INEL-95/00559
CONF-960804--38

DECONTAMINATION TECHNOLOGIES EVALUATIONS

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ABSTRACT

Testing has been completed at the Idaho Chemical Processing Plant (ICPP) on insitu recyclable abrasive grit blasting, concrete cleaning (using scabbling, chemicals and electro-kinetics) and laser light ablation of metals. Several small scale tests have also been conducted with strippable coatings, CO_2 pellet blasting and various other techniques. The results of this testing is summarized in this paper.

I. INTRODUCTION

For the past four years, the Decontamination Development organization at the ICPP, which is part of the Idaho National Engineering Laboratory (INEL), has been evaluating, developing and demonstrating various decontamination techniques for waste minimization and effectiveness. Surface cleaning of both metals and concrete has been investigated. Past work completed by the Decontamination Development organization includes testing of laser light ablation of metals, CO_2 pellet blasting, alternate chemicals and liquid abrasive grit blasting. The results of these past tests were reported in the Spectrum '94 conference.

Testing has continued on various other techniques including, insitu recyclable abrasive grit blasting, concrete cleaning, and laser light ablation. Several of these techniques are currently being used at the ICPP to reduce or eliminate liquid waste streams.

II. INSITU ABRASIVE GRIT BLASTING

A portable insitu abrasive grit blaster with recycling capabilities was tested under a Cooperative Research and Development Agreement (CRADA) with Kleiber and Schulz (K&S).[1] This Liquid Abrasive Pressure Pot (LAPP) system was developed in Europe and K&S has an exclusive US license. The LAPP system has a foot print of 5 ft. X 5 ft. and stands approximately 5 ft. tall. The main blasting system is on wheels and can be moved to the area where the blasting is performed. The system operates by placing abrasive with a small amount of water in the pressure vessel and then pressurizing it with air. This pressure closes off the top opening of the pressure vessel (where the abrasive and water are added) with a pop up valve. A valve at the bottom is then opened allowing the abrasive slurry to go through a hose to the blasting nozzle. A trigger on the nozzle is used to start the blasting. The preferred compressed air requirement for this system is 250 cfm at a maximum pressure of 100 psi. The minimum air requirement for blasting is 165 cfm at approximately 60 psi. The ICPP plant air did not meet the minimum air flow requirements to operate this system so an air compressor was used.

The LAPP uses a recycling process to reduce the amount of liquid and solid waste generated. A vacuum system collects the used grit and water and returns it to be reused. The vacuum system can stand alone or can be placed over the main blasting system for easier reuse. The vacuum system, which stands 10 ft. tall, was placed to the side of the blasting system for these tests. The abrasive slurry used in this system can contain a variable percentage of water and grit depending on how aggressive the slurry needs to be to clean the material.

The LAPP system cleaned very well with 100% of the simulated contamination on the decontaminated surfaces being removed. The amount of secondary waste resulting from the use of grit was also minimized.

The LAPP system could be improved with modifications to make it easier to use in a radioactive hot cell operation. These improvements include:

1) The design should be changed to decrease the air flow requirements to that provided by plant air systems. The current configuration requires the use of a large compressor to provide the required air flow and pressure.

2) The nozzle on this system was difficult to use and needs to be modified for use with robotic manipulators.

3) An air flow regulator, pressure gauge, and water level indicator should be added to assist in optimal operation.

4) The unit should be constructed of non-painted-stainless steel to aid in unit cleanup.

5) Improvements are needed to make the system easier to move around.

III. CONCRETE DECONTAMINATION

A concrete cleaning demonstration was conducted at the ICPP in the fall of 1994.[2,3] This demonstration included three different concrete cleaning techniques: mechanical scabbling, specialty chemical cleaning, and an electro-kinetic technique. To test the three concrete decontamination techniques, different companies cleaned a radioactively contaminated concrete trench lid (approximately 24 ft^2). The concrete lids were used to cover a settling basin which had not been used for approximately 35 years. The liquid inside the basin had risen above the bottom of the lid approximately 2-3 inches. The lid had been soaking in this liquid for approximately 20 to 25 years. The contaminants consisted primarily of cesium, with lessor amounts of uranium, plutonium, strontium, cerium, cobalt, europium and americium.

A. Mechanical Scabbling

Scabbling, which is a commonly used concrete removal technique, was used as a baseline for comparisons with other concrete cleaning technologies. The Pentek VAC-PAC (model 9) system with a pneumatic, piston-driven Corner-Cutter needle gun (containing 3 mm reciprocating needles) and a pneumatically operated Squirrel III scabbler (with 3, 1-3/4 inch diameter, 9 point tungsten-carbide tipped bits) was used to remove concrete from the lids in this demonstration. Each of these systems was equipped with a 1 1/2 inch vacuum hose and shroud to collect the dust and debris as it was removed from the surface and deliver it to an integral vacuum and waste drumming system.

The Squirrel-III scabbler was used to remove approximately 1/8 inch depth of concrete to within 2 inches of the lid edge. The needle gun was then used on the edge to prevent the dust from becoming airborne. The entire system was very flexible and easy to operate. The system generated very little waste and recontamination was not a problem. No airborne contamination was generated due to the efficiency of the vacuum unit. The lid surface, after cleaning, was level and did not have any peaks or valleys. The total time to remove 1/8 inch of concrete surface was 56 minutes. The results indicated scabbling is a good technique for removal of surface contamination on concrete (Table 1).

It is also noteworthy that after the demonstration the equipment was decontaminated and 90% of it was returned to the vendor. Only the hoses and other similar equipment was not decontaminated. This indicates this system is very well designed for radiological work.

B. Specialty Chemical Cleaning

Environmental Extraction Technologies (EET, Inc.) conducted the chemical portion of the concrete decontamination demonstration using their "TECHXTRACT" contamination extraction technology. The chemicals used by EET to clean concrete claim to have an advantage over standard chemicals in that they only use a small amount of chemical which penetrates the surface and draws the contamination to the surface to be captured.

The three different chemicals were sprayed on to the concrete lid in a particular sequence with a hand-held spray bottle, lightly scrubbed into the surface (this is an important step) and allowed to set the required length of time. Then the surface was sprayed with about the same amount of water and vacuumed off with a high efficiency particulate air (HEPA) filtered

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vacuum. Several applications were made with radiation readings taken between each application.

After the first application, prior to vacuuming off the chemicals, the surface contamination increased dramatically. Once this chemical had been rinsed and vacuumed off, the reading dropped below the initial reading. This happened several times and indicates these chemicals were drawing contamination out of the concrete to the surface to be removed. Final results of this cleaning are in Table 1. It should be noted that time constraints limited the number of applications to three. With additional time, further reductions could have been achieved with these chemicals.

Very little waste was generated (< 2 gallons of chemical and rinses for 24 ft^2 of concrete). Upon completion of the demonstration, the surface of the lid looked the same as at the start except for a small amount of water staining and bleaching. There was no visible surface deterioration.

C. Electro-Kinetic Cleaning

The electro-kinetic portion of this test was performed by Dry-Tec of North America using their "Electro-Osmotic Pulse" technique. This technique involves using an electrical field to cause contaminates to move through the concrete pores. Copper coated steel rods were used as the cathodes and titanium bars as the anodes. When the electrical circuit was connected, a controlled cyclical voltage was applied to the system to cause osmotic migration of water in the concrete from the anode to the cathode. As the moisture was either pushed or pulled out of the concrete, contamination was also pushed or pulled through the concrete.

The testing consisted of two different test set-ups with two concrete lids. One test placed a berm on the top of the lid, the anodes inside the berm and then filled it with water. This lid was place in a drip pan containing a small amount of water and the cathodes. The second setup used the water already in the concrete. The anodes were the rebar in the concrete and the lid was set in a drip pan containing the cathodes and a small amount of water (for collection of contaminants). The circuit was completed with a 110 V power source and the voltage and amperage were controlled by one 10 amp control unit. A small positive and negative pulse was used to pull the moisture and contamination from the lids.

Drytec markets this technique for preventing water inleakage into concrete structures. The results of using this technique to decontaminate concrete indicate some migration of the contamination out of the concrete (Table 1). This technique requires some installation time but does not require much attention once it is operation. This is a slow technique, meant to operate by itself over a long period of time. This technique relies on the moisture that is in the concrete to transport contaminants. This system has potential and further testing would help define the best system setup and establish its limitations. Funding to continue this testing is not currently available.

TABLE 1
CONCRETE DECONTAMINATION RESULTS

Method	% Reduction Smearable	% Reduction Contact
Scabbling	93.9 % β/γ 47.8 % α	93.3 % β/γ
Chemical	97.4 % β/γ 90.0 % α	33.3 % β/γ
Electro-Osmotic (wet)	23.8 % β/γ 46.9 % α	80 % β/γ
Electro-Osmotic (dry)	28.6 % β/γ 51.0 % α	83 % β/γ

IV. LASER LIGHT ABLATION

A. Background

When a focused laser beam irradiates a metal surface, the surface will absorb a fraction of the incoming photons and, when the laser irradiance is sufficiently great, material will be ejected from the surface by a combination of processes that include vaporization and ablation. Decontamination is achieved by removing contaminated surface layers and then capturing the ejected material before redeposition can occur.

Decontaminating a large surface area with a laser in a reasonable amount of time requires that either the laser beam be sufficiently intense to achieve useful irradiance values over a large area or that the laser operate at a very high repetition rate. In either case, the laser beam needs to be rastered quickly across the surface to achieve large area decontamination.

The initial phase of laser light ablation investigations included testing three different types of lasers to determine their efficiency for ablating metal surface material.[4] These tests demonstrated that Q-switched Nd:YAG and excimer lasers can decontaminate metal surfaces via laser ablation. Previous work determined that, using a laser with appropriate operating characteristics, ejected material could be transported away from the surface by an air stream and successfully captured with a HEPA filter.

B. Fiber-Optically Delivered Ablation System

During the second phase of development, LMIT along with Ames Laboratory, at Iowa State University, developed a proprietary laser light ablation system which uses a fiber optic delivered, acousto-optic, Q-switched, Nd:YAG laser.[3] The relatively long pulse length (1064 nm) of this laser reduced the physical strain on optical fibers caused by electro-optically Q-switched Nd:YAG lasers and allowed their use for laser beam delivery. Unlike continuous wave or long pulse width Nd:YAG lasers, the acousto-optically Q-switched Nd:YAG laser has a pulse width that is sufficiently short to prevent melting of the metal surface. Such melting could drive contaminants into the material by a combination of migration and resolidification.

A fiber optic beam delivery system has several advantages over a typical mirror and lens beam delivery system. It allows the expensive laser head and electronics to remain completely isolated from the contaminated environment. The flexible fiber optics can bend around corners, over obstructions and can thus be used to perform the laser light ablation cleaning process in a remote location without requiring sophisticated robotics to maintain alignment or mirror and lens optics.

Testing with this laser centered on determining the minimum pulse length and irradiance (or power intensity in W/cm^2) to achieve metal surface ablation without causing gas breakdown in a normal air environment. It was shown that an irradiance of greater than $1X10^7$ W/cm^2 and a pulse length less than 150 ns at a 1064 nm wavelength was required. It was found that there is at least $\pm$ 1.5 mm depth of field in which at least a 90% cleaning efficiency is available. Also, the material removal efficiency did not significantly change when the angle of incidence was varied from $\pm$ 20°. Testing of optimized parameters on materials with simulated contamination resulted in a removal of 93 to 100% of the contamination. Results were also favorable on samples of material which were radioactively contaminated with removal of about 80% of the contamination on the first laser pass.

C. Fiber Optics Radiation Resistance

The effect of radiation exposure on fiber optic performance was tested. The laser transmission efficiency of the fibers was measured then they were exposed to a high energy gamma radiation source for varying periods of time (equivalent to 7-28 days in a 100 R/hr hot cell). Then the power transmission of the fibers was remeasured. No significant degradation of the fibers was observed.

D. Lead Cleaning

Testing was also conducted using this proprietary laser system to clean lead bricks. All but one surface on the brick were effectively decontaminated after only one laser pass at the maximum translational speed achievable with the available equipment. The remaining surface was still contaminated after sixteen scans suggesting that the contaminants in this section of the brick had migrated to a significant depth.

The lead content in the air stream after the HEPA filters was measured also. The lead concentration level in the exhaust air stream was below the EPA ambient air quality standard and well below the relevant OSHA standard.

E. Additional Testing

A small amount of additional scoping testing has been conducted with the proprietary laser system at the INEL as part of a Laboratory Directed Research and Development (LDRD) grant. Flat black paint removal from carbon steel and stainless steel samples was accomplished at rates of 19.63 ft^2/hr for one pass and 9.82 ft^2/hr for two passes. Metal ablation decontamination on stainless steel with simulated fixed contamination was also completed at a rate of 1.64 ft^2/hr for one pass and 0.82 ft^2/hr for two passes. These rates are not optimized and existing equipment rastering rates was a limiting factor. Some additional testing is still being conducted.

V. Strippable Coatings

Some small scale laboratory testing was conducted on Pentek's 604 self-stripping coating. This coating is a water based organic polymer which is non-toxic and non-flammable. One gallon covers approximately 120 ft^2. This coating is painted on and it peels off by itself as it drys. The coating, which contains the removed contamination, can then be collected in a vacuum cleaner.

The first testing was done using coupons with simulated contamination and was very successful. It removed from 90-96% of the simulated loose contamination and 57-77% of the simulated fixed contamination. This coating was then used to remove loose contamination from a lead brick. After three applications, the smearable contamination was completely removed.

One problem noted by other sources is that if the surface is extremely dirty, sometimes the coating will not release from the surface. This coating would be a good choice for an area with alpha contamination. It will trap the contamination in its matrix then release from the surface and be vacuumed into a waste drum.

VI. Other Testing

The use of nitric permanganate (NP) has been encouraged at the ICPP instead of using the traditional alkaline permanganate based solutions. This is due to the problem of aglomeration of the fluidized bed during calcining of liquids containing a lot of sodium and potassium. In the product denitrator area at the ICPP, repeated flushing with nitric acid did not decrease the radiation reading in a particular line. It decreased satisfactorily after only two cycles of NP/oxalic acid. NP was also used in the calciner facility off-gas cell decontamination resulting in a final waste reduction during certain flushes of 94%.

Environmental Extraction Technologies (EET) proprietary "TECHXTRACT" chemicals were used on metal tools and other items which had been previously unsuccessfully decontaminated with nitric acid. One application of the chemicals resulted in tools clean enough to release (Table 2).

Table 2
Metal Cleaning with EET Chemicals

Tool	Fixed β/γ counts/min	Fixed β/γ counts/min
	Before	After
Carbon Steel Drill Bit	300	ND
Carbon Steel Core Bit *	1000	ND
Brass Pipe Wrench	600	ND
Aluminum Pipe Wrench	600	ND

* This bit also had 10,000 d/m α of smearable contamination prior to cleaning and ND after.
ND = Nondectectable

A new polyarcylate/polyalcohol copolymer absorbent was also recommended for use to replace the currently used corn cobs to absorb liquids in an INEL laboratory prior to waste disposal resulting in a cost savings of $15,000 per year (without considering the cost of final waste disposal). Several polymer absorbents were tested. It was found each absorbent had to be tested on this particular waste stream which was acidic and contained many "salts". For general applications each particular waste stream would need to be tested to determine the best brand of absorbent and the amount of absorbent needed. In general, these super absorbent polymers do not contain toxic or hazardous components. Vendors indicated absorbents won't break down in waste drums, however, some are formulated to break down in the sunlight. These absorbents will also hold their loads under pressure (such as stacking bags on top of one another) and add very little volume to the waste stream (unlike corncobs). All are incinerable limited only by the waste stream composition and the incinerator requirements.

A few additional tests were conducted using CO_2 pellet blasting using various systems. The results of these tests on coupons with simulated loose and fixed contamination are summarized in Table 3.

Table 3
CO_2 Cleaning Results

Method	% Loose Removal	% Fixed Removal
Cold Jet CO_2 Pellet Blasting	83 to 92	41 to 79
Alpheus CO_2 Pellet Blasting	100	75 to 100
Supersonic Ice Blasting	92 to 93	4 to 59
Centrifugal CO_2 Pellet Blasting	No Testing	57 to 90

ACKNOWLEDGEMENTS

Thanks to Rick Demmer, Kip Archibald, and Russ Ferguson of the ICPP *Decontamination Development* organization for their dedication and excellent work in providing the information presented in this report.

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