Designation: E 1278 – 88 (Reapproved 1996)ε1

Standard Guide for Radioactive Pathway Methodology for Release of Sites Following Decommissioning[1]

This standard is issued under the fixed designation E 1278; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

ε[1] NOTE—Keywords were added editorially in January 1996.

1. Scope

1.1 The purpose of this guide is to provide guidance in determining site-specific conversion factors for translating between dose limits and residual radioactive contamination levels on equipment, structures, and land areas. This guide does not endorse specific levels of allowable residual radioactive contamination, nor does it provide a methodology for population dose calculations.

1.2 Standards prescribing dose limits for decommissioned nuclear facilities or sites and/or private properties contaminated with radioactive materials are necessary to identify decommissioning methods, guide cleanup (remedial action) efforts, determine cleanup costs, identify the amount of radioactive waste to be disposed, and protect the public. Such standards, however, are not yet available for all types of nuclear facilities, sites, or properties. Regulatory Guide 1.86 of the U.S. Nuclear Regulatory Commission (NRC) **(1),**[2] as well as specific promulgations of the Environmental Protection Agency (EPA) and the Department of Energy (DOE), provide some specific guidance.

1.3 This guide is not intended to establish these federal policies. They will be promulgated by the EPA and other federal agencies. Rather, it is to serve as a guide to acceptable methodology for translating the yet to be determined dose limits into allowable levels of residual radioactive materials that can be left at a site following decommissioning.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 1034 Specification for Nuclear Facility Transient Worker Records[3]

E 1167 Guide for a Radiation Protection Program for Decommissioning Operations[3]

2.2 *ANSI Standard:*

ANSI-ASME-NQA-1 American National Standards Institute Quality Assurance Program Requirements for Nuclear Facilities[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *criteria*, *n*—goals or objectives, or both, to be achieved against which the degree of accomplishment can be measured.

3.1.2 *decommission*, *vt*—to remove a nuclear facility safely from service and reduce residual radioactivity to levels that permit release of the property or facility for unrestricted use and termination of any applicable license(s).

3.1.3 *decontamination*, *n*—those activities employed to reduce the levels of radioactive contamination in or on structures, equipment, materials, and property.

3.1.4 *dose equivalent*, *n*—the product of the absorbed dose, the quality factor (*Q*), and any other modifying factors (*N*).

3.1.5 *effective dose equivalent*, *n*—the sum of the weighted committed dose equivalents and the dose equivalent received from external sources. The sum represents the same risk as if the whole body were irradiated uniformly.

3.1.6 *nuclear facility*, *n*—a facility whose operations involve (or involved) radioactive materials in such form or quantity that a radiological hazard potentially exists (or existed) to the employees or the general public. Included are facilities that are (or were) used to produce, process, or store radioactive materials. Some examples are nuclear reactors (power, test, or research), fuel fabrication plants, fuel reprocessing plants, uranium/thorium mills, UF-6 production and enrichment plants, radiochemical laboratories, and radioactive waste disposal sites.

[1] This guide is under the jurisdiction of ASTM Committee E-10 on Nuclear Technology and Applicationsand is the direct responsibility of Subcommittee E10.03on Radiological Protection for Decontamination and Decommissioning of Nuclear Facilities and Components.

Current edition approved November 25, 1988. Published February 1989.

[2] The boldface numbers in parentheses refer to the list of references appended to this guide.

[3] *Annual Book of ASTM Standards*, Vol 12.02.

[4] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

3.1.7 *remedial action*, *n*—decontamination, waste removal, and site restoration conducted as part of a site or property decommissioning effort.

3.1.8 *surface contamination*, *n*—the results of the deposition and attachment of foreign materials (here most commonly thought of as radioactive materials) to exposed surfaces.

4. Significance and Use

4.1 Applying the considerations in this guide will provide assurance that the allowable residual radioactive contamination levels developed for a particular site will be adequate to achieve release of the site, property, or facility for unrestricted use by the general public.

4.2 By following this guide, the user will address the significant subject areas necessary to translate between field radiological measurements and the potential dose that may be received by individuals. This will provide a mechanism to allow the determination of acceptable contamination levels that may be left at a site following decommissioning.

5. Pathway Analysis

5.1 *Pathway Analysis Objectives*—The objectives of this pathway analysis guide are to:

5.1.1 Provide assurance that appropriate pathways and their relevant factors have been considered in determining allowable residual contamination levels at or for the site or property being decommissioned.

5.1.2 Provide site-specific release criteria for materials, equipment, land, and facilities on the site to be decommissioned.

5.1.3 Identify appropriate exposure scenarios, pathway transfer and dose conversion factors, and the principal radionuclides to be considered in performing the pathway calculations.

5.1.4 Estimate the annual effective dose equivalent to one or more members of a critical population group (for example, a family that establishes residence on the site after a site has been released for unrestricted use).

5.1.5 Compare the estimated annual effective dose equivalent with appropriate limits provided in Environmental Protection Agency (EPA) regulations or as provided by federal or state agencies in the interim until such regulations have been promulgated by the EPA.

5.1.6 Ensure that all significant pathways for the critical population group are taken into account in deriving allowable residual contamination guidelines from the basic dose limit identified in 5.1.5.

5.2 *Specific Pathway Analyses*—The following pathways should be considered when performing site-specific pathway analyses as recommended in this guide:

5.2.1 Exposure received from external radioactive sources in contaminated ground (for example, soil contamination), structural surfaces, or equipment. Such exposures could be to the entire body or to limited parts such as eyes, hands, feet, gonads, etc., due to handling of radioactivity contaminated tools, equipment, and the like.

5.2.2 Internal radiation sources due to inhaled dust particles, radon, or other radioactive gases.

5.2.3 Internal irradiation from ingestion of:

5.2.3.1 Radioactive contamination transferred from contaminated tools, equipment, and the like into the body by means of the mouth and hands;

5.2.3.2 Plant foods grown in contaminated soil;

5.2.3.3 Meat or milk from livestock fed with contaminated fodder and water; or

5.2.3.4 Fish from a nearby pond or stream; and

5.2.3.5 Water from wells downgradient of the decommissioned site.

NOTE 1—It is assumed that these pathways, applied to a family residing on-site, will lead to allowable residual contamination levels that are more limiting than those that would be derived for other scenarios. One must note that the estimation of the collective (population) dose is outside the scope of this guide. However, there may be situations (for example, the recycle of large quantities of activated materials, or the use of a major contaminated aquifer by a downstream community, or the agricultural use of a large low-level contaminated site for truck gardening) for which the annual collective dose might be more limiting, or certainly not in the spirit of ALARA.

5.3 *Pathway Analysis Methodology*—The derivation of allowable residual contamination from dose limits is based on the physical and environmental relation between the concentration (or contamination level) of a radionuclide in a medium available to people and the consequent radiation dose to an individual exposed to that source. A pathway analysis must be carried out to derive this relation. This section presents the generic basis and methods for calculating the pathway doses. (Some examples of models and methods available are Refs **17, 18, 20,** and **22.**)

5.3.1 Exposure scenarios are the patterns of human activity that can result in radiation dose attributable to the residual radioactivity at a decommissioned site. For the purposes of this guide, permanent residents are considered to represent the critical group, that is, the group for whom exposure scenarios need to be established (estimated) and subsequent dose calculations performed.

5.3.2 The following "residential" scenario should be considered as a minimum when implementing this guide. In the residential scenario, a family is assumed to move onto the decommissioned site, build a home, and raise crops for family consumption. Hence, members of the family are exposed by direct radiation from radionuclides in the soil or any remaining structures on the site, by inhalation of resuspended dust (if the contaminated area is exposed at the surface) or inhalation of radon gas, by ingestion of food crops grown in the contaminated soil, and by ingestion of water from a well that may be contaminated by water percolating through the contaminated site.

5.3.3 In developing any site-specific scenario, realistic credible scenarios should be used based on the region of the country and demographic experience for that region. The assignment of appropriate values to the scenario parameters should be based on existing patterns of human activity that can be expected to persist for an indefinite period of time. For most scenario parameters, this criterion should enable a straightforward determination of parameter values on the basis of data for current conditions.

5.3.4 The basis for the choice of key parameter values should be documented, especially for the fraction of the family

diet that will consist of contaminated foodstuffs (that is, the fraction of the on-site crops grown in contaminated soil); whether or not a basement is constructed (thereby redistributing "buried" soil which may have been contaminated) on the property; whether the "farm"' is large enough to support a family orchard (0.1 ha), a family pig (1 ha), or a family cow (2 ha); whether there is an on-site source of drinking water (for example, onsite shallow well capable of supplying a family of four with domestic water or some fraction thereof); and whether there is the possibility of a pond being provided on the site to raise fish for family consumption.

5.3.5 Potential exposure pathways that can contribute significantly to the exposure of an on-site resident can be different for different sites, depending on the dimensions of the contaminated zone, the amount of contaminated structures or equipment left on the site, and the environmental and scenario parameters that are applicable for the site. A diagram of the soil-to-man pathways to be considered for determination of allowable residual contamination levels is shown in Fig. 1. Potential contributing pathways that should be considered for site-specific analysis are provided in the accompanying Table 1. This list should be regarded as a set of pathway categories rather than individual pathways because many of the items shown may correspond to more than one pathway. Descriptions of the potentially relevant pathways that should be considered in determining the allowable residual contamination levels are provided in subsequent sections of this guide.

5.4 *Pathway Factors*—The pathway analyses should be structured and documented in such a way that a reviewer or auditor can dissect the problem into constituent parts. The parts should enable independent analysis, comparison, and review. An example of one such approach is included as Appendix X1.

6. Allowable Residual Contamination Levels in Soil

6.1 This section lists some possible considerations for determining site-specific allowable residual contamination levels. This task involves pathway screening, data acquisition, derivation of dose to source ratios (D/S), and finally derivation of allowable residual soil concentrations. The procedures for implementing these steps are summarized below.

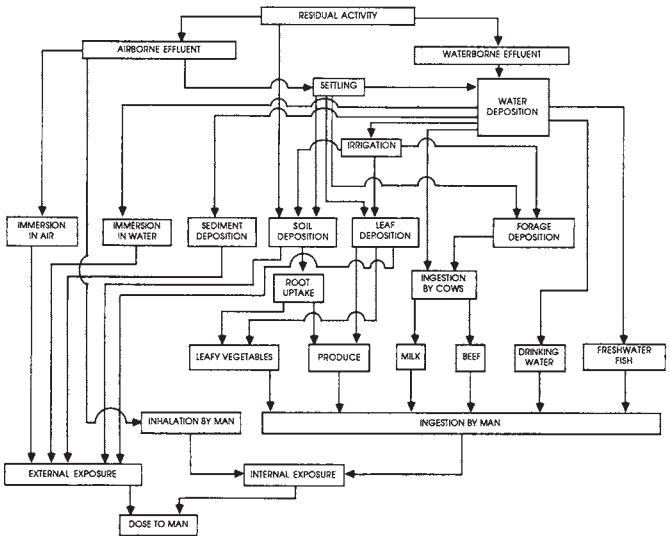

FIG. 1 Potential Pathways That Could Result in Off-Site Doses

TABLE 1 Pathway Identification

I. External radiation
A. Ground
Volume source
Surface source
B. Remaining structures/equipment
Volume source
Line source
Point source
Plane source
Equipment/hand contamination
C. Air
Dust (resuspended radioactive materials)
Radon and radon decay products
Other gaseous airborne radionuclides
D. Water (for example, pond for swimming, boating)
II. Internal radiation
A. Inhalation
Dust
Radon and radon decay products
Other gaseous airborne radionuclides
B. Ingestion/Food
Plant food (vegetables, grains, fruits)
Meat (beef, pork, poultry)
Milk
Aquatic foods (primarily fish)
C. Ingestion/Water
Groundwater (well)
Surface water
Soil/hand contamination

6.1.1 Pathway screening consists of using historical site data to assess which pathways are likely to contribute significantly to the dose to a member of the critical population group. The potential pathways, summarized in Table 1, should be used in preparing this portion of the residual contamination estimates. Conditions at each specific site will differ, and it should be possible at this stage to identify which pathways can be eliminated without carrying through a more detailed pathway analysis. In general, the direct external gamma pathway must always be included along with the dust inhalation pathway (except for cases in which only buried contamination is present). Food pathways must also be included, even for sites in urban industrial or commercial areas, unless the land is clearly unsuitable for agricultural use (for example, rocky or infertile soils, or areas with steep or irregular slopes).

6.1.2 Data acquisition involves the data needed to calculate the D/S ratios for the relevant pathways identified under the pathway screening stage. A checklist of the quantities for which site-specific data are needed is given in Table 2.

6.1.3 Derivation of D/S ratios should be based on source terms (quantity of each individual nuclide in the contaminated zone, obtained by averaging soil sample characterization data over the contaminated volume), external gamma radiation survey data on equipment and structures, dust inhalation, ingestion pathways (nonaquatic foods, aquatic foods, and drinking water), and concentration factors for water pathways (for example, groundwater factors for the contaminated, unsaturated, and saturated zones) to help calculate D/S ratios for nonaquatic pathways that have a water pathway segment.

6.2 The derivation of allowable soil concentration guidelines from the D/S ratios and the basic dose limit (to be promulgated by the EPA) should consider: