CHALLENGES ASSOCIATED WITH THE MANAGEMENT AND DISPOSAL OF WASTE CONTAINING ELEVATED CONCENTRATIONS OF THORIUM

T. Rogers, Envirocare of Utah, Inc.

ABSTRACT

Envirocare of Utah, Inc. is licensed to received, store and dispose of low-level radioactive waste in the Utah west dessert. Their current license allows them to receive wastes with Thorium-232 (Th-232) concentrations up to 10nCi/g. Th-232 has the lowest Derived Air Concentration (DAC), and therefore has the highest internal dose per unit mass, than any other radionuclide. Since Envirocare removes the waste from the containers prior to disposal, soil-type wastes containing high concentrations of Th-232 pose special difficulties and challenges in protecting the worker and the environment. In addition to the airborne dust problem associated with Th-232, Radon-220 (thoron), a daughter of Th-232, can also be a concern. This paper discusses the disposal and radiation protection practices that were implemented to overcome these difficulties.

Envirocare's current license allows them to receive wastes with radionuclide concentrations up to Class A limits. Since Th-232 does not have a listed Class A limit, a limit was established through modeling for occupational and environmental impacts. The limit of 10nCi/g for Th-232 was incorporated into the license.

Recently, Envirocare has been handling and disposing of several hundred thousand cubit feet of soil-type wastes containing concentrations of Th-232 up to the license limit. This material has been transported to Envirocare in railcars which makes unloading and disposing a challenge.

Each shipment that arrives at Envirocare first receives a radiological survey to confirm manifest values and other DOT requirements. Upon arrival of the first shipment of the high Th-232 waste, the required radiological survey was performed. The results from this survey indicated high amounts of removable material on the outside of the railcars. Some results were as high as 12 kdpm/100cm^2 gross alpha and 107 kdpm/100cm^2 gross beta. These smears were then analyzed by gamma spectroscopy for isotopic analysis. The results indicated high levels of Lead-212 (Pb-212), but Actinium-228 was not present. From this it was determined that the high removable results were from thoron releases and not the solid waste itself. Pb-212, which was collecting on the outside of the railcar is a daughter product of thoron. Since Pb-212 has a fairly short half-life (approximately 10 hrs.), the activity on the initial smears should have decreased accordingly. To confirm this, the smears were again analyzed the next day and the results confirmed that the high removable levels were due to thoron releases. After discussions with the DOT, it was determined that railcars transporting this waste were not required to be air-tight and that if Envirocare could show that the high levels were from thoron by waiting for decay and not from the solid waste itself, Envirocare could then accept the shipment.

It is standard practice of Envirocare to unload railcars in our railcar rollover facility. In this facility, the railcars, one-by-one, are actually turned over and emptied into a concrete pit. This action can cause soil-like material, if dry, to become airborne quite easily. Extensive modeling of potential airborne concentrations indicated that the railcars could not be rolled without exceeding allowable air concentration limits at the boundary.

An acceptable unloading technique was to remove the waste using a track hoe placed on tracks on top of the railcar. The waste was then placed into large dump trucks and transported to the disposal cell. The Occupational Safety Department of the company evaluated the process and deemed it to be safe. While the process takes more time, over 350 railcars have been unloaded during a 3 month time period. During this period, doses for workers handling this waste were all less than 120 mrem TEDE.

The surface area of each disposal cell is nominally 2,300m^2. Initially, the waste was placed in 0.3-meter compacted lifts and water applied to reduce dust suspension. However, high gamma radiation levels and elevated thoron concentrations over the waste were found also to be a significant problem. The gamma exposure rate a one meter was approximately 10 mR/hr, and the thoron concentration at breathing level was over several DAC.

To reduce the thoron emissions and gamma radiation to levels that are acceptable, each load of material is immediately covered with 10-15 cm of moist clay. No more than 300 m^2 of waste is uncovered at any one time. During the disposal process when the waste is actively being placed in the cell, thoron concentrations reach 1 DAC. Once covered with clay, the thoron concentration is reduced to less than 10% of a DAC. The use of water as dust suppression also aided in the thoron emissions. Thoron concentrations and gamma radiation levels are measured continuously to ensure that any problems are quickly identified and corrected.

The worker in the bulldozer, which compacts the waste into lifts, is required to use supplied air for internal protection. The dump truck operators are required to wear full-face respirators with combo cartridges because they are only on the cell for a short period of time each time they unload. Doses are assigned to the dump truck operators by DAC-HR tracking.

In conclusion, Envirocare has managed and disposed of large quantities of soil-type waste containing Th-232 concentrations of about 10 nCi/g. New procedures and protocols were instituted to reduce worker and environmental exposures to ALARA levels. Worker doses are all less than 120 mrem TEDE per quarter.

INTRODUCTION

Envirocare of Utah, Inc. (Envirocare) is licensed to receive, store and dispose of low-level radioactive waste in the Utah west desert. Their current license, which was issued and is regulated by the state of Utah, allows them to receive wastes with Thorium-

232 (Th-232) concentrations up to 10nCi/g. Th-232 has the lowest Derived Air Concentration (DAC) listed in 10 CFR 20 Appendix B, and therefore has the highest internal dose per unit volume, of the radionuclides for which DACs are listed.

In order to maximize the volume of disposal cell space available and to produce long-term structural stability, the current practice at Envirocare is to dispose of the waste itself, not the container in which it was transported. The waste is removed from the container and placed in compacted one-foot lifts to meet long-term structural stability and groundwater protection standards. The container is usually decontaminated with the use of high pressure water washers and then transported back to the generator for the use of future shipments. The containers are usually decontaminated to the transportation limits specified in 49 CFR 173 for "Return to Service" or "DOT Empty" depending on the needs of the generator.

Since Envirocare removes the waste from the containers prior to disposal, soil-type wastes containing high concentrations of Th-232 pose special difficulties and challenges in protecting the worker and the environment. In addition to the airborne dust problem associated with Th-232, the external gamma exposure from the Th-232 gamma-emitting decay products has also contributed to the challenge. In addition, Radon-220 (thoron), a decay producet of Th-232, can also be a concern. This paper discusses the disposal and radiation protection practices that were implemented to overcome these difficulties.

Envirocare's current radioactive materials license allows them to receive wastes with radionuclide concentrations up to 10 CFR 61 Class A limits. Since Th-232 does not have a listed Class A limit, a dose-based limit was established through modeling for occupational and environmental impacts. The limit of 10nCi/g for Th-232 was incorporated into the license.

Recently, Envirocare has been handling and disposing of several hundred thousand cubic feet of soil-type wastes containing concentrations of Th-232 up to the license limit. The waste also contains high concentrations of natural uranium and radium. This material has been transported to Envirocare in bulk by railcars, which makes unloading and disposing a challenge.

Each shipment that arrives at Envirocare first receives a radiological survey to confirm manifest values and other DOT requirements. The shipments are inspected to ensure that the containers are strong-tight which ensures that the waste has been contained during transport. The shipments are also inspected to ensure the transport package is placarded and labeled correctly. In addition, the inspectors perform dose rate and smear measurements to ensure that the external gamma dose rate and removable contamination levels on the outside of the container do not exceed those specified in 49 CFR 173.443. The allowable surface contamination on the outside of the container is up to 22 kdpm/100cm2 for gross beta/gamma and 2.2 kdpm/100cm2 for gross alpha upon receipt.

Upon arrival of the first shipment of the high Th-232 waste, the required radiological survey was performed. The results from this survey indicated elevated amounts of removable Th-232 contaminated material on the outside of the railcars. Some results were as high as 10 times the allowable limit for gross alpha and 5 times the allowable limit for gross beta. To help confirm that the material on the outside of the container was indeed waste from inside the container, the smears were analyzed by gamma spectroscopy for isotopic analysis to compare the isotopes with those manifested. The results indicated high levels of Lead-212 (Pb-212), but Actinium-228 was not present. Since the smears were analyzed by gamma spectroscopy, Th-232 concentrations cannot be determined directly, the decay products must be used and equilibrium assumed.

In the Th-232 decay chain, Ac-228 is present before thoron (Rn-220) and Pb-212 is present after thoron. From this, it was determined that the high removable results were from thoron releases and not the solid waste itself. Therefore, the waste is not contained in an air-tight container which results in thoron daughters contaminating nearby surfaces. To further help confirm the release of thoron from the railcars, real-time thoron monitors were placed near the lids of the railcars. The thoron monitors indicated high concentrations of thoron releasing from the railcars.

The railcars that transported this waste are not air-tight. In fact, there are significant gaps in several areas between the lip of the railcar and the lid. This allows significant amounts of thoron gas to be continuously released from the railcar. As thoron is released from the railcar, its solid phase daughters are collected on the outside of the railcar. With the high concentrations of Th-232, the thoron releases from the railcars are significant.

Since Pb-212 has a fairly short half-life (approximately 10 hrs.), the activity on the initial smears should have decreased accordingly. To confirm this, the smears were again analyzed the next day. The results indicated that the concentrations reduced by a factor that is consistent with the decay of Pb-212 and thus also confirmed that the high removable surface contamination levels were due to thoron releases. If the actual waste, which contains Th-232 was present on the outside of the railcar, the smear results would not have decreased.

After discussions with the DOT, it was determined that railcars transporting this waste were not required to be air-tight and that if Envirocare could show that the high levels were from thoron by waiting for decay and not from the solid waste itself, Envirocare could then accept the shipment. Envirocare must follow this procedure on each railcar that is shipped from this generator. Envirocare receives approximately 30 railcars per week.

For other wastes received in bulk quantities in railcars, it is the standard practice of Envirocare to unload railcars in our railcar rollover facility. In this facility, the railcars, one-by-one, are turned over and emptied into a concrete pit. This action can cause soil-like material, if dry, to become airborne quite easily. Extensive modeling of potential airborne concentrations expected from the high Th-232 contaminated soils indicated that the railcars could not be rolled without exceeding allowable air concentration limits at the site boundary, which is near the railcar rollover facility. Due to this, an alternative method of unloading railcars needed to be developed.

The two main environmental regulatory limits for allowable doses to members of the public which were of most concern were those specified in 10 CFR 20 and 10 CFR 61. The requirements specified in 10 CFR 20 include the allowable annual dose limit of 100 mrem total effective dose equivalent (TEDE) to any individual member of the public. The requirements specified in 10 CFR 61 include the allowable annual dose limit of 25 mrem to the whole body, 75 mrem to the thyroid and 25 mrem to any other individual organ of any individual member of the public. Dose determinations can be derived by utilizing the organ dose conversion factors provided in Federal Guidance Report No. 11. Handling this waste by the normal railcar unloading method would have posed a challenge to compliance with these regulations because of the projected committed dose equivalent (CDE) and the committed effective dose equivalent (CEDE), as defined in 10 CFR 20, which would result from airborne particulates containing Th-232. The CDE and CEDE were particulary restrictive because of the proximity of the site boundary. This material also poses concern for occupational exposure, which is discussed later in this paper.

An acceptable unloading technique was to remove the waste using a track hoe placed on tracks that are positioned on top of the railcar. The waste is then placed into large dump trucks and transported to the disposal cell. The Occupational Safety Department of the company evaluated the process and deemed it to be safe. While the process takes more time, over 350 railcars have been unloaded during a 3 month time period. During this period, doses for workers handling this waste were all less than 60 mrem TEDE per month except for the dust suppression technician who received 120 mrem TEDE per month.

Upon arrival at the cell, the dump truck places the material in a pile on the cell floor. A dozer then spreads and compacts the material in one-foot-high lifts. The lifts must meet compaction criteria to ensure long-term structural stability of the cell.

The disposal cell is located approximately 400 meters from the boundary of the site. Radiation monitors, including radon and thoron monitors are placed along the boundary of the site to ensure compliance with allowable dose to members of the public limits specified in 10 CFR 20 and 10 CFR 61. During the initial management and placement of this waste in the cell, the monitors indicated elevated air concentrations of both radon and thoron. The elevated thoron air concentrations were from the cell into which the high Th-232 waste was being placed.

The surface area of each disposal cell is nominally 2,300 m^2. To evaluate the thoron concentrations at the cell, thoron monitors were placed around the edges of the disposal cell. Concentrations up to 10 times the Derived Air Concentrations listed in 10 CFR 20 were measured. These measurements were repeated to determine the variability in the concentrations and validity of the measurements.

To further evaluate the thoron flux and breathing level air concentrations, modeling was performed utilizing the relationships specified in NUREG / CR-2340 titled, "A Handbook for the Determination of Radon Attenuation Through Cover Materials". The thoron flux that is calculated using the equations in this report is as high as 3.0E6 pCi/m^2s. Airborne thoron concentrations associated with this thoron flux were estimated from a breathing zone calculation and confirmed the concentrations determined from the thoron measurements.

Calculations were also performed using the NUREG equations to estimate the amount of clay cover needed to reduce the thoron flux. The calculations indicated that 3 to 4 inches of clay cover would reduce the thoron concentrations to allowable levels. The half-life of thoron is quite short and little clay is necessary to reduce the flux. The initial concern with the management of this waste was controlling the Th-232 particulates in the air. Due to this concern, water is applied to reduce dust suspension. The application of water also helps reduce the thoron flux.

Another concern was the amount of external gamma dose that the workers were receiving, especially those performing work activities on the cell. The measured gamma exposure rate a one meter was approximately 10 mR/hr. In order to reduce the exposure to the worker, the philosophy of time, distance and shielding are applied. Workers have time limits for specific cell compaction measurements as well as other duties on the cell.

The workers that receive the highest exposure are those involved in the actual placement of the waste in the disposal cell which include the dozer operator, dust suppression technician, the engineering technicians and the large dump truck operators. The dozer operator levels the waste and then instead of waiting on the cell for another load, the operator parks the dozer up on an adjacent lift area. The majority of the dust is generated when the dump trucks unload the material on the cell. The trucks unload the material near the edge of the cell. The dust suppression technician remains off the actual lift while directing the necessary water stream to the dust suppression area using an upgraded water pump system. The engineering technicians usually stay on the lift. Only while emplacing and removing the compaction test equipment are they on the cell. To help reduce their exposure, the test equipment is placed and the technician remain off the lift while the equipment retrieves the data. The trucks only travel on the waste that is covered with clay and their time on the cell is specifically limited which helps reduce the drivers' gamma exposure.

To reduce the thoron emissions and gamma radiation to levels that are acceptable, each load of material is immediately covered with 10-15 cm of moist clay. No more than 300 m^2 of waste is uncovered at any one time. During the disposal process when the waste is actively being placed in the cell, thoron concentrations are limited to 1 DAC (without daughters present) on the cell. Once covered with clay, the thoron concentration is reduced to less than 10% of the DAC on the cell. The use of water as dust suppression also aided in the thoron emissions. Thoron concentrations and gamma radiation levels are measured continuously at the site boundary and on the cell to ensure that any problems are quickly identified and corrected.

The worker in the bulldozer, which compacts the waste into lifts, is required to use supplied air to reduce the inhalation of thoron and Th-232 particulates. The dump truck operators, who are only on the cell for a short period of time during each unloading, are required to wear full-face respirators with combination (contains activated charcoal) cartridges.

Each employee is monitored for internal and external exposure. External exposures are monitored by luxel badges, which contain an Al_2O_3 detection medium which utilizes optically stimulated luminescent technology. These badges are analyzed and reported each quarter. Due to the elevated external gamma dose rates, each employee is also required to be monitored with an alarming dosimeter. This alarming dosimeters will alarm if a person is enters an area with unacceptable dose rates. In addition, it will also accumulate external dose for each person. If a person receives over the allowable dose limit, the dosimeter will also alarm and the employee must exit the restricted area immediately. To monitor for internal exposure, each employee must participate in the bioassay program. The workers associated with this project are required to submit a urine bioassay each month. In addition, employees are selected from each area to submit fecal bioassay samples for better determination of potential thorium intake.

Since the high thorium contaminated waste material is unloaded by a track hoe, the material is not completely removed from the railcar. Because of this, it is required to ship the railcar back to the generator as a placarded radiological shipment. For other materials, usually the railcars are unloaded, decontaminated to standards specified in 49 CFR 173.443 as verified by a radiological survey before release. However thoron generated by the high thorium contaminated material remaining in the railcar, again made it difficult to meet the release limit criterion for removable contamination on the railcar surface. The removable surface contamination can be 10 times the values in Table 11 of 49 CFR 173.443 on receipt, but must be below these values for release. Once again, if it can be proven, that the elevated surface contamination levels are due to thoron and not Th-232, the railcars can be released. Therefore, the same radionuclide assessment procedure that is used for receipt of railcars of this material is also used for the release.

Without the required personal protective equipment specified above and the newly developed administrative controls, the workers could potentially receive doses over the allowable federal limit. Unprotected dose rates for the various operations are shown in Figure 1. As shown, the highest dose rate occurs for the dust suppression technician for the disposal cell activities. If not adequately protected, this worker could potentially receive 6.5 rem TEDE per month, 78 rem TEDE per year, approximately 16 times the annual federal limit. Of the 6.5 rem TEDE per month, approximately 2 % is external exposure (DDE) from gamma radiation, the remaining dose is from Th-232 airborne particulate and thoron. With the required protection, the technician received approximately 120 mrem TEDE per month, all of which is from external gamma (DDE) since the worker is equipped with supplied air respiratory protection. All other workers receive less than 60 mrem TEDE per month.

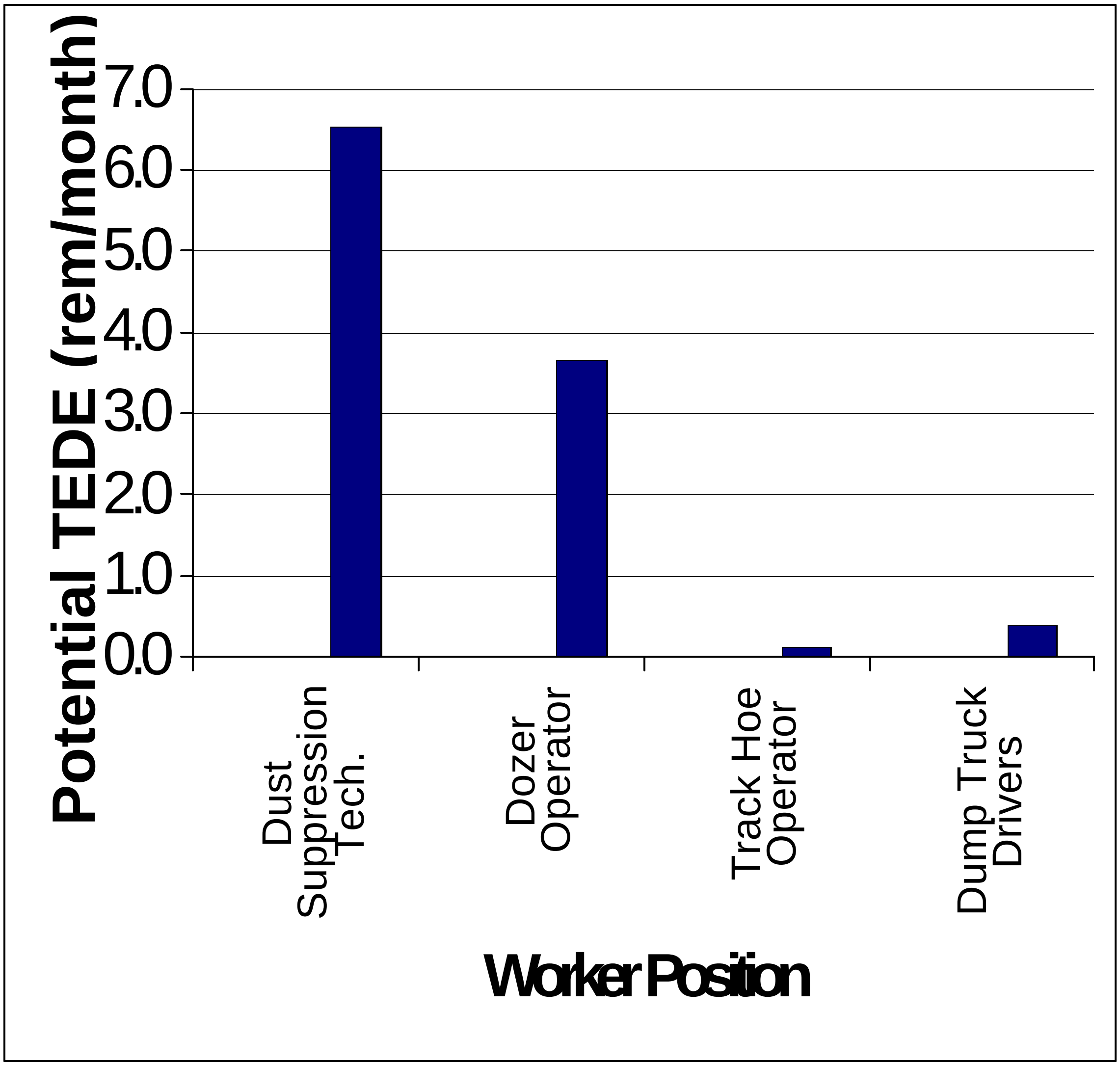

Fig. 1. Unprotected potential worker doses in rem TEDE per month.

CONCLUSION

In conclusion, Envirocare has managed and disposed of large quantities of soil-type waste containing Th-232 concentrations of about 10 nCi/g. New procedures and protocols were instituted to reduce worker and environmental exposures to ALARA levels.