Evaluation of Doses from Residual Radioactivity in Sewage Sludge at Royersford Wastewater Treatment Facility Technical Evaluation Report

Background

The Royersford Wastewater Treatment Facility (hereafter, Royersford) is a very small [~1500 m^3 (~400,000 gallons) per day] sewage treatment plant in Royersford, Pennsylvannia. Its sewage became contaminated with various radioactive materials - primarily cesium-137 (Cs-137) and cobalt-60 (Co-60) - by receiving radioactive influent from sewer releases made in accordance with 10 CFR 20.2003 by UniTech Services Group (UniTech), formerly known as Interstate Nuclear Services, License No. 37-23341-01, from approximately 1985 through 2004.

While UniTech was actively releasing material, the site's processes were contaminated with radioactive material. The NRC has been evaluating the presence of radioactivity at Royersford since the mid 1980s. The last inspection report, which provides a more complete history of the site, is available in ADAMS (ML060340233). The primary and secondary digester have been cleaned of residual material since they stopped receiving material from Unitech. The Borough of Royersford has the remaining contaminated sludge de-watering in the on-site reed bed, but proposes to remove the material and dispose of it at an industrial landfill that accepts sewerage waste at some point in the future. The on-site reed bed contains approximately 400 cubic meters of sludge with average concentrations of 4.9 Bq/g (133 pCi/g) Co-60 and 0.5 Bq/g (14 pCi/g) Cs-137.

Analysis

The technical assistance request specifies three dose assessments, for both workers and members of the public, for the site:

1) if the contaminated sludge remains on site at Royersford;
2) if the sludge is removed from the reed bed and packaged for transport; and
3) the sludge is disposed at an industrial landfill.

As neither Royersford, nor any potential future landfill, is a licensee, this analysis treats workers at either location as members of the public for the purposes of potential applicable dose limits. Potentially applicable dose limits would be either the public dose limit [i.e., 10 CFR 20.1301's 1 mSv/y (100 mrem/y)], or NRC policy for alternate disposals under 10 CFR 20.2002 of a few mrem/y, depending on the scenario under evaluation.

The site is fairly small. NRC collected data for many years from environmental thermo luminescent detector (TLD) located around the site. Figure 1 shows a sketch of the site and the relative locations of TLDs, Reed Bed 1, and various other locations of the site. Table 1 shows the gross quarterly results from selected TLDs around the site for the last four quarters monitoring was performed. In addition, an extrapolated row for Quarter 2 of 2007 is listed, derived from the 2006 Quarter 2 results assuming the natural decay of Co-60 (the predominate source of the external dose) since the final actual reading. Table 2 shows the results of sampling of the reed bed and reeds at the site, as of January 2006 and estimated concentrations as of June 2007, accounting for natural decay. Background is based on the reading from TLD 16, which is inside the brick office.

Enclosure

Table 1. Quarterly TLD Results for Selected Locations (mrem*)

Quarter	TLD 1	TLD 2	TLD 3	TLD 4	TLD 9	TLD 12	TLD 14	Bkgd
3Q05	535	301	38	64	26	24	52	17
4Q05	745	258	39	62	28	27	53	19
1Q06	486	215	38	42	30	29	47	21
2Q06	523	298	**	70	30	29	47	19
2Q07 (est)	447	256	35	62	28	28	43	20

* Multiply the results by 0.01 to convert to mSv
** The reading appears spurious at 0.1 mrem. The estimated 2Q07 reading assumes it would have been 38.

Table 2. Summary of Sample Results from January 2006

Sample Type	January 2006	June 2007 (est averages)
Reed Bed Sludge (wet weight)	Co-60: 39-212 pCi/g - Avg 161.6 pCi/g Cs-137: 4-22 pCi/g - Avg 14.5 pCi/g Mn-54: 2-12 pCi/g - Avg 6 pCi/g Zn-65: 0.2-3.9 pCi/g - Avg 1.3 pCi/g Sb-125: 0.4-1.9 pCi/g - Avg 1.4 pCi/g	133 pCi/g Co-60 14 pCi/g Cs-137 1.7 pCi/g Mn-54 0.3 pCi/g Zn-65 1 pCi/g Sb-125
Reeds (wet weight)	0.06 to 0.27 pCi/g Co-60 0.58 to 1 pCi/g Cs-137	

* Multiply by 0.037 to convert pCi to Bq

Based on the sampling data, Co-60 is currently the predominate radionuclide for exposure to workers at the facility or members of the public. Co-60 results in approximately four times as much gamma exposure per unit concentration as the other contaminates, based on a comparison of the gamma factors (Γ) in the Health Physics and Radiological Health Handbook. Since the concentration of Co-60 is approximately 10 times the concentration of Cs-137, the Co-60 contributes at least 40 times more external exposure as the Cs-137 or any other contaminant. Therefore, of the 5 mSv (500 mrem) TLD 1 reading, after subtracting background, approximately 4.8 mSv (480 mrem) was caused by Co-60, 0.12 mSv (12 mrem) by Cs-137, and 0.12 mSv (12 mrem) by all other radionuclides. The staff used this as a basis to perform simple extrapolation of the external exposure at the TLD locations using only the decay constant for Co-60 for the estimated results after one year of decay. Longer decay times would need to consider the longer half-life of Cs-137. For example, after 30 years, the Co-60 dose will have been reduced by 6 half-lives to 0.075 mSv (7.5 mrem) per quarter, and the Cs-137 dose will have reduced to 0.06 mSv (6 mrem).

As can be seen from the sampling data and the environmental TLDs, the primary source of radiation exposure is the sludge in Reed Bed 1. The reeds are relatively small residual amounts that will result in only minimal exposures to workers. Reed Bed 1 has concrete walls approximately 2 meters (6 feet) high, and is approximately 22 meters (72 feet) long by 15.2 meters (50 feet) wide. A wall about 9.1 meters (30 feet) from one end of the reed bed divides it into Cell 1 (smaller) and Cell 2 (larger). At the time of the January 2006 sampling, the reed bed sludge had reduced to approximately 1.2 meters (4 feet) high. Based on those dimensions, the reed bed contains approximately 400 cubic meters of sludge with average concentrations of 4.9 Bq/g (133 pCi/g) Co-60 and 0.5 Bq/g (14 pCi/g) Cs-137.

Dose Estimates for Public in Current Situation

There are two basic exposed public groups with the current situation with the contaminated sludge being present in the reed bed at Royersford.

The first group is the general public which can be potentially exposed by being around the site outside the fence line. Based on the results from TLD 3, which is the fence line TLD closest to Reed Bed 1, doses to this group are well below the public dose limit of 1 mSv (100 mrem) and likely to be under a few millirem per year for any reasonable estimation of exposure time. TLD 3 shows approximately 0.15 mSv (15 mrem) over background per quarter of continuous exposure at the fence line or approximately 0.6 mSv (60 mrem) per year. An individual would need to be present at or near the fence line for more than 100 hours per year to get more than 0.01 mSv (1 mrem) or more than 600 hours per year to get more than 0.05 mSv (5 mrem). However, no member of the public is reasonably expected to be present at the fence line for appreciable hours per year. The area outside the fence is undeveloped, and not readily accessible to the public on the side where TLD 3 is located.

The second exposed public group is the workers at Royersford. Royersford is not a licensee and, therefore, its workers are treated as members of the public. From the results of the monitoring on the site, the reed bed does create elevated dose rates over portions of the site near the reed bed. The dose rates reduce quickly with distance from the reed bed. An example is TLD 14 versus TLD 1. TLD 14 is on the roof of the secondary digester and elevated such that it receives direct shine from the reed bed and while it shows an elevated dose rate of approximately twice background, the dose rate is approximately 10 times less than that shown at TLD 1.

For the worker dose estimate, a simplifying assumption is made that ignores the difference between Cell 1 and Cell 2 dose rates and uses the higher dose results from TLD 1. Currently, no additional waste is being added to Reed Bed 1 and only limited maintenance activities are necessary which result in close proximity dose from the bed. Most of the time exposed to elevated dose rates would be received from the general activities as workers travel around the site and do normal activities unassociated with Reed Bed 1, such as working around the settling tanks, going to and from the lab building and the office building, traveling to the secondary digester, performing ground maintenance around the general site, etc. Based on the radionuclides involved, external exposure is the primary pathway for workers and the doses from inadvertent ingestion or inhalation can be discounted.

A bounding estimation of worker dose uses the following assumptions. Note that the dose rates will decrease with time as the Co-60 decays, with its 5.2 year half-life.

1) The dose rate close to the reed bed is 4.25 mSv (425 mrem) per quarter, or 17 mSv (1700 mrem) for a year of continuous exposure. This is based on the estimated readings for TLD 1 for the second quarter of 2007 minus the background reading.

2) Workers will be performing maintenance activities on the reed bed for 20 hours per year. As the reed bed is not actively being used, only limited maintenance activities are necessary. This could involve activities directly around the reed bed or maintenance activities such as removing the reed mass.

3) The general elevated (or net) dose rate will be assumed to be 0.25 mSv (25 mrem) per quarter, or 1 mSv (100 mrem) for a year. Dose rates from the TLDs range from approximately 0.08 mSv (8 mrem) per quarter (e.g., TLD 9 and 12) to approximately 0.4 mSv (40 mrem) (e.g., TLD 4) per quarter. As the workers will spend time over the entire site, an "average" rate was assumed. Actual weighting of dose rate across the site was not performed in establishing this assumption.

4) Workers spend one quarter of their work time (i.e., 500 hours) outside or in elevated areas of the site.

Based on these bounding assumptions, the worker receives approximately 0.04 mSv (4 mrem) from work directly around the reed beds and 0.06 mSv (5.7 mrem) from work around the entire site, for a total of approximately 0.10 mSv (9.7 mrem) per year to workers. This is a small fraction of the public dose limit.

Based on an evaluation of the current situation, neither the public nor the workers are receiving significant exposure from the residual radioactivity present at Royersford. Since the major contributor is Co-60 and no additional residual radioactivity is being added to the site, exposure should continue to reduce, halving approximately every 5.2 years. However, due to the relatively high dose rates from the sludge in the reed bed, a change in activities or site control (for example, closing the waste water treatment facility and utilizing the site in another manner or re-instituting use of the reed beds) may result in doses that are a significant fraction of the public dose limit or potentially exceed the public dose limit.

<u>Disposal of Sludge at an Industrial Waste Facility</u>

The Borough of Royersford does not intend to leave the material at the site until the radioactive material decays. It intends to ship the sludge to an industrial waste facility that accepts sewer sludge for disposal. At the present time, the industrial waste facility has not been identified. Previously, Royersford shipped other sludges (although lower concentrations) to industrial waste facilities for disposal.

The staff used the information in NUREG-1783, "ISCORS Assessment of Radioactivity in Sewage Sludge: Modeling to Assess Radiation Doses," to estimate the doses for two scenarios at Royersford. This is a report of a multi-agency dose analysis of radioactivity in sewage sludge. The report is the result of a joint effort by the Interagency Steering Committee on Radiation Standards (ISCORS) and included the U.S. Nuclear Regulatory Commission, the U.S. Department of Energy, the U.S. Environmental Protection Agency, the State of New Jersey's Department of Environmental Protection, the Middlesex County Utility Authority, and the Northeast Ohio Sewer District.

The first scenario is dose to the workers at Royersford loading the sewage sludge into conveyers to transport the sludge to the waste facility for disposal. This scenario also addresses doses to workers at the waste facility unloading the material and for transportation workers as they would likely have less exposure time than assumed in the scenario. The staff used the biosolids loading/storage scenario in section 4.7.3 of NUREG-1783. This scenario addresses possible exposure from external exposure, inadvertent ingestion, and inhalation assuming normal work conditions at sewage treatment facilities.

It is assumed the worker spends his time next to a pile of dewatered sludge (roughly 100 square meters in area) and approximately 0.5 meters thick. While the reed beds are slightly larger and deeper, this should not change the estimates greatly as the total material is limited and the total volume of material left in the reed beds will decrease in size as material is loaded. Because of the limited amount of material, staff used a more reasonable bounding estimate of exposure time of 100 hours. The base values modeled by ISCORS assume a worker spends 1000 hours per year doing this activity. It is likely that loading operations would take tens of hours to complete, rather than the ISCORS assumed time, with only 400 cubic meters at Royersford. The highest dose to source ratio for the scenario is Co-60 with 0.07 mrem / pCi/g (for 100 hours of exposure). Using the June 2007 sludge estimates, there is approximately 5.55 Bq/g (150 pCi/g) of activity in the sludge. To simplify the calculation, since Co-60 is the highest dose to source ratio, all 5.55 Bq/g (150 pCi/g) is assumed to be Co-60. The bounding worker dose would then be estimated to be less than 0.1 mSv (10.5 mrem), if the Royersford material was shipped in the near-term. If the material was not removed from Royersford for a couple more years, the worker doses would reduce as the Co-60 decayed away.

Dose to the transport worker and the unloaders at the industrial waste facility should be lower than those bounded for the on-site worker as their exposure times are likely to much less than 100 hours. In addition, standard practice at industrial waste facilities is the use of daily covers of soil-like material. These are placed on top of the waste for various reasons including reducing precipitation into the cells. Because of these daily covers and the likelihood that non-radioactive waste is placed on top of the sewage sludge in the disposal cells, additional worker dose from proximity to the emplaced waste at the industrial waste facility will be near zero. Therefore, the workers at the industrial waste facility are only exposed during unloading and emplacement activities, which should be less than that assumed for the loading activities. Dose to the workers at the industrial waste facility are likely to be less than a few millirem as disposing of 400 cubic meters of waste should not take more than 40 hours.

Possible long-term scenarios such as doses to nearby neighbors due to migration of the material to the local groundwater over time were considered. The report assumes a relatively simple design for the waste facility with a simple 0.5 m (2 ft) clay cover and a similar 0.5 m (2 ft) clay layer for the liner. The report also assumes that 20,000 m^3 of sewage sludge is disposed at the site, which is 50 times the amount of material Royersford has. It is the staff's opinion that any industrial waste facility in Pennsylvania would perform better at containing the waste than the simple design modeled in the NUREG. NUREG-1783 has estimates of doses to nearby neighbors and evaluated three scenarios - dust and airborne releases during unloading, possible releases during the monitoring phase and the long-term potential dose from groundwater release. Co-60 had a dose to source ratio of 1.45×10^{-25} mSv (1.45×10^{-23} mrem) per pCi/g, while Cs-137 has a dose to source ratio of 3.78×10^{-12} mSv (3.78×10^{-10} mrem) per pCi/g. Therefore, the disposed sludge, using the current concentrations, could lead to a groundwater release resulting in a peak dose of 5.3×10^{-11} mSv/yr (5.3×10^{-9} mrem/yr).

NUREG-1783 does not calculate the dose to an inadvertent intruder into the industrial waste facility. For the Royersford source term, the timing of the intrusion would be critical. The predominate radionuclide, Co-60, which has a 5.2 year half-life, will decay quite quickly, while the site continues to operate and closes during the monitoring period. In case of an intrusion, the contaminated sludge will be inadvertently mixed with other waste, thereby reducing the concentration further than that due to decay alone. For example, if the intrusion were to occur 30 years after disposal in 2007, the concentration in the sludge of Co-60 would be 0.07 Bq/g (2 pCi/g) and the Cs-137 would be 0.26 Bq/g (7 pCi/g). If the sludge were inadvertently mixed with cover material and other waste, the concentration would be reduced by a factor of four or more, depending on the thickness of the cover, the depth of the waste and the degree other waste is present. As a very conservative estimate, assume that the intrusion occurred 30 years after disposal, the inadvertent mixing resulted in only a factor of four reduction in concentration and a resident gardener lived on the spoils from the intrusion. To convert the concentration to dose, the staff used the screening criteria (Appendix H) from NUREG-1757, Volume 2, as a guideline for what concentration is equivalent to 0.25 mSv (25 mrem) for an annual exposure. From Appendix H, 0.25 mSv (25 mrem) results from 0.14 Bq/g (3.8 pCi/g) Co-60 or 0.41 Bq/g (11 pCi/g) Cs-137. The conservate bounding dose to the intruder would be approximately 0.07 mSv (7 mrem). If the intrusion were not to occur until 90 years after disposal, the very conservative dose estimate would drop to 0.01 mSv (1 mrem).

Conclusions

Based on an evaluation of the current situation, neither the public nor the workers are receiving significant exposure from the residual radioactivity present at Royersford. Since the major contributor is Co-60 and no additional residual radioactivity is being added to the site, exposure should continue to reduce, halving approximately every 5.2 years. However, due to the relatively high dose rates from the sludge in the reed bed, a change in activities or site control (for example, closing the waste water treatment facility and utilizing the site in another manner or re-instituting use of the reed beds) may result in doses that are a significant fraction of the public dose limit or potentially exceed the public dose limit.

However, the Borough of Royersford does not intend to leave the material at the site until the radioactive material decays. It intends to ship the sludge to an industrial waste facility that accepts sewer sludge for disposal. Doses to workers at both Royersford and the waste disposal facility will not be significant if the material is disposed at an industrial waste facility. Long-term doses from disposing of the sewage sludge at a waste facility are a very small fraction of a mrem. Intruder doses, although unlikely before the majority of the source term will decay, will result in doses of a few mrem at most under very conservative assumptions. Therefore, disposal at an industrial waste facility that accepts sewer sludge for disposal should be pursued to reduce the potential hazard to the public as compared to leaving the sludge in place.

Figure 1 - DIAGRAM OF THE ROYERSFORD WTF

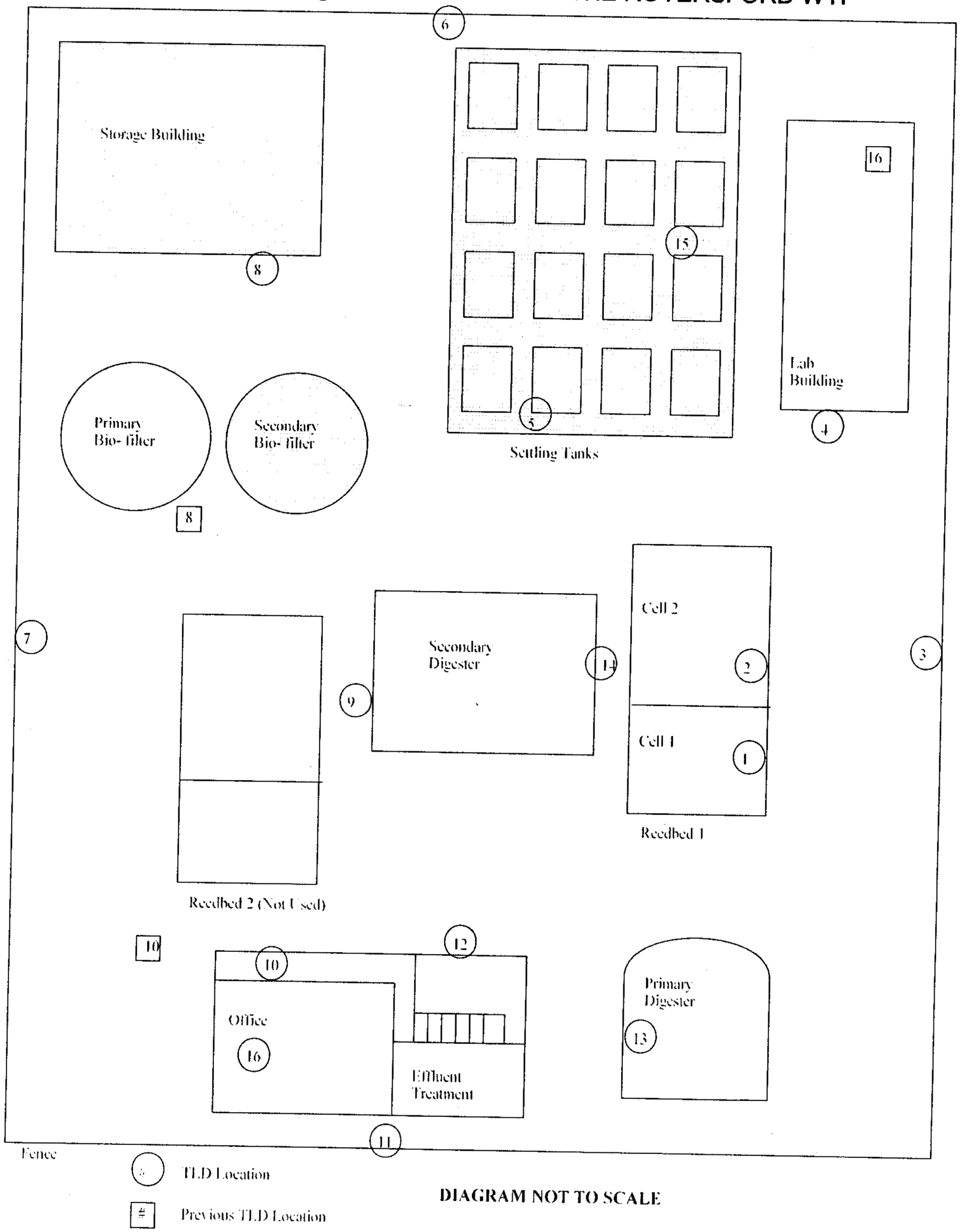

DIAGRAM NOT TO SCALE