On-Demand Radiological Decontamination and Recovery Approach
Technical Brief

December 2007
Revised September 2008

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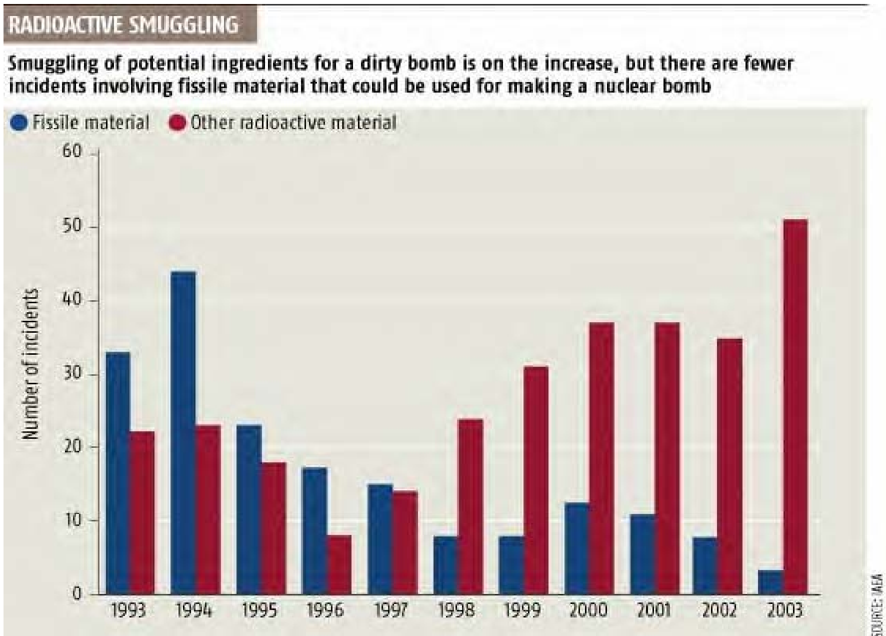
1.0 Introduction

The capacity to restore and recover infrastructure and other assets following a radiological release incident, whether intentional or accidental, is lacking due to a number of technological and logistical challenges. Rapid, efficient and cost effective recovery is critical to reduce public health risks, minimize economic impacts, restore public confidence, and in the case of an intentional incident, minimize the spread of fear thus discouraging further incidents. While a substantial number of technologies have been tested over the years to address the removal and sequestration of isotopic contamination, virtually all of these technologies exhibit shortcomings in logistics, cost effectiveness and efficacy, or a combination thereof. Additionally, Response Plans may do an adequate job of addressing many facets of a radiological event, including Law Enforcement, public health and mass casualties, psychosocial impacts, public communications, incident modeling and Command and Control, among others, but are noticeably lacking in Recovery and Restoration components.

The ability to generate decontamination solutions “on-demand” for the remediation of radiological contamination is now available. This approach provides significant logistical, cost and efficiency advantages for radiological decontamination over traditional chemical-based approaches. For example, the envisioned systems will incorporate the capacity for field adjustments of generated solutions in order to adjust to varying contaminant, substrate and environmental matrices. This advanced technological ability has been made possible due to the interaction of a series of evolving technologies, including developments from the energy industry. These same systems can also be applied to chemical and biological (CB) decontamination needs, with a single device generating a range of CB decontamination solutions as well as solutions for the efficient removal of radiological and nuclear (RN) contaminants. This allows for the development of a true CBRN decontamination system contained in a single efficient deployment unit. This outline will briefly describe the technological approach envisioned for an On-Demand radiological decontamination system, describe one possible path for the prescribed technology development, testing, optimization and validation of such a system, and will discuss a sampling of the markets where such systems could provide significant logistical and cost advantages to the customer.

2.0 Problem Statement

Significant capability gaps currently exist in available technologies and protocols to effectively deal with radiological decontamination and recovery activities. Extraction, sequestration and decontamination methods are deficient for isotopic materials on many surfaces, especially common porous materials such as granite, concrete, brick and marble, as well steel, glass and other materials found in most urban and commercial environments. Adding to the problem is the current worldwide trend of increased smuggling and trafficking of radioisotopic materials of concern, including cesium 137, strontium 90, cobalt 60 and americium 241. The following chart was produced by the International Atomic Energy Agency, and data accumulated for subsequent years shows the trend continuing to accelerate.



In a radiological incident, such as a Radiological Dispersion Device (RDD) in a typical urban setting, the ability to extract isotopic contamination from various materials is vital for an effective recovery operation. Additionally, a successful effort would seamlessly integrate into the overall response operation and consequence management plan. For example, one insidious aspect of an RDD incident is that the loose radiological contamination plume will continue to spread over time until the isotopic materials are controlled or "tacked" in place. The longer it takes to tack down the contamination, the more widespread the problem will become. This "tacking" effort may well need to take place simultaneously with other response efforts in order to minimize the spread of radionuclides and mitigate potential adverse health and economic impacts. The same decontamination systems must be capable of generating and deploying the tacking formulas in addition to the ultimate extraction and removal formulas used in the final recovery processes.

In commercial radiological settings such as Department of Energy facilities and commercial nuclear plants, similar technological challenges exist. One significant difference is that, where an RDD incident will likely result in isotopic contamination at or near the surface of the various affected materials, commercial nuclear facilities will likely have contaminants that are deeply embedded into substrates and possibly covered with layers of oil, grease and grime that has accumulated over time. In many instances, the ultimate goal may be to lower the contamination level of high level waste into low level waste, saving substantial amounts of money in handling, transport and storage while minimizing high and low level waste streams. In many instances, large and/or valuable equipment has become contaminated and rendered unusable, resulting in the cost of handling, disposal and ultimate storage of the items in addition to the loss of the assets. In order to effectuate successful asset recovery, whether for decontamination of valuable equipment or as part of Demolition and Disposal projects, additional formulas may be needed to remove gross surface contamination and to reopen subsurface capillaries for the successful removal of fixed isotopes. The On-Demand system can be used to produce the required solutions in the required concentrations in order to perform the necessary tasks to prepare the surfaces, remove accumulated debris and release and sequester isotopic materials for collection.

Another significant benefit is the ability to perform these tasks in both urban and commercial settings with environmentally benign materials. There are numerous examples of remediation projects in DOE facilities where legacy chemical extraction technologies could have been effectively employed, but the toxic chemicals involved could not be used because of the limited capabilities of liquid waste handling operations.

With DOE and some commercial clients, the risk of a criticality event with fissile nuclear materials is a significant concern during decontamination processes. This can typically be abated by the addition of neutron poisons, commonly completed with the addition of neutron absorbing materials such as boron. As an example, a sodium tetra-borate deca-hydrate (STBDH) material could be used as a neutron poison (or any other suitable material) in the alkaline portion of the decontamination solution. An electrolytic conversion of STBDH can be used to create boric acid, which can then be used for other aspects of the decontamination process, thereby providing one safety envelope when dealing with potentially fissile materials.

When evaluating radiological decontamination technologies, several factors must be considered. These include health and safety considerations, life cycle costs, ease of use and removal efficacy. The majority of current radiological decontamination solutions utilize traditional chemical components. This approach has numerous inherent problems and limitations, including (but not limited to):

- Excessive cost of the formulations and impacts to lifecycle costs
- Ineffectiveness of formulations on a wide range of substrates/isotopes without cumbersome off-site adjustments
- Significant logistical burden including transport and storage requirements
- Limited shelf life and the associated burden of handling out of date chemicals
- Hazardous chemical formulas and components that create material handling and disposal problems

3.0 Legacy Radiological Decontamination Technologies

Overcoming the challenges of effective radiological decontamination has been attempted for decades. These efforts have included primitive mechanical decontamination approaches such as high and ultra high pressure water blasting, scabbling, needle guns and grinders, along with various types of grit and CO_2 blasting. Some of the newer approaches include laser ablation, electro-chemical wands and various biological / enzyme-based approaches.

The most common group of decontamination solutions are chemical based. These include a wide range of products from simple acid/alkaline materials to complex formulations that include various sequestering components. A few of the more common chemical decontamination solutions are described below.

3.1 Cerium IV Nitrate

Used for various decontamination operations both within the Department of Energy and private industry, Cerium nitrate (in acid) is a strong oxidizer capable of oxidizing and solubilizing various isotopes and non-porous substrate components such as nickel, chrome, and iron. While reacting, the solution strips a few microns from the substrate surface, which results in the removal of some fixed radiological contamination. Other than health and safety issues (such as some references to fire), cerium nitrate is only effective on non-porous hard surfaces. This limitation makes it unusable for decontamination of an RDD type event, and the material has limited applications in DOE facilities due to moderate efficacy in removing fixed isotopes.

3.2 Citric Acid

Citric acid is one of the oldest known natural chelating compounds. Its chelating ability has been used for applications in industry with varying results. The use of citric acid (or most Carboxylic acids) may also induce the capillary rise effect on some substrates, assisting in isotopic removal. Typically, citric acid is used in conjunction with other chelating (sequestering) compounds to provide a wider range of application. The use of a simple chelating material ignores other mechanisms required for successful decontamination of substrates, including the inability to break the bonding forces holding fixed contaminants in place.

3.3 Chemical Based Decontamination Solutions

A number of chemical-based decontamination solutions have been used with varied success for radiological decontamination applications. Some successful applications of this type of process were conducted for DOE and private clients. One limitation of this process arises from the use of traditional chemical components with established, often inadequate characteristics for release and sequestration of isotopic contamination. This limits the ability of the formulation to break bonds that hold fixed contaminants in place, and thus the ability to remove contamination from surfaces. Other limitations include high formulation costs, limited shelf lives and the logistical burdens of stockpiling, warehousing and shipping quantities of often hazardous liquid formularies. Significant training is also required for the decontaminant chemicals’ effective use. Often, additional detailed off-site blending is required to address specific isotopic and substrate matrices, and formulations are easy to miss-blend, rendering them ineffective.

3.4 Strippable Coatings

Various strippable coatings have been used for decades in nuclear facilities to remove loose or “smearable” contaminants. Initially, these materials were simple polymers used to tack/reduce the spread of isotopes within nuclear facilities. Recently, chemical additions to the polymers have allowed for a more effective release and sequestration of fixed contaminants from surfaces. These improvements have increased the viability of strippable coatings as effective decontamination solutions in certain settings. However, since strippable coatings use traditional chemical components for release and sequestration of isotopes, limitations remain regarding the removal of contamination from many, especially porous, substrates. Other limitations include labor intensive removal operations and high solution costs.

3.5 Ion Exchange Media:

Various exchange media exist for applications in radiological decontamination, although most suffer from the necessity to remain wet for extended periods of time to be effective. Exchange media decontamination compounds typically include ion exchange beads, resins and various clay pastes and foam materials. For either the ion exchange beads or the clay paste, the media must remain wet during the entire decontamination process to allow for the transfer of contaminants from the substrate to the absorbing media. This represents a significant logistical burden in keeping a contaminated area wet for weeks while the electro-osmotic effects of the paste reverses the imbibition of the contaminating isotope from a porous substrate.

4.0 On-Demand Decontaminant Generation Technology

The ability to generate decontamination solutions that are precisely formulated for specific environmental, isotopic and substrate conditions, and that can be easily field adjusted to fit the existing situation, solves many of the problems noted above. Customized solution generation can be accomplished by employing a series of stable, economical, dry compounds in conjunction with modified deployment equipment based on and integrated into existing, fielded decontamination systems. For example, currently fielded Falcon Fixed Site Decontamination Systems (FSDS), High Mobility Decontamination Systems (HMDS) and other large scale deployment technologies can be effectively upgraded to include On-Demand solution generation, providing the ability to generate decontamination solutions at low cost with minimal logistical concerns. The formularies produced can be deployed as expanded Compressed Air Foam (CAF), providing visual tracking of areas treated, providing adequate dwell times on vertical, inverted and slick surfaces, and affording maximum coverage per liquid volume, all of which results in significant cost and logistical efficiencies. These solutions can be adjusted in the field to have variable oxidative / reductive states that address various isotopic matrices and substrates. Also, by utilizing various dry components and post-inject additives, additional solutions can be generated by the system, allowing for the effective performance of multiple ancillary tasks that may be required depending on the situation. An example of this scenario is the generation and application of a controllable oxidative tacking material to secure “smearable” or loose contaminants, the generation of a customized rinsate for the removal and collection of the tacking formula, and the generation and application of a reductive extraction formula customized to remove and sequester isotopic contaminants from the various substrates involved. Post injection of surfactants, sequestering agents and other compounds to address all of the mechanisms required for thorough decontamination can be readily accomplished.

Materials that are stable and dry until needed for decontamination operations significantly reduces logistical burdens, minimizes storage requirements and nearly eliminates shipping and shelf life issues. The flexibility of the generation system allows for rapid adjustments in field operations and for changing conditions. One of the key attributes of this approach is the dramatic cost savings over currently available technologies. Current chemical solutions can retail for $90 USD/gallon or more, and include all of the associated logistical issues stated above. By generating decontamination solutions as needed, or On-Demand, the cost per gallon generated is minimized. Modified decontamination and solution recovery equipment may be used for overall deployment and recovery operations, including waste handling.

Additional advantages can be leveraged utilizing this approach. Various chemical and biological decontamination solutions can be generated in the same manner as radiological decontamination solutions from dry compounds. A single system may be used to produce a full range of CBRN decontamination formulas. This versatility allows for the low cost production of decontamination solutions while minimizing logistics.

During the recovery operations, the makeup and levels of the isotopic contamination will be characterized and forensically evaluated. From this evaluation, plans can be generated for the containment and/or decontamination of the affected surfaces. After removal, sampling will be performed to confirm the effectiveness of the decontamination operations. Once cleaned to acceptable levels, the infrastructure is ready for reoccupation. Pre-planning and pre-positioning of recovery assets, training and the utilization of innovative technologies will facilitate efficient and cost effective restoration and recovery operations.

4.1 Technological Advantages

Following is a description of the technological approach, advantages, and a preliminary statement of work that addresses many of the mechanisms and requirements necessary to create a system for the successful generation of radiological decontamination solutions for an RDD recovery operation or for use in more typical DOE and commercial operations. The identification of existing associated technologies will be conducted, followed by the integration and adaptation of these technologies into a comprehensive system. This will allow for the efficient development of a market ready solution package tailored to targeted applications. Multiple advantages will be gained from the development of On-Demand CBRN decontaminant generation systems. These include but are not limited to:

Increased efficiency/efficacy – Adjusting the formulation generation in real time to effectively address specific isotopes, substrates and environmental conditions provides a significant improvement in radiological decontamination efficiency and efficacy. By ‘dialing in’ the oxidative / reductive potential of the solutions, the base chemistry components and post-inject additive materials, the same system can create formularies capable of effectively decontaminating a variety of surfaces in diverse settings.

Reduced logistics – By using materials that remain dry until needed, a significant reduction in logistics can be realized. This also substantially increases product shelf life. The utilization of a single piece of equipment to generate and deploy decontamination solutions for a variety of CBRN incidents provides logistically responsive and cost effective technology to the end user.

Reduced Cost – By increasing shelf life, reducing logistical footprints, and utilizing lower cost materials for solution composition, significant savings can be realized. When viewed from the aspect of total life cycle costs, the savings become even more significant. The ability to efficiently recover contaminated assets, whether in an urban or battlefield setting or in a nuclear facility, saves substantial costs in the recovery of the asset, material handling and disposal, and in the potential widespread economic impacts of an uninhabitable urban center or military base.

Potential for full CBRN Capability – With minor adjustments to the deployment systems and using a different group of base materials, the same systems used for RN applications can also be used for CB applications in the event of a terrorist incident or a natural occurrence such as an avian influenza pandemic. The systems will be capable of generating and deploying low cost, environmentally benign and highly effective biological decontaminants. Additional ancillary benefits exist, not the least of which is the ability to produce potable water for field use or emergency personnel.

Increased Preparedness – With an increase in RN decontamination effectiveness, a reduction in logistical burdens and the ability to tackle a wide range of incidents from the same platform, a substantial increase in overall preparedness can be achieved, filling today’s capability gap. This is enhanced by the cost reduction inherent in this approach.

4.2 Technology Development Approaches

The initial technology development approach for the program has focused on the continued advancement of the On-Demand radiological decontamination system. These efforts include the development of robust decontamination solutions that fully address the series of mechanisms required for successful radiological decontamination. The development of these solutions is being conducted in an efficient and safe manner that minimizes risk to both radiological exposure and capital outlay.

Solution developments include the formulation and application differences between RDD recovery applications and more traditional commercial applications. The RDD applications are focused on recent widespread deposition of contaminants on a range of common substrates where removal and recovery are time critical. Commercial applications typically include contamination that may have been in place for years to decades and are complicated by chemical/physical operations. This approach is typically not time critical, but the decontamination approach will commonly require additional steps and solution modifications to remove accumulated materials from substrates prior to isotopic decontamination.

Eventually, the program will be expanded to include the deployment systems, recovery systems, waste handling and disposal approaches. This will allow for the creation of a complete turn-key solution package.

4.3 Work Statement Outline

In order to advance the development of a comprehensive On-Demand decontamination system, the establishment, modification and confirmation of several mechanisms and processes will be completed. These include:

- **Tacking** –The ability to hold loose isotopic contamination in place until removal is desired (contain the problem). This enhances the removal of loose or “smearable” contamination and prepares the substrate for extraction of fixed contaminants. A tacking mechanism that is compatible with the recovery objective, along with materials and equipment, will be incorporated into the decontamination strategy. Several candidate materials have been identified and are available for assessment.

- **Breaking Bonds** – This is a critical step in the removal of fixed contamination, and includes breaking the electrostatic bonds that affix isotopes to substrates. Defining and proving the most effective materials, solution concentrations and use protocols for isotopic removal are being conducted and verified. This process is initially being tested using non-radioactive isotopes such as Co^{59} and Sr^{89} salts. This minimizes both worker exposure and analytical costs. Additional preparatory steps may be needed for commercial applications due to the entrapment of isotopes within clogged substrate capillaries.

- **Removal from Capillaries** – The capillary rise effect is often necessary to remove contaminants embedded deep in porous media. This is typically accomplished by creating a gas (such as CO2) that will displace liquids and isotopes from capillaries. Several inexpensive candidate compounds are readily available and proven effective. An effective and compatible approach for isotopic removal will be incorporated into the process. As described above, this can be initially incorporated and validated using non-radioactive isotopes to minimize cost and expedite testing.

- **Sequestering Contaminants** – Once the contaminant is released from the substrate, it must be sequestered to enable the removal and eliminate reattachment of the isotope to the substrate. Successful sequestration of a wide range of isotopes must be done effectively and at reasonable cost. Many candidate compounds are readily available and proven effective. Effective and compatible optimized compound and approaches are being defined and incorporated.

- **Surfactants** – Various surfactants are used to decrease surface tension and create a low "angle of attack" to allow for penetration of the formularies into subsurface capillaries, and assist other mechanisms, including formulation deployment as expanded foam for enhanced logistical benefits. A wide variety of these compounds are available and proven effective. Environmentally benign and compatible approaches and materials are being defined and incorporated.

- **Deployment Equipment and Configuration** – The testing and evaluation of deployed decontamination systems is being conducted. This will ensure reliable and efficient application of the decontamination solutions and assess any alterations to the systems that may need to be addressed. This assists the engineering and configuration requirements for the On-Demand system.

- **Recover and Treatment of Spent Solutions** – As part of a comprehensive decontamination system, the recovery and treatment of generated wastes must be addressed. This will include the identification and integration of commercial off the shelf or modified off the shelf equipment to recover applied solutions and treat the removed waste materials. Additionally, a proprietary system for treating liquid wastes from the decontamination process can be utilized. This process can be used to selectively remove contaminants from the waste stream, reversibly release the concentrated contaminants, and then be reused. As described above, this can be initially tested using non-radioactive isotopes to minimize costs and expedite development and testing.

- **Test Facility** – Initial "proof of concept" testing is being performed with non-radioisotopic materials to minimize cost and radiation exposure. Analytical laboratory capabilities are being used to verify removal efficacy of solutions on analogous non-isotopic contaminants. Once proven to this level, a licensed radiological facility will be employed for the handling and testing of various radiological materials.

5.0 Product Applications

The wide range of market opportunities requires the development of various flexible decontamination and recovery systems to meet requirements for an array of potential users. Initially, two types of systems are envisioned to address various applications. These include a system designed for emergency and RDD type recovery operations, and a second type of system designed for commercial nuclear and DOE activities. The systems will have many common technologies and components, but also will have a number of significant differences. For example, the deployment systems may be virtually the same, but the solution generation and liquid recovery systems may be substantially different based on specific requirements. By tailoring the systems to unique applications that can rely on the same fundamental technology, a cost effective family of decontamination and recovery systems can be produced.

5.1 US DOD, JSTDS-LS Program, Base Protection

The upcoming Joint Services Transportable Decontamination System – Large Scale (JSTDS-LS) program from the Joint Program Executive Office (JPEO) is seen as an initial impetus for the development of the On-Demand decontamination system. From previous discussions with PM Decontamination, it is expected that some level of radiological decon capabilities will be a part of the requirements for the large scale system. It is believed that having a developed and proven radiological decon technology that can be integrated into the team offering will provide a strong capability for the overall system that no competitors will be able to meet. The overall concept for the radiological capabilities was presented to PM Decon in June of 2007, and by all accounts was well received. The request was made for a base level of test data in order to begin to substantiate the technological capabilities of the system. The most recent information that has been received has the Request for Proposal for the program being issued to industry in the FY2010 timeframe.

5.2 US DOD Other, Nuclear Navy, DU Munitions

The Nuclear Navy would have use for both commercial type decontamination systems as well as for emergency/RDD type systems. Commercial decontamination systems (likely port based) can be used for asset recovery, waste reduction and routine maintenance operations. The emergency/RDD decontamination systems (likely ship based) can be used to protect individual ships, ports, and in the event of spills and leaks on board ship.

Additional decontamination activities would include routine maintenance and asset recovery operations. Some of these systems would probably be developed in conjunction with the Navy to address size constraints, configuration and other requirements.

The decontamination of facilities, equipment and activities utilizing Depleted Uranium (DU) would include production, handling, testing and use, with the exception of the actual impact zone from DU munitions due to the melting of the affected materials. The remaining area around the impact zone could be recovered and restored for use. Other applications include decontamination activities related to reactive armor manufacturing and use. Currently, the US has approximately 500,000 tons of DU available for operations.

5.3 US DHS, Urban Consequence Management Preparedness

The Department of Homeland Security (DHS) and similar agencies focus on emergency incident and RDD recovery type decontamination activities. The solutions and systems for this application will be developed with long shelf lives, tacking capability and the ability to recover contaminated solutions in an emergency situation. It has been estimated that a dirty bomb detonated in Manhattan could have cost impacts (real estate alone) in excess of $1 billion per block of contaminated real estate.

Currently, DHS has a preliminary budget of $46B in 2008. Of this budget, only $208M is being allocated to radiological detection. Additionally, DHS has not yet focused on consequence management as the entire push in the radiological preparedness arena has been focused on detection systems. Much of the technology development activities for radiological decontamination reside within DARPA, HASARPA, DTRA and other agencies. Eventually, it is thought that DHS will require decontamination systems for large scale incidents and asset protection including ports and other transportation facilities. The overall DHS system development will closely mirror the JSTDS-LS development as mission profiles and requirements will likely be similar.

5.4 US DOE facilities, Closures, Asset Recovery, Waste Reduction

Significant decontamination opportunities exist within the DOE, including facility closure activities at Hanford, Oak Ridge and Paducah, among others. The closures often require significant decontamination of the internal building infrastructure and occasionally portions of the structure itself prior to demolition.

Waste reduction from continuing operations and legacy waste storage/repackaging facilities is a significant issue within the DOE. An example includes using decontamination for routine waste reduction in converting high level waste to low level waste. Although the isotopic mass is conserved, the change from high level to low level has considerable cost savings in final disposal expenses and transport. The Transuranic (TRU) waste program is an ideal candidate for this application.

For 2008, the DOE budget proposes $5.7 billion for the Environmental Management program that protects public health and safety by cleaning up vast amounts of hazardous and radioactive contamination at 108 of the 114 sites involved with nuclear research and weapons production. An additional $9.1 billion is allocated to the NNSA for ongoing operations, with a portion of these funds being expended on decontamination, materials recovery and worker safety considerations within the ongoing operations.

At the Hanford facility alone, (estimated ~$15 billion clean up costs) the following types and quantities of radiological waste and contamination have been identified at the site, providing a wide range of decontamination opportunities:

- 2,100 metric tons of spent nuclear fuel (80% of the irradiated uranium fuel in the DOE inventory).
- 11 metric tons of plutonium in various forms at the Plutonium Finishing Plant, contained in the spent fuel at the K Reactor Basins, and in the spent fuel at the Fast Flux Test Facility.
- About 750,000 cubic meters of buried or stored solid waste in 175 waste trenches.
- About 1 trillion liters of groundwater contaminated above EPA drinking water standards, covering over 80 square miles. The contaminants include metals, chemicals, and radionuclides.
- 1,936 stainless-steel capsules of radioactive cesium and strontium, containing roughly 125M Curies of material in water-filled pools.
- More than 1,700 identified waste sites and 500 contaminated facilities.
- More than 53 million gallons of liquid radioactive waste remain in 170 aging, underground single-shell tanks (7 single-shell tanks retrieved to date).

Many of the high level waste decontamination activities will require the use of modified “decontamination robotics” due to the lethality of the dose involved. One example is the decontamination of the waste tanks and “canyon” facilities that were part of the Purex process at the Hanford Site.

Ongoing operations require routine maintenance and decontamination to protect workers and equipment. One example is the ongoing operations in glove boxes. These require routine decontamination to minimize worker exposure as they are commonly in close proximity to nuclear materials (i.e., thickness of a glove). Routine maintenance activities also commonly require decontamination efforts.

Many of the large contracts for the various facilities are coming up for re-bid over the next few years. An effective, cost competitive and environmentally friendly decontamination system that improves safety in the event of accidental releases may provide a distinct advantage to a team bidding these types of contracts.

5.5 Commercial Nuclear Facilities

Of the categories of opportunities for radiological decontamination, the commercial nuclear aspects are the largest. Additionally, commercial opportunities are typically tied to power generation, making them less susceptible to recession and outside of government spending cutbacks. The commercial nuclear industry is international in scope, and thus provides diversification in a comprehensive business model. The commercial nuclear industry is also entering a new era of growth that will probably continue for decades.

The opportunities in the commercial sector vary from routine maintenance, decommissioning, waste handling, emergency response, asset recovery and general housekeeping activities (in the commercial world, minor leaks or spills are always referred to as “housekeeping”). This wide range of applications would require the development of a variety of systems from small to large and include specific procedures and modifications to address the unique issues of a commercial facility.

To understand the scope of the commercial market, the following discussion is provided (source: Energy Information Agency). As of October 31, 2005, there were 104 commercial nuclear generating units fully licensed by the U.S. Nuclear Regulatory Commission (NRC) to operate in the United States. Of these 104 reactors, 69 were categorized as pressurized water reactors (PWR) totaling 65,100 net megawatts (electric). Thirty-five units were boiling water reactors (BWR) totaling 32,300 net megawatts (electric). Although the United States has the more nuclear capacity than any other nation, no new commercial reactor has come on-line since May, 1996. The current Administration has been supportive of nuclear expansion, emphasizing its importance in maintaining a diverse energy supply. As of April 1, 2005, however, no U.S. nuclear company had yet applied for a new construction permit.

According to the Uranium Information Center, there are currently 439 commercial reactors operating world wide. Additionally, 33 are currently under construction, 94 are planned and an additional 222 are proposed. This represents an 80% increase in reactors worldwide that will be completed over the next 10 to 12 years, with all of the growth planned in international markets.

This growth in commercial nuclear power systems has a critical pinch point, which is the availability of uranium based fuel. Currently, worldwide yellowcake production is approximately 100 million pounds per year, and demand is ~170 million pounds per year. This shortfall in fuel availability can be seen in the price of uranium, which has soared from ~$8/pound in the late 1990s to a recent spike over $140/pound, with the current price as of January 1, 2008 at $92 per pound. This spike in raw fuel prices also provides opportunity. The mining, fabrication, conversion and enrichment facilities will be under great duress to meet fuel demand. Improvements to any of these processes through decontamination, materials recovery operations or waste handling will be in high demand.

As discussed above, some high-level decontamination activities will require the use of modified “decontamination robotics” in order to protect worker safety and the environment. This will be an advancement in the development of decontamination system technologies, and will eventually loop back to military and DHS applications.

6.0 Estimated Project Timeline

The initial program thrust will focus on developing and validating a radiological decontamination technology for the US DOD, US EPA and US DHS. A completion date for the initial rounds of surrogate testing is estimated in fourth quarter FY08. Other technology applications may be developed concurrently. The time estimates noted below are for planning purposes only, and will be adjusted according to resource availability and system requirements. Some of the factors that will determine actual timelines include availability of testing and laboratory facilities, availability of funding and possible Government participation in the program from funding and oversight perspectives.

The prescribed development program has been planned with milestone progress evaluations in order to minimize investment risks. Each milestone will result in a go/no go decision point to determine whether to move forward or terminate the program. This outline represents a high-level overview of the plan to be developed. The proposed phases for development are:

1. Initial testing with non-radiological materials on multiple substrates, analysis of results, begin formulation optimization work: completion 4QFY08
2. Initial phase of radiological tests, likely with cobalt chloride and cesium chloride on multiple substrates, analysis and formulation optimization: completion 2QFY09
3. Additional testing, formulation and system optimization, incorporation into deployment systems, develop TTPs, product packaging, field logistics: completion 3QFY09
4. Compatibility and deployment testing, large scale field test & verification of technology readiness: completion TBD

In order to expedite the technology development for non-DOD and DHS applications, it may be decided to develop ancillary capabilities concurrently with the schedule outlined above. Many of the developments and modifications needed for commercial and DOE applications can be validated in the same timeframe with additional resource availability.

7.0 Ancillary Technology – DORMS Software

Response to and recovery from CBRN incidents is an exercise in decision making. Every action is predicated on a decision whose objective is to reduce or eliminate the risk posed to human health and infrastructure. The quality of the decisions, and subsequent achievement of the objectives, is directly proportional to the quality of the available decision-making information. Response and recovery actions taken following an incident should be based on health risks posed by the incident to emergency personnel and the public. Risks include many factors related to the nature and extent of the hazard as well as availability and effectiveness of response and recovery options.

How risks are managed defines the course of response and recovery and determines the ultimate success of the actions taken.

DORMS is an enterprise-scale geographic information system (GIS)-based data management and analysis software application derived from an application used for the cleanup of a nuclear weapons production facility. The application combines a GIS database system with a human health risk assessment module. The application provides accurate and rapid management of relevant data and estimate of risk to guide first responders through CBRN incidents, estimate risk to workers and residents, and produce decontamination and remediation plans.

The many steps associated with the calculation of risk, including extensive sample data analysis and management, are computationally intensive. In order to benefit response and recovery, the risk assessment process must be automated via software. The software system must be inclusive of all steps of the assessment process from data management to the output of risk calculations based on geographical areas of interest. The system must be fast and provide responders with direct interface for the purpose of querying to support rapid decision-making.

The DORMS Risk Assessment Module was developed to conform to US Environmental Protection Agency (EPA) guidelines for calculating all components of risk assessment and produces technically defensible results. Because DORMS was developed from an application to support the accelerated characterization and remediation of a nuclear weapons production facility, the GIS, data management, and risk assessment functions are strong and comprehensive for chemical, radiological and nuclear applications. Closely monitoring EPA research to develop consensus risk factors for microbial agents will allow rapid incorporation into the module as they are available.

The Risk Assessment Module is a complex application whose output provides decision-makers with risk-based information to establish priorities, monitor ongoing changes in risk to humans and infrastructure and document results for future final cleanup actions. The application calculates acute risks to humans from non-cancerous and cancerous agents as well as long-term chronic non-cancerous and cancerous effects. The module enables responders to determine appropriate PPE for workers and prioritize human demographic and infrastructure targets for maximum response effectiveness. Risks to human health and infrastructure are primary considerations in CBRN response planning, and are the attributes that set DORMS apart. A user can have access to real-time, risk-based, decision quality information as an incident unfolds and recovery progresses. Along with the cost savings delivered through maximizing efficiency and effectiveness, the client will be establishing a technically defensible basis for performing final cleanup and addressing regulatory and public interest group concerns. Coupling the DORMS software application with On-Demand decontamination capabilities provides a comprehensive platform for incident response.

8.0 Summary

Technology now exists to allow the creation of a technologically advanced system capable of generating a variety of decontamination formulas for the efficient and cost effective recovery of an area affected by a radiological incident or for decontamination of commercial facilities. The system and solutions created would address all of the factors needed for successful removal of radiological contaminants, while both user and environmentally friendly, and would result in a significant step forward in filling current decontamination capability gaps. The generated formulas would be field-adjustable to address environmental and incident-specific conditions, and formulations of varying oxidative and reductive potentials can be produced to fulfill the requirements of a recovery operation. Fielded decontamination systems can be modified to incorporate this innovative technology, and logistically advanced application methodologies can be employed to improve logistical and cost performance over the life of the system.

9.0 Initial Test Results

Initial test results for the various decontamination formulations were very encouraging. The testing was conducted on a series of substrate coupons that were contaminated with surrogate solutions of cobalt and strontium ($CoCl_2$* 6H2O and $Sr(NO_3)_2$). A series of surfactants and sequesterants were combined with the decontamination solutions to enhance effectiveness. An initial series of 9 combinations of solutions were tested and used to formulate the subsequent round of testing. During the process, only one decontamination "cycle" was applied to the coupons for comparison purposes. The primary focus of decontamination testing is on various porous media due to their inherent decontamination complexity.

Substrate	Baseline H2O Decontamination	Decontamination Cobalt	Decontamination Strontium	Comments
Marble (Travertine)	~72% Co ~78% Sr	96 – 99%	96 – 100%	Reactive porous media
Brick	~12% Co ~28% Sr	80 – 86%	89 – 95%	Initial formula – revised for subsequent testing
Steel	~97% Co ~99% Sr	99 – 100 %	100%	Non – porous media
Concrete	~0 - <10% Co ~0 – 20% Sr	N/A	N/A	In testing
Granite	~61% Co ~75% Sr	63 – 77%	95 – 100%	Reactive non-porous media

Table 1. *Initial radiological surrogate test data – contaminant applied as salts in acid solution – decontamination involved single application/removal of decontamination formulas.*

Utilizing the data collected, new formulations are being prepared for the next round of surrogate testing. Results of this round of testing should be available in early November of 2008. One additional round of surrogate testing will be conducted prior to testing actual radioactive materials in a licensed facility (this was approach was designed to streamline development efforts and minimize cost and dose).

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