration standards must be prepared to match the quench conditions in the unknown samples.

The Lumi-Scint unit is capable of counting samples with activities as high as 20,000,000 cpm. This capability is a result of optimizing the electronics to handle the much higher counting rates. For such higher activities, the background count subtraction is insignificant. Figure 1 shows the Lumi-Scint unit in operational mode, and Figure 2 shows the Lumi-Scint unit with sample drawer open.

Figure 1. Lumi-Scint portable liquid scintillation counter.

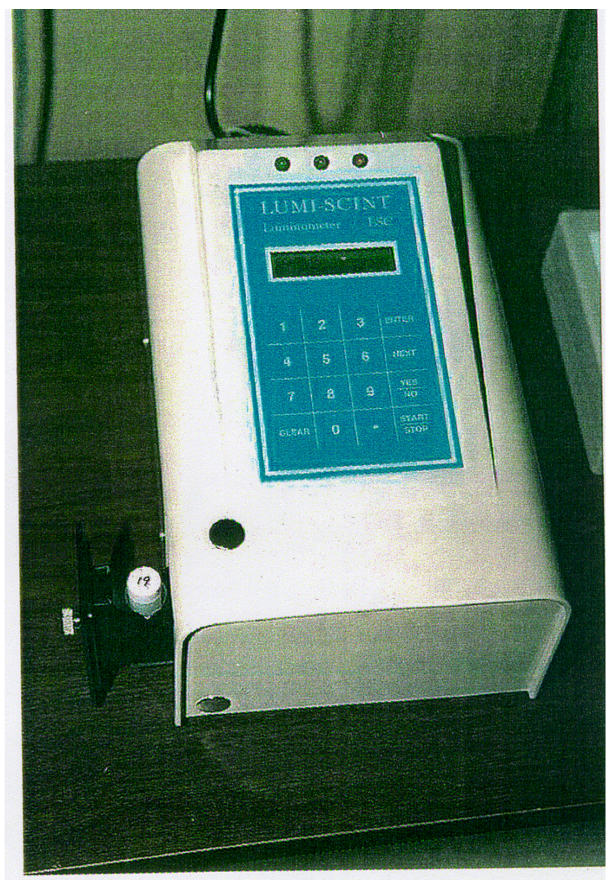


Figure 2. Sample drawer location.

System Operation

Table 1 summarizes the operational parameters and conditions of the Lumi-Scint demonstration.

Table 1. Operational parameters and conditions of the Lumi-Scint demonstration

Working Conditions	
Work area location	Mound Site, Miamisburg, Ohio; Buildings T, Room 36; and SW/R, Room 108.
Work area access	Miamisburg Environmental Management Project.
Work area description	The Main Hill Tritium area of Mound includes areas of Buildings R, SW, and T. These buildings contained laboratory and process areas that handled tritium. Some of the process equipment was exposed to relatively pure tritium and is highly contaminated. This equipment is housed in a secondary containment consisting of gloveboxes and fumehoods. These gloveboxes and fumehoods are installed in individual rooms within the building.
Work area hazards	High levels of tritium contamination in some areas.
Equipment configuration	Before using the Lumi-Scint LSC instrument, a source check was made and background reading obtained. The Lumi-Scint instrument was calibrated and proper precautions taken to ensure it was functioning within calibrated parameters.
Labor, Support Personnel, Specialized Skills, Training	
Work crew	• 1 Lead Test Engineer (LTE). • 1 Demonstration/Data Collector. • 1 Radiological Control Technician (RCT).
Additional support personnel	• Laboratory personnel. • Demonstration technicians.
Specialized skills/training	• Personnel using the Lumi-Scint LSC were properly trained according to the manufacturer's manual. • Data collectors were trained on data collection techniques. • Personnel involved in the demonstration were trained under Radiological Worker II guidelines.
Waste Management	
Primary waste generated	Chemical – LSC cocktail (radiologically contaminated, non-hazardous).
Secondary waste generated	Disposable personal protective equipment (PPE).
Waste containment and disposal	All waste generated by the demonstration was handled and disposed of according to the Mound Waste Management Plan.
Equipment Specifications and Operational Parameters	
Technology design purpose	Efficient measurement of tritium low-beta activity in the field.
Specifications	• Weight: 5 lbs. • (LxWxH): 12"x 6"x 6". • Memory: 200 samples. • Wait time: programmable (optimum-10 sec.). • Lumi-Scint is operated on 120 or 240 VAC power source. • Transformer/charger battery. • Backup battery packs in areas where there are no available electrical outlets.
Portability	Portable. It can be taken to the location where samples are being collected for counting.
Materials Used	
Work area preparation	No specific preparation was necessary for the demonstration. The Mound project already had necessary controls and preparations in place.
Personal protective equipment	During the course of the demonstration, all personnel collecting or manipulating samples were required to wear the appropriate PPE to perform work. While the RCTs were collecting swipes in the contaminated area, they donned the appropriate PPE as required by Radiological Work Permit (RWP). While handling and collecting swipes from other areas, the RCTs wore surgical gloves.
Utilities/Energy Requirements	
Power, fuel, etc.	120 or 240 VAC power source, or 12-Volt battery.

SECTION 3
PERFORMANCE

Problem Addressed

The baseline technology for analysis of swipes is to perform a swipe of a surface to collect contamination and transport the samples to a laboratory to be analyzed by an LSC. In some cases, these samples may have to join a backlog of samples for a period of time.

The purpose of this demonstration was to investigate if the centralized laboratory liquid scintillation counter could be supplemented by the portable Lumi-Scint to provide a rapid and cost-effective method of analyzing swipe samples in the field. While this objective was achieved in the demonstration, it was on the other hand noted that the Lumi-Scint LSC requires manual sample changing, whereas the baseline LSC has automatic sample changing.

Demonstration Plan

The technology demonstration focused on three separate phases in order to test for accuracy in measurements, time required for swipe analysis, and practical use in a typical environment. Swipes were taken in the T-Building of the Mound complex. Phase 1 samples were collected in a contaminated area; Phase 2, in various routine survey locations; and Phase 3, in an uncontaminated room to simulate a free release survey.

The technology demonstration was performed by an RCT at the Mound facility. The RCT gathered all the swipes, prepared the vials for the samples, and loaded the samples into the Lumi-Scint for analysis. The samples collected were analyzed by both innovative and baseline technologies. In Phase 1, a total of 100 swipes were taken in various locations in the contamination area in order to acquire a wide range of activity. From these samples, 30 samples were randomly selected for recounting 24 hours later to check the repeatability of the instrument's measuring capabilities. Phase 2 was performed at several locations as the RCT performed a normal routine survey. A total of 65 swipes were gathered during this phase. The data collected was for the comparisons of the time required to analyze swipes when using the demonstrated technology as opposed to the baseline technology. Phase 3 was designed to test the use of the Lumi-Scint in performing a free release survey.

Demonstration Site Description

The Main Hill Tritium area of Mound includes areas of buildings R, SW, and T. These buildings contain laboratory and process areas that handled tritium. Some of the process equipment was exposed to relatively pure tritium and is highly contaminated. This equipment is housed in secondary containment consisting of gloveboxes and fumehoods. These gloveboxes and fumehoods are installed in individual rooms within the buildings. There are high levels of tritium in process piping, equipment, and tanks; lower levels exist in gloveboxes and buildings and in contaminated soil and ground water around the buildings.

Major Objectives of the Demonstration

The major objectives were to evaluate the Lumi-Scint against the baseline technology in several areas including

- Cost
- Performance
- Ease of use
- Limitations and benefits.

Major Elements of the Demonstration

Both the baseline technology and the Lumi-Scint LSC were used to count swipe samples. The swipe collection methodology for the demonstrated technology is identical to the baseline technology. Swipe data for the demonstration technology were acquired the same time as data were collected for the baseline technology. One RCT was followed as he performed swipe surveys. As the demonstrated technology required a three-phase process, the data documented for the collection of swipes during these three phases were used for the baseline data as well. There were 100 swipes taken in Phase 1 in a contaminated area, 65 swipes taken in Phase 2 as a normal routine survey, and 100 swipes taken in Phase 3 for a free release survey from a "clean" room.

During subsequent data collection at PPPL, fifty swipes were collected from a radiological control area and analyzed with both the baseline LSC and Lumi-Scint LSC.

Technology Performance

Table 2 summarizes the demonstration results.

Table 2. Performance comparison of innovative vs. baseline technologies

Performance Factor	Baseline Technology Laboratory LSC	Innovative Technology Lumi-Scint LSC
Personnel, equipment, and time required to collect and analyze swipe	Personnel: • 1 RCT • 1 laboratory technician Equipment: • Laboratory LSC Time for sample collection and analysis: • 4.58 min/sample (See Page C-3 for calculation) PPE: • Surgical Gloves	Personnel: • 1 RCT Equipment: • Lumi-Scint LSC Time for sample collection and analysis: • 3.14 min/sample (See Page C-3 for calculation) PPE: • Surgical Gloves
Equipment Performance	Contamination Range: • Vendor Specification: 20 to 13 X 10^9 dpm. • Demonstration: 100 to 500,000 dpm. Minimum Detectable Activity: • 38 dpm/100cm^2 Efficiency • Range: 2.92% to 57.06% depending on quench value of samples. • 37.7% for samples analyzed based on historic average quench value for swipes at PPPL.	Contamination Range: • Equipment Specification: up to 20,000,000 cpm. • Lumi-Scint Response over Demonstration Range: Non-detect to 320,000 dpm. Minimum Detectable Activity: • 634 dpm/100cm^2 Efficiency • Range: 0.13% to 16.6% depending on quench value of samples. • 5.4% for samples analyzed based on historic average quench value for swipes at PPPL.

Table 2. Performance comparison of innovative vs. baseline technologies (continued)

Performance Factor	Baseline Technology Laboratory LSC	Innovative Technology Lumi-Scint LSC
Superior Capability	• The baseline LSC is a very efficient technology for swipe analysis in the laboratory. • Problems caused by background radiation are minimized.	• “Field” technology allows for near real-time results. • Capable of handling wide range of contamination levels. • Can be operated with battery power.

Upon analysis of the data collected at PPPL, it was observed that LSC produced results on average, 1.4 times higher than the Lumi-Scint. In the recount of the same samples, LSC still produced results on average 1.4 times higher than the Lumi-Scint. Therefore, to be directly comparable, a correlation between baseline LSC and Lumi-Scint must be established before deploying Lumi-Scint in the field.

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Technology Applicability

The goal of this demonstration was to determine if the use of the Lumi-Scint Portable LSC would significantly reduce the time required for analyzing a swipe for tritium activity. As noted earlier, the baseline technology requires a variable amount of time that may be as much as several days in order to obtain results from swipes. The demonstration was to obtain two results. One is whether the Lumi-Scint's performance characteristics are adequate compared to the baseline LSC, and the second is whether the time required for results from swipes would be significantly reduced.

This demonstration provided data that support the usefulness of the Lumi-Scint for field use at the Mound facility. When used in the field, the Lumi-Scint proved to reduce significantly the time required for obtaining quantitative results from swipe analysis. Finally, the advantage of a field technology with immediate results was apparent in the demonstration. Immediate availability of results informs the workers of the radiological conditions within the work environment so that appropriate precautions can be taken. Also, reduced handling of contaminated swipes adheres to the ALARA principles (As Low As Reasonably Achievable) when working with radiological materials.

Competing Technologies

The only other competing innovative technology for field measurement of swipes (for tritium contamination) is the Tritium Measurement System – 2000 (TMS-2000) Tritium Surface Contamination Detector developed by Ontario Hydro of Toronto, Canada. It is a gas ionization-based technology. It measures tritium on the swipes by virtue of charge buildup in air due to the outward electron flux from the contaminated surface. Temporal change in the outward electron flux can be detected for monitoring change in surface activity in real-time. This technology is scheduled for demonstration at Mound at a later date.

Patents, Commercialization, and Sponsorship

No issues related to patents, commercialization, or sponsorship are pending.

SECTION 5
COST

Introduction

The objective of this cost analysis is to provide decision makers, who are tasked with decontamination and decommissioning (D&D) programs, with sound cost information on new and innovative technologies that may provide economic advantages over standard methodologies derived for use in the Operations task mode. This analysis strives to develop realistic estimates that are representative of actual tasks to be performed in the D&D arena within the DOE complex or other agencies with similar needs. The applicability of this analysis is general. However, it is recommended that readers making decisions based on economic issues review the full cost analysis support package before implementation of this technology.

Methodology

This cost analysis is a comparison between the portable Lumi-Scint and the baseline LSC technologies. The analysis is based on the assumption that the D&D facility is in need of additional tritium analysis capability and that the purchase of a new tritium analysis instrument is anticipated or that existing tritium analysis facilities are not able to cope with the demand for tritium analysis of a D&D project. It is assumed that during D&D work at the DOE nuclear facilities, the demand for tritium testing will increase substantially. It is also noted that the time frame for D&D efforts is short compared to the operating life of a facility. This analysis investigates the effect of various cost drivers on the unit cost of the baseline system and the Lumi-Scint technology.

Significant assumptions are

- Economic life of the baseline technology is 15 years.
- Economic life of the Lumi-Scint technology is 6 years.
- D&D project life varies between 2 and 20 years.
- The demonstration data are representative of actual use.

The test engineer at the Mound facility gathered cost data for this effort from the demonstration of the Lumi-Scint LSC. The data for the baseline were gathered from a previous test; they have been reviewed and are considered valid. The two technologies operate in a similar manner; both produce measurements of low-energy beta, tritium. Both technologies use the swipe/LSC methodology, the Lumi-Scint LSC being present at the location of the swipe collection (or within a reasonable distance outside a containment area) and the baseline LSC being in a fixed location on the D&D site. Test data were collected for “swipe collection” and “tritium analysis.” The number of swipes collected during the testing was representative of expectations for reasonable working conditions.

The test data were collected for two actions:

- The time for collection of the swipes, swipe preparation in scintillation cocktail, and associated documentation
- The time for tritium counting of the prepared swipes.

For the baseline technology, two people performed these operations. An RCT collected the swipes, and a laboratory technician performed the tritium analysis. The RCT’s labor rate is double the laboratory technician’s labor rate at Mound. For the Lumi-Scint, all operations were performed by the RCT. As such, the crew labor rate per operation for the LSC (baseline) is much less than for the Lumi-Scint. This is suspected to be an anomaly of the Mound site; however, there has been no correction of the data.

Cost Analysis

The objective is to develop unit costs that can be utilized to evaluate economic alternatives. Total "Unit Cost" is defined as the sum of the following costs:

- Labor costs (based on the specific operators for each system)
- Equipment costs
- Supplies
- Personnel Protective Equipment (PPE)

For the two technologies the unit cost has been calculated on the basis of full system utilization (i.e., full life and 100% production for that life). For the baseline LSC, the life of the equipment is 15 years and that for the Lumi-Scint LSC is 6 years.

Labor costs for the collection and testing activities include the following:

- The time for collection of the swipes, swipe preparation in scintillation cocktail, and associated documentation
- The time for tritium counting of the prepared swipes

The total equipment costs are a combination of several factors that include

- Calibration costs
- Source checks
- Efficiency checks
- Purchase cost of unit
- Annual service cost of unit.

Note that there were no differences in the supplies or PPE costs between the two technologies; however, these costs are included in the total unit cost calculations (Table 3).

Table 3 presents a comparison of the various cost elements. As shown in the table, the baseline has a slight total unit cost advantage if the utilization of the system is for the full life expectancy.

Table 3. Cost comparison of baseline technology to Lumi-Scint technology for various cost elements

Cost Element	Baseline (LSC Fixed Unit)	Innovative (Lumi-Scint)
Purchase Cost of System	$35,000	$7930
D&D Unit Productivity	4.58 minutes/sample	3.14 minutes/sample
Unit Cost for Equipment[1]	$0.57 per sample	$0.53 per sample
Unit Cost for Supplies	$0.22 per sample	$0.22 per sample
Unit Cost for PPE	$0.09 per sample	$0.09 per sample
Unit cost for Labor[2]	$3.26 per sample	$3.34 per sample
Total Unit Cost	**$4.14 per sample**	**$4.17 per sample**

1. This cost is inclusive of purchase cost, calibration costs, and annual maintenance contract cost for the full life of the equipment. Reference the cost support data package.
2. Reference the cost support data package for a full discussion of the labor unit cost with specific discussion of the crew mix.

Figure 3 graphically depicts the variation in the unit cost if the D&D need for the equipment is less than the full life expectancy for the equipment.

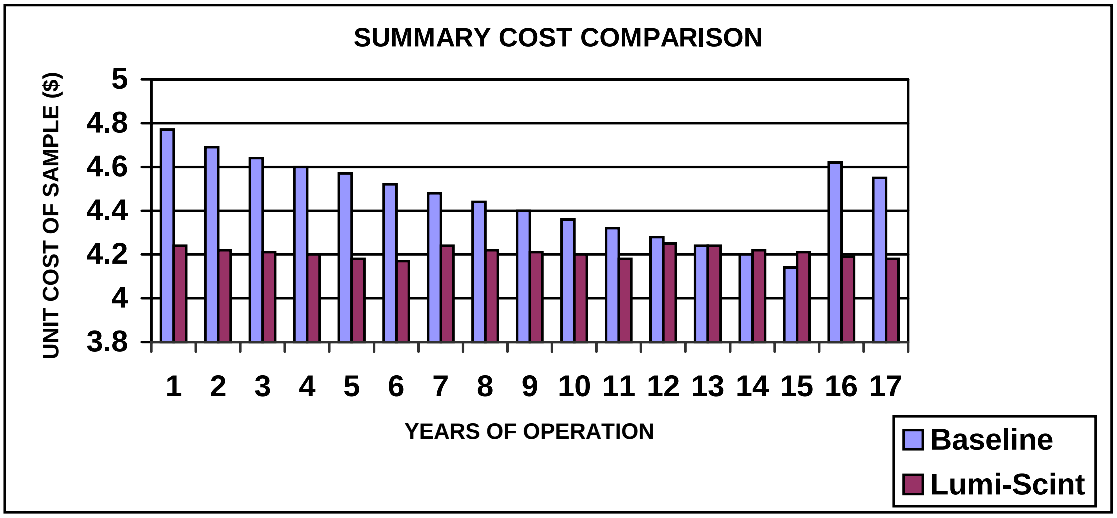


Figure 3. Results of the variation in unit cost for various project execution times.

The above discussion is based on the assumption of the D&D facility operator (a government entity) purchasing the equipment. If the procurement is by an independent contractor, then the Facilities Capital Cost of Money (FCCM) will need to be included in the above analysis.

Cost Element	Baseline Technology	Lumi-Scint Technology
FCCM	$ 0.03 per sample	$ 0.01 per sample
Total Unit Cost w/ FCCM	$ 4.17 per sample	$ 4.18 per sample

Note that the addition of the FCCM to the analysis does not change ranking of the systems but will move the payback forward in time. From the values presented above, the payback would be from 5 to 8 months, assuming 6-year project duration. Longer payback times would be experienced for longer project duration.

Cost Conclusions

From the cost comparison presented in Table 3, it is clear that there is no significant difference in the unit cost of the innovative and baseline technologies. Therefore, if there is a need on the D&D project for a quick turnaround in swipe analysis to avoid schedule delays, lost productivity, etc., it would be prudent for the D&D operator to consider the use of the Lumi-Scint portable LSC. Also, for very short D&D projects, where an LSC is not already available, the Lumi-Scint portable LSC can be the economic choice.

SECTION 6
REGULATORY AND POLICY ISSUES

Regulatory Considerations

There were no regulatory issues with the innovative technology during this demonstration.

Safety, Risks, Benefits, and Community Reaction

The Lumi-Scint is portable and can be taken to the field by using a battery or a 120 or 240 VAC power source. The benefit of the Lumi-Scint is that it is portable and reduces time requirements of transporting samples to a centralized laboratory, while giving a quantitative analysis of the radiological environment. The Lumi-Scint is capable of counting high activity. The upper limit of detection for the Lumi-Scint is more than 10 times the capacity of traditional LSCs. The only risk associated with the Lumi-Scint is background radiation in the work area as for any field instrument. The Lumi-Scint does have the ability to subtract background radiation.

The Lumi-Scint technology demonstration has not revealed any community safety issues or adverse environmental impacts.

SECTION 7
LESSONS LEARNED

Implementation Considerations

As evidenced in this report, the Lumi-Scint LSC is readily portable and may be used with either the battery pack in the unit or connected to a 120 or 240 VAC power source. The unit is easily transported into the field to support RCTs and operations with fast turnaround of results.

Technology Limitations

Hold Time for Sample

During the demonstration, a hold time for the sample, prior to analysis, needed to be determined. A short demonstration was conducted by taking a blank sample of the scintillation cocktail in a 7-mm vial and allowing it to stand in photoluminescence for approximately 20 minutes. This sample was then placed into the Lumi-Scint for counting. This process continued with different hold times (in 5-second intervals) and allowing the sample to stand in the fluorescent light between each count for the 20 minutes. A chart was created to demonstrate the changes in counts for each of the hold periods. According to the data, a 5 to 10 second hold period is adequate for allowing the decay of photoluminescence before analyzing a sample. The manufacturer, as well as the results of the demonstration, suggests that 10 seconds is the optimum wait for the luminescence to decay. This hold time can be programmed into the instrument.

Capacity of the Lumi-Scint LSC

The Lumi-Scint LSC is limited in capacity by the fact that it requires manual sample changing, whereas the baseline LSC has automatic sample changing.

Battery Life

During the demonstration, it was observed that while operating on the 12-Volt battery, the Lumi-Scint LSC became unstable when the battery became weak. Once the battery was recharged, the unit performed normally. The owner’s manual suggests a recharged life of the battery to be approximately 6 hours. Therefore, if the unit is to be operated solely on the internal battery pack, the user must pay close attention to the time of use.

Technology Selection Considerations

The baseline technology LSC is very useful for the analysis of a large number of non-time-critical swipes, whereas the Lumi-Scint LSC can analyze a small quantity of time-critical swipes very effectively. Therefore, in situations where there are only a small number of samples to be analyzed very quickly, or the current laboratory-based LSC is not able to handle demand for swipe analysis generated by a short-term D&D project, the use of the Lumi-Scint LSC may be a viable and cost-effective option.

APPENDIX A
REFERENCES

Travis Finch, January 1999, Mound Tritium D&D Large-Scale Demonstration and Deployment Project, Lumi-Scint Test Plan, prepared for Babcock and Wilcox, Ohio.

Travis Finch, July 1999, Mound Tritium D&D Large-Scale Demonstration and Deployment Project, Lumi-Scint Liquid Scintillation Detector Detailed Technology Report (DTR), prepared by Babcock and Wilcox, Ohio.

APPENDIX B
COST CALCULATIONS SUPPORT DETAILS

Basis of Estimated Cost

The activity costs used in this analysis to estimate the cost of technologies are based on the observed work activities performed for the demonstration and on experience with similar types of work at Mound. Calculations for the "Unit Cost" for innovative and baseline technologies are the sum of the following costs:

- Labor cost
- Equipment cost
- Supplies (same for both technologies)
- PPE (same for both technologies)

Significant assumptions are

- Economic life of the baseline technology is 15 years.
- Economic life of the Lumi-Scint technology is 6 years.
- D&D project life varies between 2 and 20 years.
- The demonstration data are representative of actual use.

Labor Cost

The first analysis conducted was to define the production rates for the operations that take place during the operation of the baseline LSC system. There are three separate operations listed in the raw data. They are

- Setup and collection of the swipes and the associated paperwork
- Execution of an alpha particle screen for the swipe sample
- Execution of a beta screen for the same swipe.

These production data for the baseline LSC system are presented in Tables B.1, B.2, and B.3.

Table B.1 Production data for sample collection for the baseline technology

Data Collection Values for Set-up and Swipe Collection and Associated Paperwork for the Baseline	Sample Collection Time (minutes)	Samples Collected	Production (Min/Sample)
Group A	29	14	2.07
Group B	34	32	1.06
Group C	30	20	1.5
Group D	35	25	1.4
Group E	65	78	0.83

Table B.2 Production data for alpha particle screen for the baseline technology

Execution of an α-Particle Screen for the Swipe Sample for the Baseline	Sample Collection Time (minutes)	Samples Collected	Production (Min/Sample)
Group A	7	14	0.5
Group B	12	20	0.6
Group C	4	12	0.33
Group D	4	6	0.66
Group E	18	48	0.375
Group F	47	5	0.8
Group G	27	64	0.42
Group H	23	98	0.23

Table B.3 Production data for beta screen for the baseline technology

Execution of a β Screen for the Baseline	Sample Collection Time (minutes)	Samples Collected	Production (Min/Sample)
Group A	52	14	3.71
Group B	6	5	1.2
Group C	364	76	4.78
Group D	249	100	2.49

Two operations take place in the operation of Lumi-Scint LSC. They are

- Setup and collection of the swipes and the associated paperwork
- Execution of a beta screen for the swipe.

These production data for the Lumi-Scint LSC are presented in Tables B.4 and B.5.

Table B.4 Production data for sample collection for the innovative technology

Data Collection Values for Setup and Swipe Collection and Associated Paperwork for the Innovative	Sample Collection Time (minutes)	Samples Collected	Production (Min/Sample)
Group A	47	100	0.47

Table B.5 Production data for beta screen for the innovative technology

Execution of a β Screen for Innovative	Sample Collection Time (minutes)	Samples Collected	Production (Min/Sample)
Group A	149	100	1.49
Group B	41	30	1.36
Group C	127	35	3.62
Group D	155	52	2.98
Group E	217	71	3.05
Group F	357	103	3.46

These raw data were averaged by weight; that is, the Average Weighted Collection Time with Paperwork is

$$\sum \text{Collection Time for Samples} / \sum \text{Sample Numbers}.$$

Various data groupings are explored to determine the effect of excluding out-of-bounds data points in the productivity analysis. Based on this analysis, it was decided to use the "average weighted" value based on all data. For the LSC this value is 4.58 min/sample and for the Lumi-Scint 3.14 min/sample. These values are the most representative of the data as collected for this analysis. This analysis results in the productivity times discussed in the cost section.

Equipment Cost

The total equipment costs are a combination of several factors that include

- Calibration costs
- Source checks
- Efficiency checks
- Purchase cost of unit or capital cost
- Annual service cost of unit (purchased as a package from the equipment supplier).

Table B.6 Equipment cost items

Cost Item	Baseline: LSC	Innovative: Lumi-Scint
Calibration	Semi-Annual: Takes 6 hours of laboratory technician time each occurrence.	Year 1/Quarterly, OutYears/ Semi-Annual: Takes 6 hours of laboratory technician time each occurrence.
Source checks	Automatic for each sample set (included in test time)	12 min per sample group
Efficiency checks	Daily for 1 hour	Daily for 1 hour

Table B.7 Capital cost items

Cost Item	Baseline: LSC (workday is 8 hours)	Innovative: Lumi-Scint (workday is 6 hours due to battery limit)
Unit purchase cost	$35,000	$4,950
Printer	(included above)	$995
Printer cable	(included above)	$395
6-hour battery	$0 (AC powered)	$1,590
Service contract	$3,500	$750

The calculations for the hourly equipment cost are made using the data in the above tables. This cost includes several factors: Purchase Price of the unit + Service contract price for life of unit + Calibration Cost per Frequency + Source Check Cost + Efficiency Check Cost. The LSC is calculated on a 15-year life; the Lumi-Scint is calculated on a 6-year life (full life expectancy for each). Using the full operational life to develop unit costs is the standard method for calculating the cost of equipment (USACE guide EP 1110-1-8).

Supplies and PPE Cost

There are no differences in the supplies or PPE costs between the two systems; however, these costs are included in the total unit cost calculations. PPE cost is determined to be $0.088 per sample, and supplies is $0.2188 per sample.

Unit Cost

The unit cost is developed for the cost of a sample, as this is an appropriate unit for the technologies involved. The unit costs are

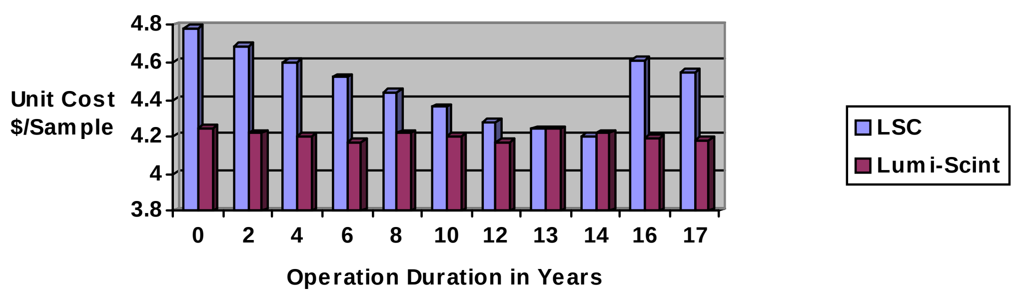
$4.14 per sample for the baseline LSC
$4.17 per sample for the Lumi-Scint

The next step was to analyze the effect on the unit cost if the project life is shortened to reflect a time less than the economic life of the system. This is considered reasonable as the D&D methods that this program is to demonstrate do have limited operational schedules. As such, time frames shorter than the LSC system life (15 years) are reasonable. Time frames as short as 2 years are not unreasonable for facility cleanups. Thus, the unit cost data for both systems of interest were manipulated based on varying project life times. The following is a tabular presentation of the 100% utilization data.

Table B.8 Sample unit cost for various project durations

Project Duration in Years	Baseline: LSC $/sample (cost per sample)	Innovative: Lumi-Scint $/sample (cost per sample)
15	4.14	
10	4.37	
6		4.17
5	4.50	4.18
3	4.67	4.21

The chart below is a reproduction of two data sets: the "LSC 100%" data line and the "Lumi-Scint 100%" data line. The "Lumi-Scint 100%" plot represents the unit cost for the Lumi-Scint system assuming 100% utilization. The "LSC 100%" line is the same criteria as for the "Lumi-Scint 100%" line. The discontinuities in these plots (at year 6 and 12 for the Lumi-Scint and year 15 for the LSC) are due to replacement cost of the units.



From this graphic, it is obvious that for projects with a duration (a need for this testing capability) of less than 10 years, the Lumi-Scint has a substantial unit cost advantage.

APPENDIX C

ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	**Definition**
CPM	Counts Per Minute
D&D	Decontamination and Decommissioning
DDFA	Deactivation and Decommissioning Focus Area
DOE	Department of Energy
dpm	Disintegration Per Minute
EPROM	Erasable Programmable Read Only Memory
FCCM	Final Capital Cost of Money
ITSR	Innovative Technology Summary Report
LLD	Lower Limit of Detection
LSC	Liquid Scintillation Counter
LSDDP	Large-Scale Demonstration and Deployment Project
LTE	Lead Test Engineer
MEMP	Miamisburg Environmental Management Project
NETL	National Energy Technology Laboratory
OMB	Office of Management and Budget
OST	Office of Science and Technology
PMT	Photo-Multiplier Tube
PPE	Personal Protective Equipment
RAM	Random Access Memory
RCT	Radiological Control Technician
RWMC	Radioactive Waste Management Complex
RWP	Radiological Work Permit
USACE	U.S. Army Corps of Engineers