I/2
ASSESSMENT OF A HIGH LEVEL *NORM* SITE

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Abstract
Zircoloy sand from a mine in New Mexico was used in wellbore fracturing studies at a research facility in Texas USA. After completion of the studies, the zircoloy sand was placed in a field behind the facility. This sand is much higher in natural radioactivity than most soil and sand. The piles of discarded zircoloy sand were found during a health, safety, and environment survey of the facility 3 years later. The location of the piles, approximately 1-kilometer upstream from a creek bed, prompted an investigation of the activity concentrations and possible migration of the zircoloy sand. A site characterization survey was performed using handheld survey instruments and a shielded 7.6-cm x 7.6-cm NaI(Tl) detector with a computer-based multichannel analyzer mounted in a van. These aided in collection of meaningful samples for a quantitative laboratory analysis that was performed later using an HPGe detector. The results of this investigation showed no measurable migration of the zircoloy sand from the piles. Soil samples from the area surrounding the pile measured 41 Bq kg^{-1} (1.1 pCi g^{-1}) of Radium-226 and 21 Bq kg^{-1} (0.56 pCi g^{-1}) Radium-224. The zircoloy sand contained approximately 3900 Bq kg^{-1} (106 pCi g^{-1}) of Radium-226 and 250 Bq kg^{-1} (6.6 pCi g^{-1}) Radium-224. Although migration does not appear to be a problem, the high specific activity of the zircoloy sand warrants proper disposal.

Introduction
As companies become more environmentally conscious and aware of the possibility of future regulatory requirements on materials which are currently unregulated, site remediations are sometimes warranted when the risk of future liabilities are present. The public's perception of the risk associated with radiation exposure continues to be a real issue and the risk of future litigation due to the exposure of Naturally Occurring Radioactive Material a definite possibility.

A site that had Zirconium material placed on it was evaluated. A determination was made that if future use of the site could entail public access and land development, it would be in the best interest of the company to remove the liability of future litigation due to radiation exposure from the zirconium material. The Zirconium material was in the form of a silicate, commonly known as zircon, which was made into cylindrical targets and held in place with a binding resin. These targets were used as standards for jet perforating charges to penetrate. As a result of numerous tests, a large volume of waste materials was generated as a byproduct. Upon completion of these studies, the material was placed onto the property, as a fill, located upstream from a creek bed. During a health, safety, and environmental audit of the facility, elevated levels of radioactivity were detected and reported to the Radiation Safety Section for identification and recommendation. As a result of the investigation, it was found that the material had come from a mine in New Mexico USA several years ago. A review of the regulations at this time revealed that the material was exempt from regulation since the radioactivity had not been technologically enhanced from what was found in nature. After reviewing these factors and the potential future liabilities it was determined that a site characterization should be conducted and the site remediated to remove the elevated levels of radioactivity caused by the Zirconium.

Qualitative Analysis
Qualitative analysis was performed initially using a handheld ratemeter in conjunction with a 2.5-cm x 2.5-cm NaI(Tl) probe. The use of handheld meters allowed for a quick determination of local "hot spot" areas. Hot spot areas were defined as readings that were twice the amount of background. It was determined from the survey instrument readings that the location of "hot spot" areas emanated only from the zircoloy pile. The zircoloy pile had readings from 1 μSv hour^{-1} (100 μrem hour^{-1}) to 1.2 μSv hour^{-1} (120 μrem hour^{-1}), while background readings were an average 0.1 μSv hour^{-1} (10 μrem hour^{-1}).

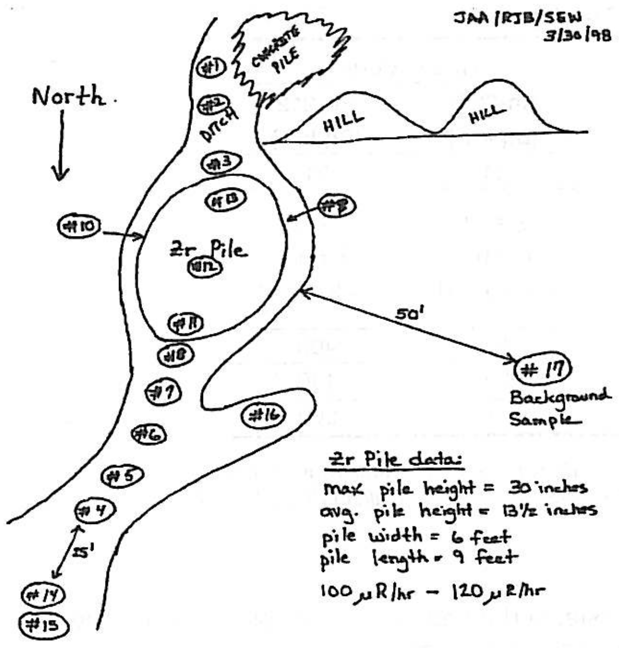

Figure 1: Pre-cleanup radiation survey

As shown in Figure 1, a total of 17 samples were collected. Samples were taken upstream and downstream from the zircoloy pile. A background soil sample was taken approximately 15 meters (50 feet) northwest of the pile. In addition, three samples were taken directly from the pile. The samples were placed in 500 mL, plastic, Marinelli beakers. The samples had a net weight ranging from 504 grams to 1185 grams. Samples were relatively dry because of the lack of rainfall in the area.

Samples were qualitatively analyzed in the field using a shielded 7.6-cm x 7.6-cm NaI(Tl) detector with a multichannel analyzer. The analysis equipment was set up in the rear of a van with the power supplied via the vehicle battery. Sample analysis software ran on a computer that was capable of performing a region of interest analysis, however, it was not capable of performing a nuclide identification function. The multichannel analyzer was set up to look at seven regions of interest. The regions of interest included radionuclides listed in Table 1. Each sample was placed on a 10-cm x 10-cm x 5-cm thick lead brick with the shielded detector on top of the sample. Samples were then analyzed for 1000 seconds each. From this information, the approximate radium concentration could be calculated using previously determined efficiency calibration curves.

***Table 1:* Regions of interest for multichannel analyzer**

Region of Interest	Radionuclide	Decay Series	Peak of Interest
ROI #1	Radium-226	U-238	186 keV at 4.0%
ROI #2	Lead-212	Th-232	239 keV at 43.1%
ROI #3	Lead-214	U-238	296 keV at 18.9%
ROI #4	Lead-214	U-238	352 keV at 36%
ROI #5	Bismuth-214	U-238	609 keV at 41.2%
ROI #6	Bismuth-214	U-238	1120 keV at 13.6 %
ROI #7	Bismuth-214	U-238	1764 keV at 15.8%

Performing a qualitative analysis in the field proved to be advantageous. This type of analysis allowed for a relatively quick assessment of when sufficient samples had been taken, and also where more samples needed to be taken.

Quantitative Analysis

Quantitative analysis was performed at Halliburton's Nuclear Physics Laboratory located in Duncan, Oklahoma. A high purity germanium (HPGe) gamma ray detector was selected to perform the analysis because of its high energy resolution. Soil samples were analyzed for a live count time of 30,000 seconds. Nuclide identification and quantitative analysis was performed using a gamma ray spectrum analysis software program. Table 2 shows the results of the analysis.

Table 2: **HPGe gamma ray analysis data**

Sample	U-238 Series		Th-232 Series	
	Ra-226 (Bq kg^{-1})	**Pb-214 (Bq kg^{-1})**	**Ra-224* (Bq kg^{-1})**	**Pb-212 (Bq kg^{-1})**
(kg) soil	41	14	21	21
Soil (13 samples surrounding the Zr sand)	χ = 61 σ = 20 r = 47 - 117	χ = 19 σ = 5.7 r = 14 - 40	χ = 21 σ = 6.0 r = 9.3 - 31	χ = 21 σ = 6.0 r = 9.3 – 31
Zr Sand #1	3900	2000	400	400
Zr Sand #2	4000	1900	140	140
Zr Sand #3	3900	1900	200	200

**Ra-224 concentration derived from Pb-212 activity when not detectable. This assumes equilibrium exists between Ra-224 and the decay products Pb-212 because of the short half-life of Rn-220 (55 s).*

Cleanup

A contract vendor, specializing in hazardous waste, performed the zircoloy pile cleanup. The waste was placed in a 25-cubic yard totally, enclosed container.

Radiological and safety precautions as prescribed in 29 CFR 1910.120 Appendix B (Level D) and 10 CFR 20 are recommended in NORM cleanup. Level D requires workers to wear long sleeve shirts, long pants, steel-toed shoes, and gloves. Radiological controls require the contractor to have established baseline bioassays for its workers before performing the excavation and then performing a second bioassay after the completion of the excavation. Additionally, contractors are required to perform whole-body frisks continuously with a GM pancake probe throughout the entire job evolution.

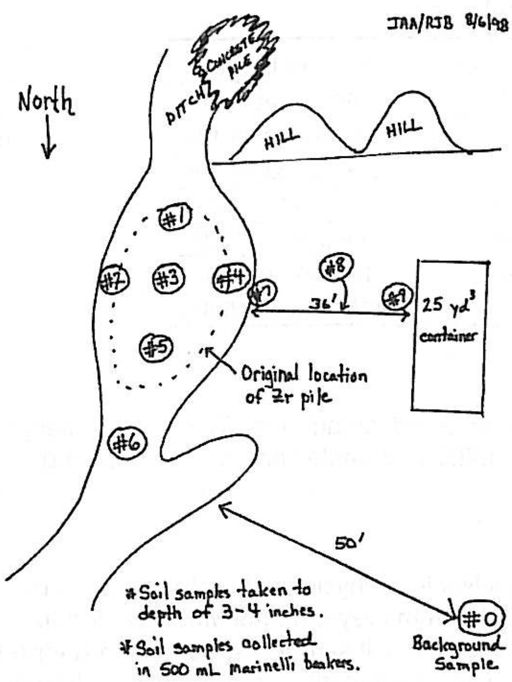

Figure 2: Post cleanup radiation survey

Post Cleanup Assessment

After the NORM material was collected into the 25 cubic yard container, an additional radiation assessment was performed. A handheld ratemeter coupled with a 2.5-cm x 2.5-cm NaI(Tl) detector was used to perform a qualitative radiation survey of the container holding the NORM and also the surrounding area. Additionally, nine soil samples from the area where the original NORM pile was located were collected. A background soil sample was also collected 15 meters (50 feet) north-west of the pile to establish a baseline. Collected samples were placed in plastic, 500-mL Marinelli beakers. Figure 2 illustrates the location of collected radiation samples as part of the post clean-up effort. Table 3 shows the results of the HP-Ge quantitative analysis performed at the HES Nuclear Physics Laboratory. As shown in Table 3, it was determined that the contractor had not removed all the NORM material, and therefore, was required to perform a second cleanup.

After the second cleanup effort, the site was surveyed again and found to be clean of NORM material. The collected NORM material will be disposed of following a chemical analysis of the waste material. It is planned to dispose of the NORM material at the Windmill Hill facility located in Andrews County, Texas.

Table 3: **Post Cleanup Soil Analysis Data**

Sample	U-238 Series		Th-232 Series	
	Ra-226 (Bq kg^{-1})	Pb-214 (Bq kg^{-1})	Ra-224* (Bq kg^{-1})	Pb-212 (Bq kg^{-1})
(kg) soil (#0)	38	16	20	20
Soil #1	160	64	32	32
Soil #2	51	21	23	23
Soil #3	80	31	19	19
Soil #4	200	100	38	38
Soil #5	50	20	18	18
Soil #6	43	15	19	19
Soil #7	370	160	54	54
Soil #8	38	15	19	19
Soil #9	600	200	81	81

**Ra-224 concentration derived from Pb-212 activity when not detectable. This assumes equilibrium exists between Ra-224 and the decay products Pb-212 because of the short half-life of Rn-220 (55 s).*

Discussion

The results of the laboratory analysis of the zircoloy sand samples indicate that in the U-238 series, the decay products of Ra-226 are not in equilibrium with their parent radioisotope. This is in contrast to the situation normally found in petroleum scale samples. This occurs because the zircoloy sand is a porous, loose, material compared to the compact, nonporous, petroleum scale material. The porous sand material allows for the Rn-222 gas to escape and thus lower the ratio of the decay products to the parent radioisotope. Whereas, the compact material in scale, traps the Rn-222 gas and its decay products inside. The ratio of the parent to the decay product is approximately equal in petroleum scale NORM.

In the Th-232 series, the decay products of Ra-224 are almost always in equilibrium with their parent radioisotope in any material. This is the result of the Rn-220 gaseous component having only a 55-second half-life. This prevents it from escaping even in porous materials.

Conclusions

The zircoloy sand that was used in wellbore fracturing studies and later placed in a field was found not to present any significant radiological hazards. However, because of its high specific activity and the fact that it could possibly migrate to waterways, a cleanup procedure was initiated. This cleanup was facilitated by first surveying the area for radioactive hot spots. Then qualitative analysis was performed in the field to help optimize sample collection for quantitative analysis in the lab later. This procedure allowed for maximum site characterization for the resources invested.

The results of the laboratory analysis provided the information necessary to determine the radiological hazards involved. Because the radioactivity of the soil samples surrounding the zircoloy sand pile were near background levels, there had been no significant migration of the radioactive material. The external exposure rates were low; therefore, the material did not present an external exposure hazard where it was located. The potential for hazards existed if the material was to be transported to off-site locations by outside forces, such as floods, human activity, or if the loose material were to become airborne causing a significant inhalation hazard. Therefore, it was decided that the best solution was to dispose of the material as hazardous waste. This was accomplished by using an outside contractor to remove and dispose of the material. Radiological and environmental oversight was provided before, during, and after the removal process to ensure adherence to proper regulatory procedures.