TRANSPORTATION WORKER EXPOSURE FROM THE TRANSPORT OF BRC RADWASTE

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ABSTRACT

The radiation exposure to workers who would transport short-lived radionuclides to sanitary landfills has been evaluated using a metropolitan scenario for Houston. This scenario also was used in a recent BRC radioactive waste study commissioned by the Texas Low-Level Radioactive Waste Disposal Authority. The transportation worker exposure as calculated in that study is compared to the exposure calculated with IMPACTS-BRC using the same data as well as to that calculated with point-kernel integration codes for an idealized front-end loader collection vehicle.

INTRODUCTION

A recent study (1) commissioned by the Texas Low-Level Radioactive Waste Disposal Authority (Authority) has lead to the implementation of a Below Regulatory Concern (BRC) radioactive waste disposal rule for placing short-lived radionuclides (half life 300 days) in sanitary landfills. In that study it is assumed that any such waste disposed by a generator will be picked up during the course of routine municipal solid waste collection and processed and disposed of as municipal solid waste. For the majority of radionuclides examined in the study, the allowable concentration for disposing them in the municipal solid waste stream was limited by the exposure of a transportation worker involved in municipal waste collection. It should be pointed out that the allowable dose to the maximally exposed individual in that study was set to be 1 mR/yr. The transportation worker exposures as calculated in that study (1,2) are compared with exposures calculated using the IMPACTS-BRC transportation worker methodology (3) and using two point-kernel shielding codes, QAD-CGGP (4) and MICROSHIELD (5). The methodology used in the IMPACTS code is first reviewed since it is the basis for the one used in the Authority study. The modified methodology used in the Authority study is recapped and a front-end loader truck model is introduced for use with the point-kernel codes. A comparison of the transportation worker exposures calculated with each approach is made for a metropolitan waste scenario.

EXPOSURE CALCULATION METHODOLOGIES

IMPACTS-BRC Methodology (3)

The truck driver exposure as calculated for the Authority study employs a methodology that is based on the one found in the Nuclear Regulatory Commission's de minimis waste impacts code IMPACTS-BRC, but modified to be consistent with EPA-ORP procedures (2). In IMPACTS, the transportation worker's exposure, D_w, is calculated using the following formula:

$$D_w = C_w[d_d/d_w]PKCFDFEDFPDCF\text{-}5 \quad (1)$$

where

PDCF-5 = the radionuclide specific exposure rate per year 1 m above the air-soil interface for soil having an infinite thickness, infinite lateral extent, and a uniform contamination of 1 Ci/m^3. It stands for Pathway Dose Conversion Factor-5 (3). These factors in IMPACTS were derived from the work reported in Ref. 6.

DF = the distance factor which corrects the exposure rate for the actual distance as compared with 1 m that the worker is from the surface of the waste.

CF = the geometry correction factor which corrects for exposure rate for the finite lateral extent of the truck.

EDF = the fraction of the year during which the transportation worker is being exposed or involved in collecting municipal refuse.

d_d/d_w = the ratio of the soil density (1.6 g/cm^3) assumed in deriving the PCDF-5 to the waste density in the truck.

PK = the packaging factor which is 1.33 if the waste is assumed to be packaged, otherwise it is 1.0. It corrects for changes associated with decreased waste density in the truck due to the loss in compaction from transporting packaged waste. and

C_w = the actual radionuclide concentration in the truck (Ci/m^3)

This methodology assumes that any differences between soil and municipal solid waste composition are minor except for density. Variations in the composition of the solid waste should have a relatively small effect on the PCDF-5 based on the soil composition variation studies reported in Ref. 6. It is important to note that only the lateral extent of the truck is incorporated into the corrections and not the finite depth of the truck. No decay of the radionuclides occurs during collection of the radionuclide waste in IMPACTS.

In addition it is assumed that during each collection trip, three hours elapse with the radionuclide waste in the truck. Of that three hours, it is assumed that the worker sits in the truck cab for two hours, stands beside the truck for 0.5 hour, and is sufficiently far from the truck to receive no exposure for the other 0.5 hour. The factor CF is calculated using these assumptions and by assigning an effective source radius of 2 m to the waste while the worker is in the truck cab and a 4 m effective source radius when the worker stands beside the truck. The CF factor furthermore assumes that the worker is located at the midplane of the waste volume and a distance of 1 m from the truck during exposure at both locations. It should be noted that the effective source areas would actually be rectangular.

The Authority Study Methodology (1,2)

In the Authority study, the IMPACTS methodology was modified as follows. The radionuclide waste was allowed to decay for 12 hours prior to being loaded into the transportation vehicle. However, no credit was taken for decay en route to the sanitary landfill. The factor EDF was reduced by 1/2 to compensate for partial loading of the truck, i.e. the worker starts with an empty truck and gradually fills it up along the collection route. In addition, the PDCF-5 was replaced by the factor $DF_g/\mu(Eg)$ where DF_g is the external gamma-ray exposure conversion factor in mR/yr per Ci/mconsistent with the EPA methodology (1,2). The factor $1/\mu(E_g)$ is related to the transformation of an infinite volume source to an equivalent infinite surface source in ray theory (7). The term $\mu(Eg)$ is the linear attenuation coefficient for gamma rays in soil.

An additional factor was also incorporated into Eq. (1) in order to take credit for the shielding provided by the truck cab and waste container wall, namely,

$$\exp\{-[d_{Fe}/d_d]\mu(E_g)\ x\} \qquad (2)$$

where d_{Fe} is the density of iron (7.86 g/cm^3) and x is the assumed shielding thickness of 3 cm. In the Authority study, the concentration in Eq. (1) was replaced by $C_w'\ f_v$ where Cw' is the concentration of the radionuclide in the waste as picked up at the waste generator site and fv is the fraction of the total waste collected by the worker that is short-lived radionuclide waste.

Point-Kernel Code Computations

For comparison with exposures calculated using the two above mentioned methodologies, two point-kernel integration shielding codes were used to calculate the transportation worker exposure. They provide a more exact modelling of the volumetric source represented by the waste in the truck, but are not to be considered exact solutions to the problems. The Grove

Engineering code MICROSHIELD version 2.0 (5) and QAD-CGGP (4) were used to calculate exposures for a generic 15.3 m^3 truck. In these code runs, the solid waste was assumed to have the composition of soil used in Ref. 6 as per IMPACTS. An idealized model of a 15.3 m^3 front-end loader collection vehicle was used to perform the point-kernel exposure evaluations. A front-end loader was chosen as it is more likely to make collections at commercial locations than rear-end loading vehicles. The solid waste compartment was assumed to have the following inner dimensions: a length of 372 cm, a height of 193 cm, and a width of 213 cm. Most front-end loader vehicles have greater capacity than 15.3 m^3, but this size was used to match the volumes used in IMPACTS and the Authority study.

For consistency with the other two methodologies, the exposure to the transportation worker was always calculated at the midplane of the waste volume. Once again the worker was assumed to be 1 m from the truck when he stands beside it; however, he was now placed 2.6 m from the waste when in the cab of the vehicle. The walls of the waste container, the cab wall, and the compaction blade were explicitly included in the point-kernel calculations as iron with thicknesses of 0.48 cm, 0.15 cm, and 0.65 cm, respectively. The gamma-ray fluence-to-exposure factors used were those embedded in the MICROSHIELD code when that code was used and those from ANSI 6.1.1 (8) when the QAD-CGGP code was employed.

Since the Authority study assumed that the radionuclide waste was packaged, the packaging effect was included in the point kernel code runs by using a waste density (0.23 g/cm^3) which was 75% of the waste density (0.3 g/cm^3) employed in that study. This also meant that the radionuclide concentration were decreased to be 75% of the Cw value used in the other methodologies. These changes are taken care of in those two methodologies by the packaging factor by arguing that the resultant lower radionuclide concentration and lower attenuation except for increasing the number of trips to haul a given quantity of waste by a factor of 1.33 (3). This argument is based on the work reported in Ref. 6 which is true for an infinite source medium but may not be fully appropriate in this case

RESULTS OF THE EXPOSURE CALCULATIONS

In the Authority study, the most limiting radionuclide disposal concentrations, C_w, were found to be for a metropolitan Houston disposal scenario, so all results in the present work are based on that scenario (see Ref. 1 for details). In the Authority study, for each nuclide the C_w value which would deliver a 1 mR per year exposure was determined. These concentrations were used in the present work to generate the required input data to run the IMPACTS, MICROSHIELD, and QAD-CGGP codes. Note should be made here that the exposures reported herein for IMPACTS were adjusted to take credit for 12 hours of decay and divided by two to allow for the partial load credit taken in the Authority study. In addition, the Authority study assumed a shorter vehicle trip time than is assumed in IMPACTS so a correction was performed to compensate for that difference.

The point-kernel code calculations were performed assuming a source strength of 1 Ci/m^3 in the waste for 28 energy groups between 0.015 and 9.0 MeV with QAD-CGGP and for 21 energy groups between 0.1 and 10.0 MeV with MICROSHIELD. The exposure inside the cab and alongside the truck were determined for each of the energy groups. These two values for each group were appropriately weighted and folded with the actual gamma-ray emission probabilities itiesitiesitiesfor each radionuclide. The resulting yearly exposures are tallied in Table I along with the C_w values from the Authority report and the appropriately adjusted IMPACTS exposures.

ANALYSIS

The two point-kernel code exposures are in good agreement except for Tc-99m and Ce-141. The reason for the disagreement between these two values is not generally known but may be due to the buildup factor (9) and dose conversion factor differences between the two codes. The differences between the IMPACTS-BRC and Authority study are attributable to the credit taken for the truck shielding in the Authority study, to some degree to the different dose conversion factors used, and to the exclusion of exposure buildup in the waste in the Authority study. The use of an area-source to dose conversion factor, DF(E_g), to obtain an approximate volume-source to dose conversion factor, DF(Eg)/μ(Eg), allows for attenuation in the waste but not for buildup in the Authority study. This buildup omission and the different waste to cab distance help to explain the difference between the point-kernel code results and the Authority study. For example, position averaged buildup factors derived from QAD-CGGP code runs are approximately 2.3, 4.4, and 11 for Sc-46, Cr-51, and Ce-141, respectively. This apparently accounts for a major portion of the difference between the point-kernel code results and the 1 mR/yr of the Authority study.

However, more scrutiny of this improved agreement reveals that it is fortuitous since the value of the geometry factor, CF, used in IMPACTS and the Authority study must be changed for the front-end loader vehicle model as does the distance factor, DF. Recall that these two methodologies employed effective area source radii for the cab location and truck side location of 2 and 4 m, respectively. If one wants to calculate the CF value for the front-end loader vehicle source geometry, the effective area source radii then become 1.14 m and 1.51 m leading to a CF value of 0.0425 as opposed 0.185 (3) and a DF value of 0.96 compared to 1.0 (3). This would indicate that if the same point-kernel geometry were used in IMPACTS and the Authority study, those exposures would be reduced by a factor of 5.0. This does drive the IMPACTS calculated exposures much closer to the point-kernel results although they would now be lower.

CONCLUSION

It is apparent that more thought must be given to the transportation worker scenario since it is the limiting exposure pathway for many of the short-lived radionuclides. Since the exposures under consideration in the disposal of BRC radioactive waste will be difficult to measure above background, computer modelling must be used to assess the delivered exposures. Therefore, more sophisticated external exposure calculations are warranted as well as the development of transportation scenarios which use more realistic vehicle modelling.

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