Challenges to Collection of High Quality Samples of Saltstone -17468

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ABSTRACT

The Savannah River Site (SRS) Saltstone Disposal Facility (SDF) is used to dispose of low-level radioactive liquid waste in the form of grout. The SDF is comprised of a series of concrete saltstone disposal units (SDUs) that receive the grout. The grout solidifies into a cementitious waste form known as saltstone. Properties of saltstone that influence contaminant release have been measured on simulant material but not on samples of emplaced saltstone because samples of emplaced radioactive saltstone are difficult to obtain, transport, and store in a manner that protects the properties of interest. Savannah River Remediation (SRR) initiated a project to obtain samples of emplaced saltstone such that the two critical properties, hydraulic conductivity and reduction capacity, are negligibly impacted by the sample collection effort. The sample collection project was established to manage sample collection efforts beginning with sample collection mock-up activities through field execution. The project focused on three phases: mock-up in a clean environment, development of equipment needed to maintain an inert environment during sample transport and laboratory storage, and coordination of Facility operations and support resources and schedules to support sample collection.

A mock-up facility was constructed at SRS to mimic the SDU. Core drill equipment was tested, procedures developed, and operator training conducted using the mock-up facility. Concurrent with mock-up activities, inert transportation and storage equipment was designed, manufactured, tested, and specific operating instruction included in the sample collection procedure. Inerting equipment minimized oxidation from the atmosphere as the samples were removed from the disposal unit, transported, and stored in the laboratory awaiting analysis.

Coordination with the Saltstone Facility began during construction of the mock-up platform to collect current as-built information for platform construction. Baseline data was collected from the disposal unit vapor space to assess the potential for personnel exposure from chemical hazards associated with trapped vapors. Based on this data, mitigating actions were incorporated into the project scope. Finally, project and facility schedules were integrated to assure that facility non-processing windows, support personnel, equipment fabrication, and field preparation activities were in alignment and supportive of the overall sample collection objectives.

During May 2014, 485 linear cm of approximately 5 cm diameter radioactive core material was successfully collected from three access ports in SDU Cell 2A, inerted, transported to the laboratory, and stored in an inert environment for analysis.

INTRODUCTION

The SRS is a DOE site located in south-central South Carolina, approximately 161 kilometers (100 miles) from the Atlantic Coast. The major physical feature at SRS is the Savannah River, approximately 32 kilometers (20 miles), which serves as the southwestern boundary of the site and the South Carolina-Georgia border. The SRS includes portions of Aiken, Barnwell, and Allendale counties in South Carolina. The SRS occupies an almost circular area of approximately 803 square kilometers (310 square miles) and contains production, service, and research and development areas. The Liquid Waste facilities are located in the industrialized central portion of the site known as the General Separations Area (GSA). The Savannah River Site (SRS) Saltstone Disposal Facility (SDF), located in the SRS Z-Area (Figure 1), is used to dispose of low-level radioactive liquid waste in the form of grout. The physical and chemical properties of emplaced saltstone in the SDF impact the rate of release of contaminants, primarily Technetium-99 (Tc-99) and Iodine-129 (I-129), and ultimately doses estimated in the Performance Assessment for the Saltstone Disposal Facility at the Savannah River Site. The Performance Assessment (PA) [1] uses assumptions of these properties based on both published literature and laboratory studies of simulants. The properties of saltstone that influence contaminant release have been measured on simulant material but not on samples of emplaced saltstone. This is due, in part, to the fact that samples of emplaced saltstone are difficult to obtain, transport, and store in a manner that preserves the properties of interest.

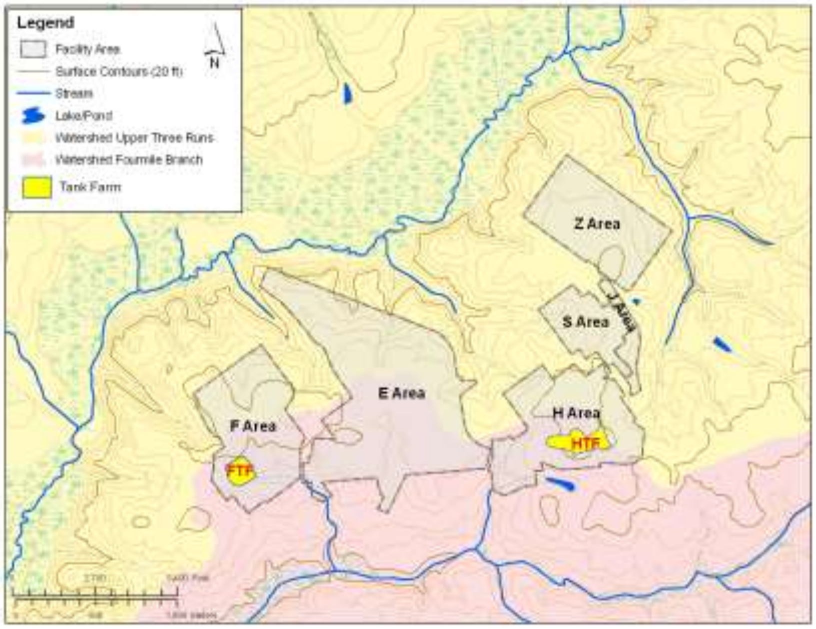

Fig. 1. SRS General Separations Area.

SRR initiated a project to obtain samples of emplaced saltstone such that the two critical properties, hydraulic conductivity and reduction capacity, were negligibly impacted by the sample collection effort. Sample collection options were constrained by the physical configuration of the SDU's and the physical characteristics of the emplaced saltstone.

The sample collection project was established to manage sample collection efforts beginning with sample collection options evaluation, to mock-up activities, and finally through field execution. The project focused on three phases; mock-up in a clean environment, development of equipment needed to maintain an inert environment during sample transport and laboratory storage, and coordination of Facility operations and support resources and schedules to support sample collection.

Mockup facilities were established in a clean environment at the SRS. Mockup included construction of a platform to mimic the SDU roof, development of a 2 meter deep saltstone simulant monolith placed under the platform. The mockup facility was used to evaluate the viability of core drill equipment used in the sample collection effort, train operators in the use of the equipment and conditions likely to be encountered during the actual sample collection, and evaluate equipment fabricated specifically for use in the sample collection effort, such as inerting transport tubes, shield plates, remote cameras, etc.

During mockup activities, the facility developed and refined the SDU operating procedure [2] to incorporate core drill operations, collected baseline data on SDU vapor space conditions, and coordinated facility and support resources needed to enable safe and efficient sample collection and transport.

DISCUSSION OF CORE DRILL PREPARATION AND FIELD EXECUTION ACTIVITIES

Mockup Activities

Sample collection mockup activities were performed at the TNX area of SRS. TNX is a radiologically clean area used for testing of various pumps and other equipment used in SRS waste tanks, and was ideal for establishing mockup facilities needed to test and perfect sample collection techniques. Core drilling was selected as the preferred sample collection method due to the constraints of SDU access points and the fact that saltstone physically resembles hard clay. In addition, core drill equipment and techniques are mature technology, with a wide selection, availability and modest cost of drill motors, bits, and drill string needed for the effort.

To effectively mockup core drilling in a SDU, a 3.2 meter tall platform was constructed with plate steel used to replicate the SDU roof. Two 30.5 cm holes were cut in the steel to replicate camera ports that would be used to access the saltstone. For core drill operations, one port served as the drill location while the sister port was used to install a micro camera to observe coring operations within the cell. A 2.1 meter tall sonotube was filled with 2 meters of a non-radioactive saltstone simulant and allowed to cure. This represented saltstone lifts to the same thickness of grout placed in the SDU over time. The sonotube was then and placed under the platform to mimic the saltstone of the SDU. Remote cameras and shield plates were fabricated and placed in the plate steel holes of the SDU surface. The camera was inserted through a hole in one steel plate, placed over the camera port, and connected to a local monitor.

Two additional steel plates were fabricated with 10 cm slots to install around over the second camera port where the drill string was inserted. Extraction tubes (Figure 2) consisting of clear PVC tubes and a toothed basket were fabricated to insert into the grout and extract the intact cores after they had been drilled.

Fig. 2. Clear PVC Extraction Tube

The mockup platform was constructed in a flat paved area of TNX, away from support equipment and services. Therefore, a portable generator and water buffalo were used to supply power and water to drill equipment.

Mock up activities began with engineering performing set up and check out of equipment prior to use. Engineering performed test drills and established a rough procedure to be followed by operations. After engineering checkout, operations, procedures, training, and RCO personnel familiarized themselves with the equipment and draft procedure; and they practiced core drilling and sample extraction. Mockup activities allowed operators and RCO to obtain experience and proficiency in equipment in a non-radioactive environment, minimizing learning required in the radioactive environment of the actual SDU. It also resulted in valuable lessons learned that were incorporated into procedures, training and qualification packages, and modifications to tools and equipment.

Specialized Tools and Equipment

The physical, chemical, and radiological characteristics of saltstone, along with the sample quality requirements needed to achieve reliable results, required development and fabrication of tools and equipment tailored for this evolution.

To mitigate drill string vibration and allow repositioning of the drill equipment anchor, the drill equipment to the concrete cell roof, anchor bolts were installed in the roof at the three camera ports. A shop-fabricated drill mounting platform was installed over the anchor bolts, securing the drill rig to a stable foundation. Commercially available collapsible dryer vent was used as a drip shield around the drill string. This was critical in preventing water from saturating personnel protective clothing that would compromise its protective ability.

Special core extraction tools were fabricated to extract core material remaining in the holes after drilling. Core extraction tools were developed and refined through mock-up activities conducted prior to field execution. Each tube was made of clear polyvinyl chloride (PVC). A glued coupling was fitted on the top of the tube so that threaded extension rods could be installed to insert and remove the tube from the hole. Another thinned-glued coupling and a "toothed" basket was installed on the bottom end of the tube to capture sample material. During mock-up the misalignment of drilled core material in the drill hole was encountered. To increase the probability of successfully retrieving core material, a glued coupling with a hand crafted "scoop" was fitted at the bottom end of the tube. The "scoop" was used to assist in centering cores relative to the extraction tube. Each extraction tube contained drilled drain holes so water from the drilling did not remain in the tube after extraction. Rotating the extraction tube with the "scoop" design would enhance the ability to align core material and provide a greater probability of successful core extraction.

Special inerting tubes (Figure 3) were fabricated to ensure that the samples were maintained in an oxygen- free environment after extraction and throughout transportation to Savannah River National Laboratory (SRNL) for eventual storage in an anaerobic chamber. Inerting tubes were approximately 96.5 cm length with the main tube body being 7.6 cm diameter PVC. A quick disconnect was added to one tube end to connect the nitrogen gas supply. A purge valve fitted with a high-efficiency particulate air (HEPA) filter was added at the opposite end of the tube.

Fig. 3. Inert Transport Tube.

The configuration of the samples and inerting tubes did not fit into standard sample shipping containers used by SRR. In order to ship the core sample material, a 142 liter Igloo® cooler was qualified as SRS-1 packaging, in accordance with the SRS transportation requirements. The transportation packages were qualified to ship samples quantities of 0.9 linear meters or less. The packaging was qualified, shipping procedures modified to incorporate the new shipping containers, and the Radioactive Package Approval Log was updated to reflect the change. This approach eliminated the need to use more sophisticated and cumbersome transportation casks as well as minimizing the rigging and labor required to manipulate and move those transportation packages.

A special anaerobic chamber (Figure 4) was fabricated to receive, store, and prepare the samples for analysis in an inert environment at SRNL. The chamber contained a transfer chamber to introduce samples to the main anaerobic chamber, a main anaerobic chamber equipped with gloves, and an integrated oxygen monitoring/nitrogen purge system.

Fig. 4. Anaerobic Chamber.

Field Preparation

Various risks and possible mitigation strategies were developed and reviewed with the project team. Risks generally centered around protection of personnel from hazards associated with the activities, risks associated with the drill equipment, and risks associated with unanticipated conditions encountered from drilling. A Risk Identification and Mitigation Matrix was developed to not only identify postulated risks requiring mitigation, but also enabled timely identification of baseline data requirements such as vapor space chemical concentrations and facilitated evaluation of the need for mitigative actions.

Since this activity was non-routine facility work, a mission status checklist was also developed. The mission status checklist identified both direct and support organizations supporting the activities, status (either go or hold), open items that would preclude initiating the mission, specific actions required to close open items, and individuals responsible for conducting those actions. The mission status checklist proved valuable in ensuring accountability and quickly identifying issues preventing initiation of work activities, as well as resolutions to those issues.

The Risk Identification and Mitigation Matrix identified the need to establish baseline vapor space concentrations of constituents of concern. Industrial Hygiene (IH) data was obtained from the cell vapor space prior to initiating cell modifications.

To conduct core drill activities in a contaminated environment, containment huts were shop fabricated and installed over each camera port (Figure 5). Each hut was approximately 4.57 meter by 4.57 meter by 3.66 meter high with an adjacent air lock. Temporary ventilation was added to each hut while in use as a precaution in case airborne concentrations exceeded radiological work permit (RWP) and IH levels.

Fig. 5. Contamination Control Hut on SDU cell 2A.

SDUs normally have only passive ventilation. Supplemental active ventilation was installed to ventilate the cell vapor space, induce negative pressure in the containment huts, and reduce or eliminate both airborne radiological contamination as well as chemical contaminates of concern.

To anchor the drill equipment to the concrete cell roof, anchor bolts were installed in the roof at the three camera ports. A shop-fabricated drill mounting platform (Figure 6) was installed over the anchor bolts, securing the drill rig to a stable foundation. Shims were also used to enhance the ability to lock the movable drill mounting plate in place during drilling operation.

Fig. 6. Slotted mounting plate at an SDU 2A camera port (left) with drill rig installed (right).

Sample Collection

Core drilling, sample extraction, inerting, and sample transportation activities were initiated on April 16, 2015. A detailed summary of events [3] and results was developed to document salient events and observations from the entire evolution Since baseline vapor space data previously indicated elevated levels of some chemicals, each daily entry into SDU cell 2A began by initiating cell ventilation to reduce vapor space concentrations and minimize the potential for elevated levels within the containment hut. IH surveyed the cell ventilation exhaust each daily entry and ensured that ventilation exhaust was vented away from support personnel. Following cell ventilation activities, entry into the hut was made, camera port covers removed, and IH and radiological surveys performed to ensure that conditions were within limits for work activities to begin. Routine surveys were conducted throughout the core drill/extraction activities to ensure that conditions remained within specified limits to ensure worker health and safety. Mercury levels as high as 0.007 mg/m^3 were observed in the breathing zone within the containment hut shortly after entering a containment hut, but these levels dropped as the cell ventilation actively removed trapped vapors from the cell vapor space.

Camera port B was used for the initial drilling activities, beginning on April 16, 2015, since it was the closest port to the inerting station established off SDU cell 2A in a low radiation dose area. Drilling began using the DD 200 ® drill motor and a KOR-IT® drill bit. The initial 61 cm of drilling behavior was as expected from mock-up and training experience. However, at the 61 cm level water flow dropped significantly and the drill motor traverse speed slowed significantly. At approximately 122 cm the drill motor penetration speed slowed even further and dramatically increased drill resistance was encountered. This behavior continued until the targeted depth of approximately 198 cm below the grout surface was attained.

Per the initial procedure, the drill string was removed and any material remaining in the drill string was to be pushed out of the drill string back into the hole. However, material was bound in the drill string so tightly that it could not be removed safely with the tools available inside the contamination area. The drill string and bit containing the bound material was removed, sleeved to prevent spread of contamination, and staged inside the hut away from the drill activities. Per procedure, the drill mounting plate was moved to the retracted position to begin drilling the second hole in the camera port.

Since the initial bit remained plugged with material, a Diamond® drill bit was used for the second hole in camera port B. Drilling behavior in the second hole in camera port B was as expected for the initial 122 cm. At the 122 cm level both the water flow and the drill penetration speed dropped significantly. A dramatic increased drill resistance was again encountered. Since this behavior was experienced once again, the team decided to suspend drill operations and workers were removed from the hut.

Over the next several days, the core drill team preformed a post-job evaluation of the activities, including the conditions encountered on April 16, 2015. The evaluation prompted development of a new approach for restart of the core drill operations. Key changes to the restart plan included using the more powerful DD 350 ® drill motor to allow a greater range of operating speeds and minimize vibration, frequent removal of overlying drilled material, and flushing of the hole prior to drill motor restart.

On April 22, 2015, the team re-entered the hut to resume core drilling activities. The restart approach proved effective at reducing drill resistance, though drill penetration speed remained slower than expected until a depth of approximately 198 cm was attained. Drill string was removed and core retrieval was initiated. The core retrieval process was able to retrieve, package, inert, and ship approximately 9 inches of core from the hole [Sample ID: SDU2A-0931-B-2-L]. At that depth, the retrieval tool encountered blockage and could not be inserted further into the hole. The likely cause of the blockage was small fragments of saltstone, fractured during the core drilling operation, filling the kerf. The operators described the material as "feeling like gravel". This condition was encountered during mock-up and training activities and was an anticipated but undesired condition. A post-job evaluation was conducted to assess the day's activities and further improve the operational plan. The improvements stemming from the extensive post-job evaluation included planned drill stoppage at specified depths, followed by material removal, followed by flushes of the hole bottom. A minor revision to the procedure was required to implement the new sequencing. In addition, since the second hole in camera port B rendered good quality sample material from the upper section of the monolith a decision was made to collect this core material as well, place it in an inerting tube, and transfer it to SRNL along with the lower cores.

Based on the experience gained from the April 16, 2015, and April 22, 2015, activities, implementation of the new plan and accompanying procedure revisions, it became apparent that the time required to perform the core drill scope would increase as a result. RCO recognized the additional dose implications of this and implemented additional measures to reduce worker dose such as requiring workers in the airlock to remain in low dose areas until their airlock function was required and rotating support personnel to minimize individual dose. These improvements were implemented in camera port C. Camera port C, Hole #1 drilling activities began on April 28, 2015, and used refinements developed from lessons learned from camera port B. Drilling began in the retracted drill position using the DD 350 ® drill motor and the same Diamond® drill bit used in camera port B. The initial 30.5 cm of material was drilled, removed, and the hole flushed thoroughly. Drilling recommenced and the next 76 cm was drilled, removed, and inerted as the upper core sample [Sample ID: SDU2A-0931-C-1-U]. The hole was once again thoroughly flushed and the drill reset at the bottom of the hole. The final 76 cm was then drilled, approximately 53.3 cm removed, and inerted [Sample ID: SDU2A-0931-C-1-L]. Both core sections were shipped to SRNL.

Camera port C, Hole #2 drilling activities began on April 30, 2015. Using the operator aide, along with a desire to maximize sample material from the lower depth, the upper discard portion was targeted at 45.7 cm from the grout surface. Drilling began in the extended drill position using the DD 350 ® drill motor and the same Diamond® drill bit used since camera port B. The first 45.7 cm of material was drilled and 43.2 cm was measured as removed and contained in the extraction tool. However, the hole depth was measured at 38 cm. Had this material remained in the hole the upper core sample would have been from a region higher than anticipated. This would have also resulted in the lower sample being from a higher region than anticipated. To ensure that the samples would be from the appropriate region the next 76 cm was drilled, the top section (approximately 15 cm) was removed and discarded, then approximately 61 cm removed, and inerted as the upper core sample [Sample ID: SDU2A-0931-C-2-U]. The hole was once again thoroughly flushed and the drill reset at the bottom of the hole. The final 76 cm was then drilled, approximately 73.7 cm removed, and inerted [Sample ID: SDU2A-0931-C-2-L]. Both core sections were transported onsite to SRNL.

The new drilling and retrieval approach resulted in higher quality samples but, as expected, increased the time required to perform the work. RCO measures instituted to control worker dose maintained total dose essentially constant even though the total time to perform the work increased from the initial approach. Camera port A, Hole #1 drilling activities began on May 5, 2015, and used refinements developed from lessons learned from camera ports B and C. Drilling began in the retracted drill position using the DD 350 ® drill motor and the same Diamond® drill bit used in camera ports B and C. The first 61 cm of material was drilled, removed, and the hole flushed thoroughly. The next 61 cm was drilled, 56 cm was extracted, and inerted as the upper core sample [Sample ID: SDU2A-0931-A-2-U]. The hole was once again thoroughly flushed and the drill reset at the bottom of the hole. The final 61 cm was then drilled, approximately 43 cm removed, and inerted [Sample ID: SDU2A-0931-A-2-L]. Both core sections were shipped to SRNL.

Camera port A, Hole #2 drilling activities began on May 6, 2015. Drilling began in the extended drill position using the DD 350 ® drill motor and a new Diamond® drill bit. The first 38 cm of material was drilled. During removal of the drill string to extract the top 30.5 cm of material, it became apparent that the initial angle of the hole was not perpendicular. TNX mock-up experience demonstrated that this condition could yield poor samples. The initial drill string and bit were discarded and the bit used in Hole #1 was attached to new drill string. This was repositioned between Hole #1 and the initial attempt to drill Hole #2. The new hole will be referred to as Hole #2A. The position of Hole #2A required a small overlap of Hole #2. Since Hole # 2 did not penetrate the upper core region (i.e., 61 to 122 cm from the surface), the overlap did not impact the upper core sample region of Hole # 2A. The slowest drill speed was used to carefully establish a kerf in Hole #2A in a perpendicular direction. This approach proved successful and Hole #2A was drilled from this position.

The first 61 cm of material from Hole #2A was drilled, removed, and the hole flushed thoroughly. The next 61 cm was drilled, 61 cm was extracted, and inerted as the upper core sample [Sample ID: SDU2A-0931-A-1-U]. The hole was once again thoroughly flushed and the drill reset at the bottom of the hole. The final 61 cm was then drilled, approximately 43 cm removed, and inerted [Sample ID: SDU2A-0931-A-1-L]

CONCLUSIONS

Saltstone sample generation, collection, and shipment can be performed safely and produce high quality samples for analysis. Although this work resulted in significant dose to personnel a one-time effort was justified to verify assumptions of saltstone used in the Performance Assessment. Routine sampling efforts of this nature are not expected to yield additional information that would justify the personnel exposure required for the task. The keys to successful saltstone sampling efforts are 1) performing thorough mockup activities in a clean controlled environment; 2) practicing with tools and equipment developed, fabricated and tailored to the needs of the sample collection requirements; 3) anticipating, mitigating, or being prepared to mitigate potential risk that jeopardize the mission; and 4) flexibility to respond to field conditions. Planning, practice, anticipating risks, and field flexibility resulted in successful core drilling, retrieval, inerting, transportation, and laboratory storage of radioactive emplaced saltstone.

REFERENCES

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