DISCUSSION OF ASSUMPTIONS AND CALCULATIONS FOR THE DOSE ASSESSMENT FOR EXPOSURE TO SHIPPING CONTAINERS AT 4 Bq cm^{-2}

The National Institute for Occupational Safety and Health (NIOSH) performed a radiation exposure pathway analysis to estimate potential effective doses to workers who might be exposed to shipping containers that are contaminated at a level of 4 Bq cm^{-2} with I-131, Cs-137, or Sr-90. The pathway analysis mirrors the analysis of the "room occupancy scenario" for surface contamination in ANSI N13.12, "Surface and Volume Radioactivity Standards for Clearance." The exposure scenario is consistent with deriving doses from large surface sources and assumes continuous occupancy of unprotected workers in a commercial facility after clearance of the sources at the prescribed limit. The pathways that are considered are: 1) direct radiation from a contaminated surface; 2) inhalation of resuspended contamination; and 3) ingestion of transferred contamination. This estimate is considered bounding[1] based on conservative assumptions with respect to annual average worker location relative to shipping containers, and the average level of contamination on those shipping containers.

This calculation differs from previous preliminary calculations by examining the long-term dose consequence to the average worker from potential exposures to contaminated containers. Previous preliminary estimates used short-term bounding conditions to derive maximum doses in worst-case acute exposures. It was inappropriate to infer annual doses from these estimates given that the assumptions used were plausible only under exposures that were of short duration.

Direct Radiation

Information and assumptions used in the direct radiation pathway calculation:

- All containers are contaminated at 4 Bq cm^{-2} with Cs-137, the nuclide under consideration that results in the highest effective dose. The decay product of Cs-137, Ba-137m, is included in the analysis.
- The shipping containers approximate an infinite contaminated plane, so the dose coefficients for exposure to contaminated ground surfaces from Federal Guidance Report No. 12 of the U.S. Environmental Protection Agency (EPA) are used.
- The worker spends 2000 hours in a year at an average distance of 1 m from the contaminated shipping containers.

Under these conditions, the worker would receive an effective dose of 17 mrem per year. Actual doses received by workers are expected to be far smaller because the assumptions about worker position relative to containers and the number of contaminated shipping containers are considered bounding rather than realistic.

Inhalation

Information and assumptions used in the inhalation pathway calculation:

- All containers are contaminated at 4 Bq cm^{-2} with Sr-90, the nuclide under consideration that results in the highest effective dose.

[1] A bounding estimate is one that is expected to exceed, or bound, the maximum effective dose that a worker would receive under real-life conditions.

- Solubility Class Y (least soluble) is assumed for Sr-90 because it results in the highest effective dose.
- The worker spends 2000 hours per year in close proximity to an array of shipping containers contaminated at 4 Bq cm^{-2}.
- A resuspension factor of 1E-06 m^{-1} is utilized as in the "occupied building" scenario in ANSI/HPS N13.12. Other, higher resuspension factors might be chosen in this context, but the assumption that all shipping containers the worker encounters are contaminated at the reference level and the assumptions of worker position with respect to shipping containers provide safety factors of orders of magnitude. Informal reports of contamination surveys of roughly 100 shipping containers indicate that the average smear samples was less than 4 Bq cm^{-2}.
- Average breathing rate for the worker is taken as 1.2 m^3hr^{-1}.
- Dose coefficients to convert inhaled activity to effective dose are taken from the EPA Federal Guidance Report No. 11, which uses the recommendations from Publication 30 of the International Commission on Radiological Protection (ICRP). Those recommendations are the basis for current U.S. Nuclear Regulatory Commission (NRC) dose limits. Current Occupational Safety and Health Administration (OSHA) dose limits, which are numerically equivalent, are based on ICRP Publication 2, which does not provide methodology to calculate effective dose.

Under these conditions, the worker would receive an effective dose of 3 mrem per year.

Ingestion

Information and assumptions used in the ingestion pathway calculation:

- All containers are contaminated at 4 Bq cm^{-2} with Sr-90, the nuclide under consideration that results in the highest effective dose.
- The most soluble form of Sr-90 is assumed because it results in the highest effective dose.
- An effective ingestion transfer rate of 1E-4 m^2hr^{-1} is used. This has the effect of assuming that each hour of the work year the worker ingests the contamination from 1 cm^2 of shipping container area.

Under these conditions, the worker would receive an effective dose of 30 mrem per year.

The maximum values per pathway cannot be summed to obtain the maximum potential effective dose to a worker, because each is caused by a different nuclide or solubility class. The following table illustrates the effective doses that result from contamination at 4 Bq cm^{-2}, based on this bounding evaluation. Each line in the table represents the effective dose that a worker would receive via each of the pathways, as well as the total effective dose from all pathways, if the 4 Bq cm^{-2} of contamination consisted solely of that radionuclide.

Radionuclide	Effective Dose (mrem/year)			
	Direct Radiation	Inhalation	Ingestion	Total
Cs-137	17	0.1	11	28
Sr-90 least sol.	0.2	0.6	30	31
Sr-90 most sol.	0.2	3	2.6	6
I-131	0.34	0.00	0.37	0.71

Note: Sr-90 direct radiation effective dose includes contribution from Y-90, a short-lived decay product of Sr-90.

These estimated annual doses are below the OSHA standard for radiation exposure (1250 mrem per calendar quarter). The NRC prescribes a limit of 100 mrem per year for doses to members of the general public due to licensed activities. While this limit is potentially not applicable, the annual effective doses from this bounding estimate are within that limit.

References

American National Standards Institute, Inc. Surface and Volume Radioactivity Standards for Clearance. ANSI/HPS 13.12-1999. The Health Physics Society, McLean, VA; 1999

U.S. Environmental Protection Agency (EPA). Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion. Federal Guidance Report No. 11. Office of Radiation Programs, U.S. EPA, Washington, DC; 1988

U.S. Environmental Protection Agency (EPA). External Exposure to Radionuclides in Air, Water, and Soil. Federal Guidance Report No. 12. Office of Radiation and Indoor Air, U.S. EPA, Washington, DC; 1993

Appendix

COMPARISON OF EFFECTIVE DOSES TO WORKER EXPOSURE STANDARDS

The values in the "Total" column of the table represent the total potential effective dose to a worker, if the 4 Bq cm^{-2} of contamination consists of a single radionuclide. The values in the "Total" column of the table can be compared to the exposure standards for annual exposure. The 1250 mrem per calendar quarter OSHA standard is equivalent to 5000 mrem per year. The total effective dose for Cs-137 from the table is 28 mrem. This represents 28/5000, or 0.56% of the OSHA standard. Similarly, 28 mrem represents 28/100, or 28% of the NRC limit to the general public. The same calculation can be performed for each radionuclide (each line) in the table.