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Report on the

Workshop on Radionuclides in Wastewater Infrastructure Resulting from Emergency Situations

Office of Research and Development
National Homeland Security Research Center

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The workshop participants, listed in Appendix A, provided critical input into the discussions and are gratefully acknowledged. In addition to their contributions to the discussion during the workshop, many made presentations that covered the breadth of topics important to elucidating workshop outcomes.

WERF, a not-for-profit organization, funds and manages water quality research for its subscribers through diverse public-private partnerships between municipal utilities, corporations, academia, industry, and the federal government. WERF subscribers include municipal and regional water and wastewater utilities, industrial corporations, environmental engineering firms, and others that share a commitment to cost-effective water quality solutions. WERF is dedicated to advancing science and technology addressing water quality issues as they impact water resources, the atmosphere, the lands, and quality of life. Neither WERF, members of WERF, nor any person acting on their behalf: (a) makes any warranty, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this report or that such use may not infringe on privately owned rights; or (b) assumes any liabilities with respect to the use of, or for damages resulting from the use of, any information, apparatus, method, or process disclosed in this report.

Foreword

The U.S. Environmental Protection Agency's (EPA) Homeland Security Research Program (HSRP) is helping to protect human health and the environment from adverse impacts following chemical, biological, radiological, or nuclear (CBRN) contamination; whether it involves an intentional act such as terrorism, a natural disaster, or an industrial accident. Information about HSRP is found at http://www.epa.gov/nhsrc.

An important focus of HSRP research is improved detection, response, and recovery capabilities related to radiological contamination of the nation's drinking water and wastewater infrastructures. HSRP is currently investigating data gaps in these areas that, if filled, could assist wastewater plant operators in making decisions about whether and how to accept wastewater contaminated with radionuclides during an emergency situation. This work is being performed with input from key water sector and security stakeholders.

The HSRP is pleased to make this publication available to assist the drinking water and wastewater communities in preparing for and recovering from disasters involving radiological contamination.

Gregory D. Sayles
Acting Director, National Homeland Security Research Center

Executive Summary

The Water Environment Research Foundation (WERF), in partnership with the U.S. Environmental Protection Agency (U.S. EPA) National Homeland Security Research Center (NHSRC), hosted an expert workshop December 3-4, 2012, in Alexandria, Virginia, to engage with subject matter experts and wastewater utility stakeholders on a number of topics surrounding radionuclides in wastewater collection and treatment systems, should the radionuclides enter the systems as a result of an emergency situation. The workshop included presentations and discussion on topics such as:

- ***How radioactive materials may contaminate water entering municipal wastewater treatment plants.*** These include naturally occurring sources, medical sources, regulated wastewater discharges from U.S. Nuclear Regulatory commission (NRC) licensed facilities, accidents, criminal acts, and response and decontamination activities following a radiological incident.
- ***Impact of radioactive materials on the operation of wastewater collection and treatment plants.*** The consequences of wastewater plant failure to continue operation during major disasters was vividly demonstrated recently by Super Storm Sandy.
- ***Fate and transport of radiological material in collection systems and treatment.*** Wastewater collection systems are complex, highly engineered, and composed of many locations and materials that may potentially serve as sinks for radioactive materials.
- ***Past projects related to the release of radiological contaminants by emergency situations.*** Department of Homeland Security and EPA have conducted exercises and research and development projects related to the catastrophic release of radiological contaminants.
- ***Past projects relevant to the introduction of radiological contaminants by non-emergency situations.*** The Interagency Steering Committee on Radiation Standards undertook a survey of radioactivity in sewage sludge (biosolids) at the request of the Government Accountability Office following discovery of radioactive materials in sewage plants resulting from regulated activities.
- ***Case studies of actual radiological contamination.*** This includes not only the Fukushima Dai-ichi nuclear power plant catastrophe, a number of domestic incidents, and hydrofracking that provide valuable insights.
- ***Worker Health and Safety.*** Because wastewater treatment plants are critical infrastructure, treatment plant workers may be considered part of the emergency response team in the event of an RDD incident. Most treatment plant workers have not had training and experience dealing with radiation.

- ***Risk communication and management.*** Public perception of radiation is fatalistic. Risk communication is therefore extremely important. Part of the workshop included a participatory exercise during which attendees created message maps, i.e., pre-planned messages for crisis communication, for several audience types.

The key objective of this workshop was to provide EPA NHRSC recommendations and technical information in the area of radionuclides in wastewater infrastructure resulting from emergency situations, as well as related needs and concerns of, and potential solutions for, the wastewater industry. Workshop participants considered several key questions regarding radionuclides in the wastewater treatment process. Theses questions helped guide and focus the discussions and define and prioritize key next steps, including:

- What is needed / required for utilities to accept radioactive contaminated wastewaters?
- What sorts of tests, protocols, and regulatory guidance are needed? What is needed for permit authorities to guide / allow utilities to accept these wastes?
- How should these be designed or implemented? Who should design and evaluate these? Are there other "simpler" tests and protocols?
- What is needed to address concerns and issues raised by the public, wastewater workers, and operators?
- What are the data gaps and what type of research is needed?

The discussion included overarching issues, criteria for wastewater plants' acceptance of wastewater, impact of contamination on collection systems, and impact on biosolids. Potential solutions and needs discussed included pre-planning, sampling and analysis, worker safety and training, crisis communication for multiple audiences, application of regulations, and funding. The discussion phase of the workshop defined six general categories for further investigation. The workshop developed consensus about prioritizing key next steps/needs, summarized in the table below. The table includes only the most important needs; in addition, other needs were identified.

Category	Highest Priorities
Worker Health and Safety	• RAD safety and training for workers that is available based on need.
Identification, Characterization, and Containment	• Scenario-based, generic response plan that wastewater utilities could incorporate into their existing emergency response plans. • Decision tree for plant managers to help them provide guidance to first responders on the criteria for the acceptance of radionuclide contaminated wastewater. This would include guidance on when first responders can discharge contaminated wastewater, the best places in the collection system or headworks for discharge, and acceptable chemical limits for discharge water.
Communications	• Guidance on how utilities should work with first responders and the Joint Information Center of the Incident Command Center.
Regulatory and Permitting	• Clarification on regulatory relief during emergency situations for both potential quality violations and how these violations are logged into the online OECA database. The hope is that there is a way to label the violations as linked to an emergency situation.
Scientific and Engineering	• Research on fate, transport, and remediation of radiologicals in wastewater treatment plants. Remediation research should also include potential legacy scenarios resulting from deposition in pump stations, pipes, and plants. • Generic sampling plans that can be included in generic emergency response plans. • Increased capacity for sample analysis, perhaps via more rapid analysis.

TABLE OF CONTENTS

Introduction 4

Background 5
- Radiological Dispersion Device (RDD) Exercises 5
- Non-RDD Case Studies 7
- Radiological Contamination Pathways 9
- Fate and Transport of Radiological Material in Collection Systems and Treatment 11
- Working with Key Stakeholders 12

Risk Communication and Management 14
- Message Mapping 101 Exercise 14

Workshop Outcomes 17
- General Discussion 17
- Discussion of Potential Solutions and Needs 18
- Table of Prioritized Needs 21

Appendix A: Workshop Participant Contact List A-1
Appendix B: Workshop Agenda B-1
Appendix C: Additional Resources C-1

INTRODUCTION

The Water Environment Research Foundation (WERF), in partnership with the U.S. Environmental Protection Agency (U.S. EPA) National Homeland Security Research Center (NHSRC) hosted an expert workshop December 3-4, 2012, in Alexandria, Virginia, to engage with subject matter experts and wastewater utility stakeholders on radionuclides in wastewater collection and treatment systems. The key objective of this workshop was to provide EPA NHRSC with recommendations and technical information in the topic area (radionuclides in wastewater infrastructure resulting from emergency situations), as well as related needs and concerns of, and potential solutions for, the wastewater industry.

The NHSRC conducts research to detect, respond to, and recover from terrorist attacks on the nation's water and wastewater infrastructure. The U.S. EPA has been conducting research on ways to prevent, detect, contain, and treat contaminants in water and wastewater, and is also producing tools and procedures for decontamination. All of this work is being performed with input from U.S. EPA's primary water security stakeholders. NHSRC is currently investigating what research gaps exist in order to help guide wastewater plant operators to decide whether and how to accept some or all wastewater contaminated with radionuclides as a result of an emergency situation. More information on U.S. EPA's homeland security research program can be found at www.epa.gov/nhsrc.

Participants considered several key questions regarding radionuclides in the wastewater treatment process. These questions guided the discussions throughout the workshop:

- What concerns need to be addressed?
- What is needed / required for utilities to accept radioactive contaminated wastewaters?
- What sorts of tests, protocols, and regulatory guidance are needed?
- How should these be designed or implemented?
- Who should design and test these?
- Are there other "simpler" tests and protocols?
- Other questions or concerns?

In addition the following questions were used on the second day to help define and prioritize key next steps:

- What is needed for utilities to accept radionuclide contaminated waters?
- What types of tests and protocols are needed (and what is the design for such tests) by Stakeholders?
- What is needed for permit authorities to guide / allow utilities to accept these wastes?
- What is needed to address concerns and issues raised by the public, by workers, and operators?
- What are the gaps and what types of research is needed?

This report summarizes key points of the discussion that took place during the workshop. It also outlines future needs and steps. Additional meeting materials such as the participant list and agenda are included in the Appendices.

BACKGROUND

The workshop provided an opportunity for wastewater and drinking water representatives, subject matter experts, and regulatory representatives to discuss scenarios where radionuclides could be introduced into the treatment system. The scenarios included radionuclides that may be bound or unbound to other substances and may have entered the wastewater system in a number of ways, including: (1) after radiological dispersion device detonation, (2) detonation of an improvised nuclear device, (3) via an incident at a nuclear power plant, (4) intentional introduction, (5) unintentional introduction, or (6) enhanced natural background sources, among other pathways.

Radiological Dispersion Device (RDD) Exercises

During the workshop, two exercises were described to inform participants' thinking about what might happen during a radiological dispersion device (RDD) or dirty bomb scenario. These were the scenarios of the Wide Area Recovery and Resiliency Program (WARRP) in Denver, Colorado and the Liberty Radiological Exercise (LibertyRadEx) in Philadelphia, Pennsylvania. The assumption for both exercises is that the RDD would contain the radioactive isotope Cesium 137.

Wide Area Recovery and Resiliency Program (WARRP) Overview, Denver, Colorado

The Department of Homeland Security (DHS) and the Denver Urban Area Security Initiative (UASI) initiated a collaborative program aimed at enhancing wide area recovery capabilities of large urban areas, military installations, and critical infrastructure following a large-scale chemical, biological, or radiological (CBR) incident. The goal of the WARRP was to work with interagency partners to enhance recovery capabilities in the Denver metropolitan area and other regions across the nation. The exercise focused on developing key capability areas in:

- Front end systems study and gap analysis
- Wide area recovery framework
- Science and technology development
- Workshops exercises and demonstrations
- Transition to end users

The WARRP developed a number of products that are available on the website, www.warrp.org. These products include:

- Response and Recovery Knowledge Products (RRKP) that include key planning factors for recovery from a radiological terrorism incident.
- Interim cleanup strategy that documents a sample approach for state and local recovery managers to develop guidance on determining cleanup levels. This is useful to aid in defining goals for site and incident specific recovery. This strategy does not represent a specific policy.
- Waste screening and segregation methods for waste minimization that identifies high-priority waste streams from the radiological event and also waste streams that have potential to be minimized.
- Cesium (Cs) RDD Wash-Aid technology that is designed to decontaminate key infrastructure.

Lessons Learned for Wastewater Treatment from WARRP

WARRP revealed a need to focus on developing scalable technologies for radiological sampling and decontamination. Some of these, especially those for decontamination, are water-based technologies that will generate significant quantities of wastewater. Treatment plants need to consider the role they will play in the treatment of this wastewater. A waste estimation tool developed for WARRP showed that several billion gallons of radiologically contaminated wastewater could result from decontamination activities. It may therefore be necessary that the wastewater utility deal with a sizeable fraction of this decontamination water.

WARRP also revealed unexpected consequences for wastewater treatment. For example, the Denver Urban Area includes agricultural areas which may generate significant amounts of livestock and agricultural waste. This may include livestock that may be rendered unsuitable for consumption, that may die due to the blast, or that may have to be euthanized because of animal welfare concerns. It may also include contaminated dairy products – millions of gallons of milk that may have to be disposed of through wastewater treatment plants. It is important to educate dairy farmers, perhaps through agricultural extension county agents, about treatment plant limitations – these farmers may just pour this milk down the drain without considering the implications on the collections or treatment systems. Until such education, perhaps enabled by communication plans, wastewater plants may need to assume they will be receiving large quantities of contaminated milk.

Liberty Radiological Exercise (Liberty RadEx), Philadelphia, Pennsylvania

Liberty RadEx was a national exercise sponsored and designed by the U.S. Environmental Protection Agency (U.S. EPA) to practice and test federal, state, and local assessment and cleanup capabilities in the aftermath of an RDD incident in an urban environment. Liberty RadEx was unique in that participants practiced their "post-emergency" phase responsibilities and coordination, and worked with stakeholders and the public to plan for community recovery. Liberty RadEx also provided the opportunity to share information and procedures while strengthening relationships among federal, state, and local partners in Pennsylvania and adjoining states.

As part of the exercise, a community advisory forum was established that included members of the public and organizations that would have been directly affected by the radiological plume. Their focus was to prioritize cleanup scenarios either based on highest concentration of radiological materials, highest population, or a combination of concentration and population. The community advisory forum decided against starting at the most highly contaminated area or the most populated area in the evacuated zone and instead decided to start cleanup at the outer perimeter of the contaminated area and work towards the middle.

The community advisory forum was also asked to identify temporary waste staging areas for the contaminated waste. The advisory forum chose one area from the three options given to them and then picked other additional sites beyond the options presented to them that included an abandoned super fund site. A good lesson learned from this exercise was that when faced with important decisions, the public did not show a great deal of not-in-my-back-yard, or "NIMBY" (not in my backyard), behavior and they were dedicated to finding solutions.

Lesson Learned for Wastewater Treatment from Liberty RadEx

There will be much waste generated from an RDD event and the community will have to handle it. Projected costs of shipping waste and gaining acceptance at a nuclear disposal landfill were estimated at close to one billion dollars. Because of the high cost, Pennsylvania would consider local or regional solutions to waste disposal in the event of an RDD event.

The radiological plume is large – in this exercise it extended almost 50 miles. There will be people living with levels of radiation that are higher than typically observed background levels. Their daily activities (washing clothes, flushing toilets, etc.) will introduce radiation into the collection and treatment systems.

Weather will play a role in the dispersal of the radionuclides. For areas with a high likelihood of rain, stormwater and wastewater systems will receive radioactive runoff and will need to both treat this water and also become one of the sites of the cleanup effort.

Aqueous decontamination will most likely be limited to within a few blocks of the detonation site within the first few days. This means that collection and treatment systems will most likely see the largest concentration of radioactive material and the largest volumes of water in those first few days.

There may be wastewater treatment plants within the 'hot zone' whose treatment operations will need to be maintained as critical infrastructure. They will need to receive supplies of chemicals and have workers who are trained in radiological disasters to maintain plant operations.

Non-RDD Case Studies

Also discussed were non-RDD case studies where treatment plants were affected by radiological materials.

Fukushima Dai-ichi

The events at Fukushima produced millions of gallons of contaminated wastewater, containing both radioactive isotopes and salts. This wastewater was primarily a result of the introduction of sea water, either from the tsunami or from the deliberate decision to introduce sea water into the core cooling system. Efforts were made to try to contain the contamination; however, radioactive isotopes were found in local water channels, on foliage, and in the ocean. Iodine 131 from Fukushima was detected in Pennsylvania two weeks after the meltdown event.

Quickly after the event, Japanese officials requested a treatment system that would recycle water to eliminate the need to introduce new water to the cooling system. The requirements of the treatment system were:

- Must avoid ocean release of wastewater and radioactive materials
- Effectively remove Cs and reduce salinity
- Create recycled water that can be used for reactor cooling

A system was designed that includes a selective Cs removal media and a reverse osmosis system for desalination. The introduction of the Cs removal media significantly reduced waste volumes. Future needs include the treatment of the reverse osmosis brine, treatment of the sub-drain water to remove Cs from dilute seawater, and strontium removal from the recycled cooling water.

While there has been a great deal of local support for the cleanup, the issue of long-term waste disposal needs has not been resolved.

Royersford Nuclear Laundry

A laundry that served nuclear power plants in Pennsylvania was discharging its wastewater to the Royersford wastewater treatment plant. Radioactivity was concentrating in the plant's reed beds, in its digesters, and in the biosolids that the plant was land applying. Since the laundry was licensed by the NRC, they argued that the cleanup was not their responsibility, but rather, that it was the responsibility of the treatment plant. The utility ended up paying for cleaning the reed beds and digesters.

Kiski Ash Lagoon

In March 1977, the Kiski Water Reclamation Authority received wastewater that consisted of sanitary and sewage water from a U.S. Nuclear Regulatory Commission licensed laundry. The sewage treatment process included a collection of solid wastes from both primary and secondary treatment, followed dewatering and onsite incineration. The ash was sent to the ash lagoon for disposal. The authority stopped sending ash to the facility in 1993, when it reached its capacity. In the early 2000s, the Pennsylvania Department of Environmental Protection (PADEP) and Kiski Water Reclamation Authority worked with NRC to develop a decommissioning plan for the ash lagoon. In

2006, the ash was shipped to a RCRA subtitle C disposal site.

Hydraulic Fracturing Water

Hydraulic fracturing practices create millions of gallons of wastewater. This wastewater contains significant amounts of organic compounds, salts, and naturally occurring radioactive material (NORM). A number of vendors offer mobile treatment units to hold, transport, treat, and store hydraulic fracturing wastewater for the natural gas and ancillary support industry. An internet search of “mobile fracking water treatment systems” reveals technologies with claims about performance that might prove useful, but have not necessarily been rigorous investigated, for holding and treating wastewater from nuclear decontamination activities.

According to some workshop participants, the acceptance of wastewater from hydraulic fracturing provides a cautionary tale to the wastewater treatment industry. Namely, some treatment plants have accepted this wastewater in the past without fully understanding how the high salinity, radioactivity, and concentration of organic compounds may affect treatment systems. This can pose a threat to receiving waters due to plant upset, failures, and inadequate treatment for salts, radionuclides, and organic compounds.

Iodine 131

In Pennsylvania, elevated levels of Iodine 131 (I-131) in drinking source waters are being observed independent of the Fukushima Dai-ichi incident (the half-life of I-131 is about 8 days). It is hypothesized that the source of the I-131 are medical patients who are receiving it as a thyroid treatment. Wastewater from hospitals is monitored; however, patients may be leaving the hospital with 0.005 to 0.2 curies of I-131 in their bodies and eliminating quantities into the sewer system via urination. This poses a problem because drinking water MCLs are measured in pico curies/liter. While the elevated concentrations of I-131 in source waters may not pose a human health risk, they will affect drinking water providers who must treat drinking water to the low MCLs. Thus, it is important to consider the impacts of wastewater utility acceptance of radionuclides on drinking source waters when making decisions.

Tritium Exit Signs

Standard exit signs used in many buildings use tritium that is enclosed in glass tubes lined with a compound that emits light in response to the low-energy beta radiation from the tritium. These signs are prevalent, their use is not licensed, and the distribution and disposal are not well controlled. For this reason, over 90% of the landfills in Pennsylvania show tritium concentrations above background levels. PADEP put monitoring protocols in place for landfills and have not found any situations where tritium is posing a human health risk from landfill leachate.

Radiological Contamination Pathways

During the workshop, many potential avenues of radiological contamination of wastewater treatment plants were discussed including, but not limited to, large-scale decontamination efforts, wash water from contaminated clothing, as well as run-off from rain events. Participants presented different scenarios for comment as outlined below.

Release of Radionuclides from Contaminated Clothing during Laundering

The study looked at the implications of washing contaminated clothing after, for instance, a radiological dispersion device (RDD) or an accident at a nuclear reactor facility. The data would be used to make recommendations for handling radioactively contaminated clothing. The assumption is that people living outside of exclusion zone are likely to wash clothing and other soft porous items. The goal was to be able to provide a scientifically based answer to the question, “Should I wash contaminated clothing?”

The project was designed to answer two questions:

- How effective is washing to remove radioactive contamination from swatches of soft porous materials?
- What is the impact of washing uncontaminated clothing with contaminated swatches-- percentage removal and the fate of the contamination in the wastewater and within the washing machine?

Results:

Washing with detergent removed more than 95% of the contamination under the different test cases. Washing with detergent was marginally more effective than washing without detergent. Most of the Cs removed from the clothing ends up in the wastewater. There is a small amount of contamination left in washer with detergent. In addition, uncontaminated clothing washed with contaminated clothing became contaminated.

In summary, it was noted that washing contaminated clothing will likely occur outside of the exclusion zone; however, this will introduce radioactive contamination into wastewater streams, which will impact wastewater treatment plants.

This study is published under the following citation: *Assessment of the Fate of RDD Contamination after Laundering of Soft Porous Materials* EPA/600/R-12/053.

Wash-Aid Program

The goal of this program is to develop a cost-effective means of decontaminating an urban setting for the purpose of restoring critical infrastructure and operational activities after a radiological release. The decontamination system will focus specifically on removing cesium from building materials, brick, concrete, tile, asphalt, vehicle surfaces and other surfaces important for rapid restoration of public services and critical infrastructure. All methods will use commercial, off-the-shelf technologies, common reagents, and familiar unit operations to decrease response time and expense.

In addition, these technologies may require the use of massive amounts of water.

The project explored various decontamination approaches:

- Cover contamination zone with agent (e.g., film) to control re-suspension and perform decontamination operations at a later date
- Wash down contamination zone, divert water and dilute in local, natural reservoir
- Wash down contamination zone, allow water to travel through sewer system and treat at downstream location
- Wash down contamination zone, introduce sequestering agents, allow water to travel through sewers and treat downstream
- Wash down contamination zone, contain water locally and dispose
- Wash down contamination zone, introduce sequestering agents and contain water locally and dispose
- Wash down contamination zone, introduce sequestering agents, contain water locally and treat water to free release or reuse and dispose of sequestering agents

The project focused on this final scenario because of the water reuse potential. Research has demonstrated the effectiveness of salt brines for the release of radioactive ions from rocks and clays. The use of salt brines also eliminates the need to use harsh acids or redox agents. In addition salts are commonly available in large quantities. Salt brines must be very concentrated in order to remove radionuclides from porous surfaces; brines of 0.5M were able to achieve removal rates of 60%, even from certain aged surfaces. For some un-aged surfaces, removals can reach close to 90%.

The research also looked at how to effectively create and deliver the brines. One method was to use firefighter technologies, including temporary reservoirs and foam eductors that can deliver massive amounts of brine-containing water per day.

Clays are then used as sequestering agents in the decontamination water. Sequestration is highly dependent on the structure of the clay. Different clays work better for different radioactive salts and concentrations. The clayslurry can achieve up to a 90% sequestration of Cs ions in water. Of note is that some synthetic materials also work very well; however, the cost and availability of these materials is likely prohibitive for this application.

The project also explored containment of the decontamination wastewater through a variety of methods. Use of the existing wastewater collection system (sewers) as a reservoir was explored; however, because of the large amounts of wastewater that may be generated, it was thought that there would not be enough capacity in the collections systems for storage.

A more viable solution was to store at street level with methods to minimize infiltration into the sewers. Berms that are filled with clay were employed. HESCO brand Concertainers®, which can be rapidly deployed in basic military ballistic protection and flood control applications, were also found to be effective in building bermed enclosures for wastewater containment.

Various options were explored in order to filter the wastewater slurry for recycle, storage, or disposal. A viable option is filtration trucks that are designed to generate potable water during emergencies. These trucks rely on membrane filtration. However, for the Wash-Aid system, centrifugal filtration units are preferred to membrane filtration because of their continuous output, high flow-through rates, and avoidance of membrane fouling. The centrifugal filters are readily obtained and can be configured in series to increase efficiency.

The centrifugal filter produces concentrated solids that can be stored in bladders or tanker trucks for transportation to the final treatment or disposal center.

Fate and Transport of Radiological Material in Collection Systems and Treatment

There was much discussion during the workshop on the fate and transport of radiological material in wastewater treatment plants. Radioactive materials may be present in water entering municipal wastewater treatment plants due to various factors. These include:

- Regulated wastewater discharges from NRC licensed facilities (e.g., utilities, laboratories, universities, medical institutions, nuclear laundries, and industrial users of radioactive materials)
- Medical isotopes discharged from patients' homes
- Naturally occurring radioactive materials, such as radium and uranium in the community water supply, water infiltrating into the sewer system, residuals from water purification systems, and/or runoff of global radioactive fallout into storm sewers.

Wastewater treatment plant processes have the potential to concentrate these radioactive materials in biosolids. In addition, treatment plant operations may lead to worker radioisotope exposure.

Assessment of Radioactivity in Sewage Sludge

In 1991, during an aerial radiological survey of a licensee's site, NRC inadvertently discovered Cobalt-60 in the Southerly Sewage Treatment plant in Cleveland, Ohio (archive.gao.gov/t2pbat3/151920.pdf). This prompted the Government Accountability Office (GAO) to issue a statement on the need for action with regards to radioactive contamination at sewage treatment plants. In response, the Interagency Steering Committee on Radiation

Standards (ISCORS) was formed, and it undertook a survey of radioactivity in sewage sludge (biosolids).

The voluntary survey had two components: a questionnaire and a program for sampling and analyzing sewage sludge and incinerator ash. Questionnaires were sent to 631 publicly owned treatment works (POTWs), requesting information regarding wastewater sources, wastewater and sludge treatment processes, and sewage sludge disposal practices. Using the information from the 420 returned questionnaires; NRC and EPA selected 313 POTWs to be sampled. The selection emphasized POTWs with the greatest potential to receive waste from licensees and in areas with higher levels of naturally occurring radioactive material (NORM). Altogether, 311 sewage sludge samples and 35 ash samples were taken. Approximately half of the samples were analyzed by the U.S. Department of Energy's Oak Ridge Institute for Science and Education (ORISE) in Oak Ridge, Tennessee, under contract to NRC, and the remainder were analyzed by the EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama. This study utilized about half the lab capacity of these facilities for several months.

Results:

- 45 radionuclides detected in biosolids or ash at treatment plants
- Six were reported only once (Ce141, Cs134, Eu154, Fe59, La138, Sm153)
- Eight were reported in more than 200 samples (Be7, Bi214, I131, K40, Pb212, Pb214, Ra226, Ra228)
- Short-lived medical isotopes (I131, Sr89, Ti201) were found in the highest concentrations
- Samples from areas using groundwater as a source of drinking water had higher Ra228, Th232, Bi214, Pb214, Ra226
- Samples from areas using surface water as a source of drinking water had higher Cs137, Be7, Th232
- POTWs with combined sewers had higher radiation levels than POTWs with separate sewers
- No unexpected correlations were found

In addition, ISCORS conducted dose modeling to calculate potential human exposure. Pathway analysis approach used standard computer code (RESRAD) with uncertainty analyses. ISCORS calculated dose-to-source ratios (mrem/y per pCi/g) and summed doses from all important radionuclides.

The study did not identify any cases in which radioactive materials in biosolids are a threat to the health and safety of POTW workers or to the general public. Estimated doses to potentially exposed individuals are generally well below levels requiring radiation protection actions. However, for limited POTW Worker and Onsite Resident scenarios, doses above protective standards could occur, primarily due to indoor radon generated as a decay product from NORM (e.g., Ra226 and Th228). In addition, for both the POTW Worker and Onsite Resident, exposures can be decreased significantly through the use of readily available radon testing and mitigation technologies. The final reports can be found at www.iscors.org

Working with Key Stakeholders

Due to the general perception of radionuclides as 'high-risk' contaminants, much time was spent during the workshop discussing methods to work with both plant workers and the public.

Worker Health and Safety

Because wastewater treatment plants are critical infrastructure, treatment plant workers may be considered part of the emergency response team in the event of an RDD. Most treatment plant workers will not have training and experience dealing with radiation.

The water infrastructure role in the emergency response will happen quickly – most likely workers will need to be onsite immediately where there may be exposures to radiation. This means that there may initially be little awareness of levels of contamination. It will be important to preemptively identify radiation exposure risks for certain situations and develop an emergency response plan (ERP) related to RDD. A model ERP would be very beneficial to POTWs seeking to either prepare one, or to use, in the event of an incident. It will be essential to provide advance warning to workers regarding exposure risk, as well as messaging (see next section) that management can use to respond to the incident.

Some considerations when preparing this plan include:

- What is their role in the response? Do they need to be there? For example, POTWs have been identified as being critical to response and recovery during and after recent hurricanes; wastewater treatment plant workers were identified as among the first responders; and the same would hold true for a radiological emergency.
- Controlling worker exposure to radiation is the most important concept. In all decisions, use the "As Low as Reasonably Achievable (ALARA)" standard. Ask yourself, "What are all the ways to minimize exposure while they are doing the most important tasks?"
- Define what detection methods will work best. There is highly sensitive equipment; however, it is important to know how to interpret what the measurement is telling you.
- Workers need information and training in order to make informed personal decisions. They will want to know the potential long- and short-term impacts of radiation exposure.
- If workers are expected to come into contact with contaminated media, they will need personal protection equipment (PPE) and training on how to wear it properly.
- The need to consider decontamination for the utility and workers.
- Do not forget other safety risks. Slips, trips, and falls cause more worker deaths than radiation exposure every year.

In addition, a decision maker may need to consider key OSHA regulations that pertain to worker safety when dealing with radionuclide contamination.

- HAZWOPER; 29 CFR 1910.120
  - If the employer anticipates that an employee will be exposed to radiation, the employer must comply with a list of requirements in this regulation designed to protect the employee. This may not apply since treatment plant workers have no 'anticipated' risk of exposure.
- Ionizing Radiation Standard; 29 CFR 1910.1096
  - This standard describes the maximum worker exposure level of 1.25 rem per quarter.
- Respiratory Protection Standard; 29 CFR 1910.134
  - This standard is always applied if an employee has to wear a respirator.

RISK COMMUNICATION AND MANAGEMENT

Public perception of radiation is fatalistic. Risk communication is therefore extremely important. Focus group results in risk communication for other topic areas provide important guidelines to follow when communicating during an RDD situation:

- Check for contradicting statements
- Provide prioritized instructions
- Say, “Instructions will be updated” instead of, “Instructions will change.” The last statement was often interpreted to mean that they were given the wrong instructions
- Tailor messages to specific audiences

Message Mapping 101 Exercise

Part of the workshop included a participatory exercise during which attendees went through the steps of creating their own message maps, i.e., pre-planned messages for crisis communication. This exercise was useful, not only to educate participants on risk communications, but also to help identify knowledge gaps with regard to the utility’s ability to accept and treat for radiological contamination. The process for message mapping and the results of the exercise are summarized below.

There are four primary steps used to create a message map:

1. Define your situation or issue
2. Identify audiences who will need information
3. Anticipate a list of questions for each audience type. Think about the following question categories:
    a. Overarching – these are broad questions
    b. Informational – these are questions that help inform the public’s personal decisions
    c. Challenge – these are questions that try to ‘catch’ you in a situation and may stem from the public’s distrust of the subject matter and/or spokesperson
4. Create answers to those questions following the formula below:
    a. Three key messages
    b. 27 words in total
    c. Nine seconds long when spoken

Scientific studies have found that up to 95% of questions that will be asked during an emergency situation can be predicted in advance.

Message Map Results

1. Define Issue/Topic: Scenario: A dirty bomb contaminates wastewater infrastructure.

2. List of Identified Audiences:

Residential Customers	Local City Emergency Operations Center Staff	Agricultural Extension County Agents
General Public	Social Media	Commercial/Industrial Customers
Public Officials	Staff and Operators	Medical Professionals
Media	Downstream Facilities	Regulators
Police Department/ Security Officials	Downstream Government	Other WWTPs, Partner Organizations
Professional Associations	Landfills	
	Farmers Who Take Biosolids	

3. Table of Anticipated Questions by Audience Type:

Customers and General Public	What happened? How is it affecting the facility? How is the situation at the facility affecting me? What is my risk? What can I do? What should I do? What am I allowed to do – flush, shower, launder, drink? How long will this last? What makes you an expert? Who is in charge? Who is going to fix it? How will it be fixed? How soon? Where can I find more information?
Farmers	Is the sludge contaminated? Can I apply the sludge? When will I start getting sludge again (that is not contaminated)? What should I do with my milk? Should I decontaminate my cows? Can I use the treated effluent?
Downstream Organizations	Is our source water contaminated? Are there procedures in place to minimize contamination? Drinking water treatment plants will ask is there anything they can do onsite to reduce contamination to drinking water? What can we expect with regards to concentrations and duration of exposure? What are the ecological impacts? What is being done to assess ecological impact? What is being done for remediation? Is it safe to fish? Is it safe to walk along the riverbank? Is it safe to conduct recreational activities? Is the mud safe? How can you still be putting this stuff in my river? Will you be testing my private well water? Will you be providing alternative water sources if my well is contaminated? Who does testing?
Workers	What happened? What is the extent of the contamination? Do I have to stay and keep working? What are the risks to my family? What can I tell my family? Will it make me sick? Are we set up to deal with this? Do we have the right equipment? Is there a SOP? How long will we be in emergency mode? Why do we have to deal with this? How do you expect us to do our job without adequate resources?
Public Officials	What's going on? Impact on workers? Impact on facility? Do we have to shut plant down? High-level impact on plant users? Impact on environment? Can we help POTWs? Do we have a plan? How long and cost of cleanup?

4. Sample Message Maps by Audience Type:

Farmers	Is the sludge contaminated?	1. The sludge you have now is safe. 2. We have stopped shipping sludge and are testing sludge now. 3. Please contact your extension officer for more information.
Downstream Community	What can we expect with regards to surface water contamination?	1. We are monitoring our facility's discharge. 2. We are monitoring the river levels. 3. We will update you on the results. Follow-up question: What are you seeing? What does that mean for the downstream community?
Public (Media Proxy)	The media asks, "Contaminated facility, what are you doing?"	1. We are continuing to operate. 2. Our primary concerns are worker health and safety and containing the contamination. 3. We are implementing our emergency response plan.
Workers	What happened and what do we need to do?	1. We are receiving decontamination water from the RDD event. 2. Wear your personal protective equipment and follow SOPs [these need developed for radiological events]. 3. As we get more information we will keep you updated. Supporting point: Until we have more information, we are taking every precaution possible.
Public Officials	What is going to happen to POTWs?	1. The POTW will be contaminated. 2. We will develop a cleanup plan when we know the extent of contamination. 3. The cleanup will be costly and will take considerable time.

WORKSHOP OUTCOMES

During the workshop discussion, questions were used to help focus participant's thinking with regard to the issue of radionuclides in wastewater. Key points from the discussion, as well as a table of prioritized needs, are summarized below.

General Discussion

Overarching Issues

Workshop participants acknowledged that sewers and POTWs may not be best place to dispose of RDD decontaminated water. There are two main issues when POTWs consider whether or not to accept radioactively contaminated wastewaters. The first is the viability for treatment and much greater understanding of how the radioactive decontamination water containing radionuclides, as well as salts, surfactants, and other chemicals, introduced during response activities, will affect plant treatment system operations. The second is the volume of treatment water and how it will affect the hydraulics of the treatment system.

Criteria for POTW Acceptance of Wastewater

It is important to remember that the local POTW primary responsibility under the presented scenario is to protect treatment plant operations. POTWs must consider, at a minimum, the following criteria when deciding whether or not, as well as how, to accept wastewater that may contain radionuclides or residuals from decontamination:

- What is the level of total dissolved solids?
- What is the expected radiological level?
- What are the chemicals present and in what concentrations?
- What is the timeframe needed for disposal of the radioactively contaminated water to the POTW (and whether this can be introduced over a period of time)?
- What is the time of year?
- What is the volume (how many gallons) of wastewater?
- What is the ratio of monovalent/divalent cations in the salt solutions? Changes in this ratio affect settling within the plant, negatively influencing plant performance.

Based on its consideration of these criteria, and in consultation with other relevant organizations (e.g., EPA, radiological experts, POTW operators, elected and appointed decision makers), the POTW could provide guidelines for the time acceptable for discharge, the place in the collections system best suited for such discharge, and the flow rate for the discharge that will cause the least issues for plant performance. In formulating these guidelines, larger POTWs have a reasonably good model of how the treatment system performs; however, there is great variability in POTWs across the country and there are many extremes. This means that not every wastewater system performs the same. In fact, sometimes plant operators do not have sufficient information or understanding about the plant to know how it will perform under a specific situation.

POTW personnel must be educated so they can make informed decisions on the implications on their treatment plant, the environment, and human health of accepting decontamination wastewater. As decision-makers (including plant operators) are not typically aware of the unusual conditions presented by radionuclide contamination and subsequent decontamination activities that will affect the plant, they have to be conservative with their estimations until they have more data on how these conditions will affect plant performance. The kinds of tests needed for plant acceptance would include a SOUR (Specific Oxygen Uptake Rate) test, TDS measurement, and nitrification inhibition studies. These tests are fairly standard and are used to understand the impact of many types of contaminants, not just those resulting from radionuclide decontamination.

There was much discussion during the workshop about the criteria for POTWs to accept radioactive decontamination water; however, workshop participations also understood that even if the POTW does not accept this wastewater, contamination will probably occur anyway by other means, including:

- Precipitation carrying runoff into sewers
- Decontamination water infiltrating manholes and sewer systems
- Human activity, including showering and washing clothes
- Political decisions to use sewers for disposal

Impact of Contamination on Collection Systems

Collection system remediation plans for POTWs were also discussed. There is a large gap in understanding both radiological transportation and deposition in the collection systems. Pump stations could have deposition of radioactive contaminants due to potential adherence of materials to the pipes and pumps. In addition, there may be accumulation in wet wells, and radiologically contaminated solids may be released from the walls. The timescale of this release might range from slow (e.g., a gradual release) to fast (e.g., dislodgement of a contaminated solid).

Impact on Biosolids

Radioisotopes tend to concentrate in biosolids, which may then be considered a low-level radioactive waste. Further, some decontamination approaches may affect the ability of POTWs to utilize their regular routes of biosolids disposal, e.g., land application or disposal at a landfill. If the POTW is contractually obligated to supply quality biosolids to certain farmers, the POTW may become in breach of contract should they not be able to comply for an indeterminate time. Thus it is important that the impact of biosolids-related issues be considered prior to acceptance by the POTW of wastewater associated with a radiological release or subsequent decontamination activities.

Discussion of Potential Solutions and Needs

Pre-Planning

There is a need for a generic emergency response plan (ERP) for radiological emergencies (i.e., RDDs, nuclear plant failures, etc.) that utilities could use to update their ERPs. A scenario planning exercise for a generic RDD event using a 'typical' POTW could be conducted to assist in drafting this plan. This plan would include solutions to the biosolids issues discussed above; including identifying potential waste disposal sites, obtaining permits, or providing a regulatory mechanism to obtain quick permits, as well as defining up front who will be responsible for disposal costs. Some wastewater utilities located near nuclear power plants may have similar plans, but the possibility of unexpected widespread transport of radiological contamination during radiological emergencies suggests that it may be prudent for all POTWs to have such plans.

In terms of understanding impacts of radiological decontamination of collection systems, cataloging legacy scenarios for certain contaminants may be useful for understanding radiological contamination. For example, it was noted that PCBs, because of their persistence and toxicity, would be a good proxy for radionuclides to study when looking at these legacy issues. Another relevant example may be Los Angeles, which had DDT buildup in large pipes that became apparent 15-20 years after this pesticide was banned.

Sampling and Analysis

As critical infrastructure, it is important that POTWs receive priority for radioactivity sampling and analysis in order to protect worker health and safety, as well as safeguard receiving waters. POTWs would need to know as soon as possible the concentration and idendiy of radionuclides (or radiation type if the exact radionuclide cannot be verified) would be coming into the system. Lab capacity is a critical issue, as illustrated in the study of non-emergency radiological contamination in which the study alone consumed much of the lab capacity of both DOE and EPA. An emergency contamination incident could generate far more samples and completely overwhelm the existing capacity. Capacity can be increased through the use of more rapid analytical methods. Finally, there may need to be an ongoing, long-term, monitoring plan in place to deal with the issues of radioactive contaminants deposited onto collection system and treatment plant construction materials. As mentioned above, these could be released over a timescale potentially ranging from slow (e.g., a gradual release over years to decades) to fast (e.g., dislodgement of a contaminated solid over days to weeks).

Worker Safety and Training

Training and preparing workers for radiological events can be difficult, expensive, and time consuming. The threat has to be credible and compelling for the utility to invest in worker safety and training. However, it was recognized that it is extremely important that POTW workers have sufficient training and adequate protections in case they are exposed to radioactive wastes. These preparations include SOPs (standard operating plans/procedures), on-time training, sufficient personal protective equipment, and plans for communicating accurate information to workers about potential hazards. This type of communication is a subset of a more general need for crisis communications by the POTW, and it can be included in a radiological emergency response plan or as an annex to the a general emergency response plan. Considerations for developing a worker health and safety plan are provided above in the "working with key stakeholders' section.

Crisis Communication and Multiple Audiences

Communication is critical during the crisis phase and for many months after the event. One critical need is for the key people at POTWs to be able to access the emergency response team (incident command) and to be included in discussions at the Joint Information Center. In the past, it has been difficult for utility personnel to gain access to the emergency response team. In addition, the utility representative and the emergency response team may not use the same vocabulary. It is advised that the utility establish relationships with emergency responders who will staff and operate the Emergency Operations Center before an incident. In addition, there is a need to identify a credible spokesperson from the POTW and develop or formalize communications support. Some utilities do not have the capacity or expertise to handle the emergency communication needs.

The workshop included a message mapping exercise, and the questions developed during that exercise (presented above) can be used as a starting point for creating communication materials, including appropriate training for POTW personnel. EPA's Office of Radiation and Indoor Air has worked to develop communications approaches related to various aspects of radiation; some are available at www.epa.gov/rpdweb00/pubs.html#accidents-emergencies These resources may also serve as a useful resource although may need to be tailored to the POTW.

Application of Regulations

It is understood that standard clean water and drinking water regulations will apply even in emergency situations; however there is room for enforcement discretion, as has occurred during major natural disasters, such as in floods and hurricanes. One of the issues with enforcement discretion is that the violations are still recorded in the online OECA database and they are entered into the POTW compliance history without explanation of the extenuating circumstances. A policy change is recommended that would allow OECA to designate certain non-compliance events as a product of a natural or man-made disaster, thus the violation was due to force majeure.

Funding

The economic effects of a radiological event, including waste disposal, collections and treatment systems cleanup, potential economic hardship payments to farmers who will not be receiving biosolids, and short and long-term monitoring, will result in massive expenditures for POTWs. It is important for POTWs to understand outside funding and compensation mechanisms (under what circumstances do they apply, how to apply for funding, etc.) or these costs will get passed on to the rate payers. There was a general understanding that for an RDD event, the Stafford Act would eventually be used to pay for the response. The high visibility of a radiological emergency may help ensure rapid use of the Stafford Act. The wastewater utility will need to communicate to officials responsible for providing disaster funding that POTWs are critical infrastructure and that the cleanup efforts will be both necessary and costly.

Table of Prioritized Needs

During the discussion phase of the workshop, six general categories were defined for further investigation. The final afternoon of the workshop was dedicated to consensus about prioritizing key next steps. These are summarized in the table below. The bullet points in bold were identified as the most important needs.

Category	Prioritized Needs
Worker Health and Safety	• **RAD safety and training for workers that is available based on need** • Standard operating procedures (SOPs) • Criteria for defining when workers cross the “RAD worker” threshold(i.e., 100 millirem or above) • Educational handouts on radionuclides • Badges and dosimetry for workers to monitor exposure • Stock of personal protective gear (PPE) • Decision of whether normal PPE will suffice for workers
Identification, Characterization, and Containment	• **Scenario-based, generic response plan that wastewater utilities could incorporate into their emergency response plan** • **Decision tree for plant managers to help them provide guidance to first responders on the criteria for the acceptance of radionuclide contaminated wastewater. This would include guidance on when first responders can discharge, the best places in the collection system or headworks for discharging, and the acceptable chemical limits for discharge water** • Increased ability to test at plants/develop lab networks to help with testing • Sampling protocols and tests for emergency and non-emergency situations
Communications	• **Guidance on how utilities should work with first responders and Joint Information Center** • Guidance on what it means for a utility to be “critical infrastructure” to aid in communications with political decision makers during an emergency • Online resource with key messages for an emergency situation • Communications strategy and identify a credible spokesperson in the community
Regulatory and Permitting	• **Clarification on regulatory relief during emergency situations for both potential quality violations and how these violations are logged into the online OECA database.** The hope is that there is a way to label the violations as linked to an emergency situation. • Clarification on who will pay for storage, cleanup, disposal, and economic hardship to farmers during an emergency situation • Assistance in getting emergency landfill permits for the disposal of contaminated biosolids
Scientific and Engineering	• **Research on fate, transport, and remediation of radiological contmainants in wastewater treatment plants.** Remediation research should also include potential legacy scenarios resulting from deposition in pump stations, pipes, and plants. • **Generic sampling plans that can be included in the generic emergency response plan** • **Increased capacity for sample analysis, perhaps through more rapid analysis methods** • Treatability studies for conventional wastewater treatment plants • Investigation of applying to radiologically-impacted water mobile treatment units commercially offered to hold, transport, treat, and store hydraulic fracturing wastewater for the natural gas and ancillary support industry • Study of the effect of radionuclide contamination and subsequent decontamination activities on tests routinely used to assess treatment plant

Category	Prioritized Needs
	performance, e.g. specific oxygen uptake rate test, total dissolved solids measurement, and nitrification inhibition. • Best judgment on if all the pathways are mapped for worker exposure to radiologicals at the plant • A one-pager to the Federal Radiological Preparedness Coordinating Committee on the prioritization of sampling needs for wastewater treatment plants for the continuity of plant operations with bulleted list of priority sampling sites

APPENDIX A
Workshop Participant Contact List

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Water Environment Research Foundation (WERF)

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APPENDIX B
Workshop Agenda

Collaborative Workshop on Radionuclides in Waste Water Infrastructure
Resulting from Emergency Situations

U.S. Environmental Protection Agency / National Homeland Security Research Center (NHSRC)
Water Environment Research Foundation (WERF)

Dates: Tuesday and Wednesday, December 4 & 5, 2012
Location: WEF Conference Room 3rd Floor 601 Wythe Street, Alexandria, VA 22314

Agenda

Tuesday, December 4, 2012

8:00 AM Continental Breakfast

8:45 AM Welcome and Workshop Objectives
Matthew Magnuson and Emily Snyder, EPA NHRSC

9:00 AM Workshop Protocol, Ground Rules, and Round Robin Introductions
Amit Pramanik, WERF

9:15 AM WARRP Program Overview
Lori Miller, Department of Homeland Security

9:30 AM Release of Radionuclides from Contaminated Clothing During Laundering
Emily Snyder, EPA NHRSC

9:45 AM Wash-aid Program Overview and Its Implication on Wastewater Systems
Mike Kaminski, Argonne National Laboratory

10:15 AM Coffee Break

10:30 AM Overview of Assessment of Radioactivity in Sewage Sludge (non-emergency situations)
Bob Bastian, EPA OW

11:00 AM Overview of the RDD Scenario and Implications on Wastewater
Bill Steuteville, EPA Region 3

11:30 AM Worker Health and Safety (radiation focused)
John Ferris, Office of Homeland Security

12:00 PM Working Lunch
(Includes 30 min personal break for participants to check emails / voicemails, etc.)

1:00 PM Pennsylvania's Experience with Radionuclides
David Allard, Director, Bureau of Radiation Protection, PA Dept. of Environmental Protection

- PA experience and lessons-learned with the EPA LibRadEx
- Applicable national DW Standards with a RDD, IND or NPP accident
- Rad contaminated PA POTW case studies (i.e., Royersford and Kiski Valley)
- Philadelphia I-131 in DW issue and EPA & NRC regulatory gaps
- Tritium in landfill leachate and potential impact on DW, and,
- NORM / TENORM issues related to oil & gas production

1:45 PM Afternoon Break

2:00 PM Utilities and S&T perspectives – Speakers from confirmed attendees

- *Antonio Quintanilla* – MWRD of Greater Chicago, IL
- *Theresa Pfeifer* – MWRD, Denver, CO
- *Raj Bhattarai* – City of Austin, TX
- *John Consolvo* – Philadelphia Water Department, PA
- *Jamie S. Heisig-Mitchell* – Hampton Roads Sanitation District, VA
- *Chris Hornback* – National Association of Clean Water Agencies (NACWA)
- *Chris Rayburn* – Water Research Foundation (WaterRF)
- Others – TBD

4:30 PM Overview of Radionuclide Removal from Water Technologies (Fukushima Experience)

Abigail Holmquist, UOP LLC (A Honeywell Corporation)

4:45 PM Question & Answer Session

5:15 PM Recap of Day One

Amit and Matthew

5:30 PM Adjourn

6:30 PM Group Dinner (*Villa D' Este, 818 N St Asaph St., Alexandria, VA 2231*)

Wednesday, December 5, 2012

8:00 AM Continental Breakfast

8:30 AM Risk Communication and Messaging

Jessica Wieder, U.S. Environmental Protection Agency

9:30 AM Coffee Break

9:45 AM Risk Communication and Messaging (continued)

11:15 AM Brainstorming Session (*Facilitated by Amit Pramanik*, WERF)

Initial list of questions for group discussion:

- What other concerns need to be addressed?
- What is needed / required for utilities to accept radioactive contaminated wastewaters?
- What sorts of tests & protocols & regulatory guidance are needed?
- How should these be designed or implemented?
- Who should design and test these?

- Are there other “simpler” tests & protocols?
- Other questions or concerns?

12:00 PM Working Lunch

1:00 PM Brainstorming Continued

2:15 PM Afternoon Break

2:30 PM Group consensus on Key Questions:

- What is needed for utilities to accept radionuclide contaminated waters?
- What types of tests & protocols are needed (and what is the design for such tests) by Stakeholders?
- What is needed for permit authorities to guide / allow utilities to accept these wastes?
- What is needed to address concerns and issues raised by the public, by workers & operators?
- What are the gaps and what types of research is needed?

4:00 PM Summary Consensus Statements

4:30 PM Closing and Adjourn
Matthew Magnuson & Amit Pramanik

5:00 PM Adjourn

APPENDIX C
References and Additional Resources

1. *Containment and Disposal of Large Amounts of Contaminated Water: A Support Guide for Utilities*. EPA 817-B-12-002. United States Environmental Protection Agency, Sept. 2012. http://water.epa.gov/infrastructure/watersecurity/emerplan/upload/epa817b12002.pdf

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