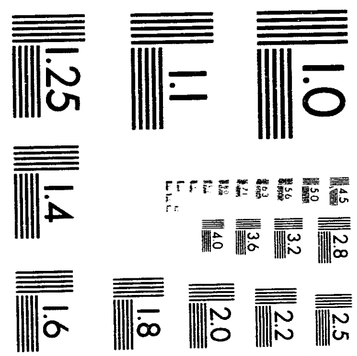
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PNL-SA-21839

CONTROL LEVELS FOR RESIDUAL CONTAMINATION IN MATERIALS CONSIDERED FOR RECYCLE AND REUSE

R. L. Hill
R. L. Aaberg
D. A. Baker
W. E. Kennedy, Jr.

September 1993

Presented at the
Topical Meeting on Environmental
Transport & Dosimetry
~~September 1-3, 1993~~ Aug. 31 - Sept. 3, 1993
Charleston, South Carolina

Work supported by
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

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CONTROL LEVELS FOR RESIDUAL CONTAMINATION IN MATERIALS CONSIDERED FOR RECYCLE AND REUSE

R. L. Hill, R. L. Aaberg, D. A. Baker, W. E. Kennedy, Jr.
Pacific Northwest Laboratory
P.O. Box 999, MSIN K3-51
Richland, WA 99352
(509) 375-2918

ABSTRACT

Pacific Northwest Laboratory (PNL) is collecting data and conducting technical analyses to support joint efforts by the U.S. Department of Energy (DOE), Office of Environmental Guidance, Air, Water and Radiation Division (DOE/EH-232); by the U.S. Environmental Protection Agency (EPA); and by the U.S. Nuclear Regulatory Commission (NRC) to develop radiological control criteria for the recycle and reuse of scrap materials and equipment that contain residual radioactive contamination. The initial radiological control levels are the concentrations in or on materials considered for recycle or reuse that meet the individual (human) or industrial (electronics/film) dose criteria. The analysis identifies relevant radionuclides, potential mechanisms of exposure, and methods to determine possible non-health-related impacts from residual radioactive contamination in materials considered for recycle or reuse. The generic methodology and scenarios described here provide a basic framework for numerically deriving radiological control criteria for recycle or reuse. These will be adequately conservative for most situations.

INTRODUCTION

The recycle and reuse of materials and equipment has increased in recent years partly for two reasons: a recognition of the economic opportunities presented and an increased societal awareness of the benefits of conserving raw materials and natural resources. The processes involved in maintaining, refurbishing, and decommissioning nuclear fuel cycle facilities generate materials and equipment that are radioactively contaminated or activated to varying degrees. Materials that contain only trivial quantities of radionuclides could realistically be exempted or released from regulatory control for recycle or reuse. The DOE is currently developing radiological control criteria for the recycle or reuse of metals or equipment containing residual radioactive contamination from DOE operations. Existing DOE Orders (i.e., DOE 5400.5[1] and DOE 5480.11[2]) give guidance on release of radioactively contaminated materials from controlled areas. However, this guidance is given in terms of surface, not bulk, radioactive contamination, and no values are given for transuranics.

The main objective of this study is to illustrate methodologies for developing practical radiological criteria, or control levels, for key radionuclides that are generated during DOE operations and that may be contained in metals, concrete, or equipment to be considered for either recycle or reuse. The scenarios and information developed by the International Atomic Energy Agency (IAEA) in Safety Series No. 111-P-1.1 (1992)[3] are used as the initial basis for this study.

The analyses were performed for selected worker populations at metal smelters and concrete manufacturing facilities, for the public downwind of a smelter facility, and for consumers who may use items made from recycled metals. The results and data generated using this generic assessment are expected to be useful to the DOE in developing radiological control values for residual levels of radionuclides in DOE-generated metals and equipment.

CALCULATIONAL METHODS

To determine if radioactively contaminated (or activated) materials can be released from regulatory controls, it is necessary to resolve two issues: whether future use of the materials is likely to cause radiation doses to members of the public in excess of dose criteria specified by the DOE, and whether increased levels of radiation will cause non-health-related impacts on electronics or film. Generic radiation exposure scenarios may be used to model conceptually the potential conditions, events, and processes that could result in radiation exposures. These scenarios are a combination of radiation exposure pathways in which specific conditions involve concentrations of radionuclides in various media (such as surfaces, air, soil).

The radionuclides included in this study are chosen from listings of radionuclides either potentially present or known to be present in some DOE waste. The radionuclides are further categorized into four groups according to the following characteristics: 1) alpha emitters with large inhalation dose conversion factors (i.e., Sv per Bq intake), 2) photon emitters with large external dose conversion factors, 3) non-photon emitters with moderate internal dose conversion factors, and 4) other radionuclides with low dose conversion factors.

To explore fully the potential for recycle and reuse, four categories of recycle and two categories of reuse are considered: the recycle of steel, aluminum, copper, and concrete (as aggregate for new concrete); and the reuse of surface-contaminated rooms and tools/equipment. The scenarios and models used to estimate radiation doses reported in this paper are necessarily generic; however, based on a review of related literature, an attempt has been made to identify and evaluate the most important potential exposure pathways.

The calculations for human radiation dose involve numerous radiation exposure scenarios, including 1) workers in a smelter or concrete recycle center, 2) individuals downwind of a smelter, 3) consumers using products made of recycled materials, and 4) consumers using materials after unrestricted release. Multiple exposure pathways are considered, including inhalation, secondary ingestion of contaminated dust transferred hand to mouth, and external exposure to penetration radiation. The scenarios selected for consideration in this study were those found to be the most limiting for recycle of scrap materials[3] (Table 1). The internal dose conversion factors from International Commission on Radiological Protection (ICRP) Publication 30 were used in this study. External dose conversion factors were calculated using the EXTDF module of the GENII Software System,[4] in which the radiation sources are generally represented either by a self-absorbing, homogeneous, cylindrical volume or by a surface-contaminated source with the dose point on the axis of the cylinder.

Doses to the public downwind of a smelter were estimated using the generic data on atmospheric dispersion and medium-high population density in the EPA's CAP88-PC software.[5] Doses were calculated to the maximally exposed individual (MEI) downwind of a smelter in a medium-high population area, with assumption of a unit release of 1 Ci/y of each of the 40 radionuclides considered in this study.

Additional analyses are performed to estimate non-health-related impacts on film caused by residual contamination in recycled metals. One concern is that these recycled materials may be used as material for making film storage boxes and could potentially damage the film contained therein. There are a variety of exposure conditions and types of films to consider when assessing the potential exposure to film from recycled materials. The generic scenarios used were developed to encompass the pertinent parameters that may control this type of exposure. The film-storage scenarios assume that the film is stored in a rectangular container made from undiluted, contaminated steel that may include an interior, uncontaminated lead shield. The film storage box was modeled based on the type of box used in medical x-ray departments. The external dose factors for the film scenarios were calculated using the GENII EXTDF module.[4]

Based on the radiation exposure scenarios that would result in the largest doses, control levels are derived for each of the 40 radionuclides considered (as well as for two additional concrete activation products). These derived radiological control criteria are based on the concentrations of the various radionuclides in any one of the following situations: 1) the presence of recycled or reused materials that would result in an individual dose rate of 1 mrem/yr (10 μSv/yr), 2) a public dose rate of 0.1 mrem/yr (1 μSv/yr), or 3) a 0.2 mrad (2 μGy) exposure to film stored one month in a box constructed of either undiluted recycled steel or concrete. The latter dose rates are consistent with the recommendations provided by the National Council on Radiation Protection and Measurements.[6]

RESULTS AND DISCUSSION

Decommissioning of nuclear facilities could result in large quantities of radioactively and non-radioactively contaminated materials. To limit the volume of low-level wastes that are generated and to allow recycle or reuse of the materials, a defined set of radiological control limits is needed. The criteria for these control limits should include both maintaining human health effects at negligible levels and minimizing the effects on industry. Among today's high-technology industries seeking high-quality starting materials are those that manufacture film, integrated electronic circuits, and low-background-radiation detectors. Both electronics and film products can sustain damage from ionization effects caused by radiation. If recycled and reused metals are going to gain in acceptance, both health and non-health criteria must be satisfied.

Preliminary control levels have been generated using the generic exposure scenarios, assumed parameters, and radionuclides as described above. The detailed results are quite lengthy because of the number of scenarios, radionuclides, and exposure pathways considered in the analysis, and because dose estimates were produced both for individuals and for the total population potentially exposed. A summary of the resulting radiological control levels is presented in Table 2. For all radionuclides considered (except ^{238}U), the individual doses were more restrictive than the doses to the downwind public population. In

Table 1. Recycle and Reuse Scenarios for Dose Estimates

CATEGORY	SCENARIO	INTERNAL PATHWAYS[a]	INDIVIDUAL EXPOSURE DURATION (hr)	COLLECTIVE EXPOSURE DURATION (hr)	NUMBER OF EXPOSED INDIVIDUALS	AIR CONC. (g/m^3)
STEEL RECYCLE	Slag Worker	Inh. & Ing.	25	25	10	0.001
"	Automobile Use	---	2,000	300	1,200	---
"	Large Equipment Use	---	2,000	1,000	200	---
ALUMINUM RECYCLE	Furnace Operator	Inh. & Ing.	50	50	3	0.001
"	Automobile Use	---	2,000	300	3,400	---
"	Frying Pan Use	Ing.	180	60	10,000	---
COPPER RECYCLE	Furnace Operator	Inh. & Ing.	50	50	3	0.001
"	Water Pipes Use	Ing.	6,000	2,000	1,000	---
"	Frying Pan Use	Ing.	180	60	8,000	---
CONCRETE RECYCLE	Smelter Yard Worker	Inh. & Ing.	80	80	10	0.001
"	Use in New Room	---	6,000	2,000	10	---
CONCRETE REUSE	Building Renovation	Inh. & Ing.	200	40	10	---
TOOL/EQUIP. REUSE	Hand Tools	Inh. & Ing.	600	100	100	---
"	Large Pump	Inh. & Ing.	200	80	40	---

[a] Inh. represents inhalation and Ing. represents ingestion.

general, the scenario associated with film exposure from recycled steel used in film storage boxes was found to be more restrictive than those derived from doses to smelter workers or consumers for the photon-emitting radionuclides (14 of 40 nuclides).

A review of the literature showed that most electronic components can withstand doses in excess of the 25 mrem (250 μSv).[7] Thus, recycling the materials considered in this report at or below the human health radiological control levels indicated would have little impact on the electronics industry.

These results are considered to be preliminary because of the conservative assumptions used in the analysis and because it is unlikely that storage areas for film would be constructed of undiluted, recycled steel or concrete. Further evaluations of the scenarios, assumptions, and data are needed.

ACKNOWLEDGEMENT

Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

TABLE 2. Summary of Most Restrictive Bulk Radiological Control Criteria for Recycled Metals and Concrete for the Radionuclides Considered[a]

CONTROL LEVEL RANGE (pCi/g)	α-EMITTERS LARGE DCF		β/γ-EMITTERS LARGE DCF		β-EMITTERS MOD. DCF		β/γ-EMITTERS LOW DCF		β-EMITTERS LOW DCF	
	NUCLIDE/SCENARIO		NUCLIDE/SCENARIO		NUCLIDE/SCENARIO		NUCLIDE/SCENARIO		NUCLIDE/SCENARIO	
≤ 5	^{229}Th	IND1	^{60}Co	FILM1	---	---	^{54}Mn	FILM1	---	---
	^{232}Th	IND1	^{65}Zn	FILM1						
	^{232}U	IND1	^{94}Nb	FILM1						
			^{110m}Ag	FILM1						
			^{134}Cs	FILM1						
			^{137}Cs	FILM1						
			^{152}Eu	FILM1						
			^{154}Eu	FILM1						
>5 & ≤10	^{237}Np	IND1	---	---	---	---	^{125}Sb	FILM1	---	---
	^{239}Pu	IND1								
	^{240}Pu	IND1								
	^{241}Am	IND1								
>10 & ≤15	^{228}Th	IND1	---	---	^{106}Ru	FILM1	---	---	---	---
	^{230}Th	IND1								
	^{238}U	PUBLIC								
	^{238}Pu	IND1								
>15 & ≤100	^{233}U	IND1	---	---	^{57}Co	FILM1	---	---	---	---
	^{234}U	IND1								
	^{235}U	IND1								
>100	^{226}Ra	IND1	^{93}Zr	IND1	^{90}Sr	IND1	^{36}Cl	IND1	^{3}H	IND1
			^{129}I	IND4	^{241}Pu	IND1	^{55}Fe	FILM1	^{14}C	IND1
			^{144}Ce	FILM1			^{99}Tc	FILM1	^{41}Ca	IND4
			^{147}Pm	IND1					^{63}Ni	IND1
			^{151}Sm	IND1					^{79}Se	IND1

[a] DCF = internal dose conversion factor (Sv/Bq intake).
IND1 = individual dose based on bulk steel contamination.
IND4 = individual dose based on bulk concrete contamination.
PUBLIC = based on 0.1 mrem/yr (1 μSv/yr) dose to MEI in population surrounding smelter that handles 100 tons of steel per year.
FILM1 = based on 0.2 mrad (2 μGy) exposure to film in steel storage box.

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