DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Radiation Protection and
Bureau of Land Recycling and Waste Management

DOCUMENT NUMBER: 250-3100-001

TITLE: Final Guidance Document on Radioactivity Monitoring at Solid Waste Processing and Disposal Facilities.

EFFECTIVE DATE: January 2, 2004

AUTHORITY: Solid Waste Management, Act of July 7, 1980, P.L., No. 97, as amended, 35 P.S. Sections 6018.101-6018.1003; Radiation Protection Act, Act of July 10, 1984, P.L. 688, No. 147, 35 P.S. Sections 7110.101-7131.1101; The Administrative Code of 1929, Section 1917-A, 71 P.S. Section 510-17; Solid Waste Regulations, 25 Pa. Code Chapters 273, 277, 279, 281, 283, 284, 288, 289, 293, 295 and 297; Radiological Health Regulations, 25 Pa. Code Chapters 215-240.

POLICY: To protect the environment and the public health, safety and welfare from the possible dangers of radioactive material that is delivered to solid waste processing and disposal facilities.

APPLICABILITY: This guidance document applies to all owners and operators of solid waste processing and disposal facilities that are required by regulation to monitor for radiation from incoming loads of waste, and to those facilities that choose to monitor even though not required. This guidance document also applies to all Department personnel and activities involved with waste facility permitting, operations and enforcement, radiation protection, grants, monitoring, administration and emergency response.

DISCLAIMER: The policies and procedures outlined in this guidance are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements.

The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of DEP to give the rules in these policies that weight or deference. This document establishes the framework within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.

PAGE LENGTH: 38 Pages

LOCATION: Volume 5, Tab 7

DEFINITIONS: See attached.

GUIDANCE DOCUMENT ON RADIOACTIVITY MONITORING AT SOLID WASTE PROCESSING AND DISPOSAL FACILITIES

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DEFINITIONS

Absorbed Dose: Measure of energy absorbed by material interacting with radiation. The unit in the older conventional system is the rad, which is equal to the energy of 100 ergs per gram of irradiated material. In the System International (SI), the unit for absorbed dose is the gray (Gy), which is equal to 100 rads.

Activity: Rate of decay for radioactive material. The older conventional unit is the curie (Ci). The System International (SI) unit is becquerel (Bq), where 1Ci = 3.7 x 10^{10} Bq.

Byproduct Material: (1) Radioactive material, except special nuclear material, yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material and (2) the tailings or wastes produced by the extraction or concentration of uranium or thorium from ore processed primarily for its source material content, including discrete surface wastes resulting from uranium or thorium solution extraction processes. Underground ore bodies depleted by these solution extraction operations do not constitute "byproduct material" within this definition. (10 CFR §20.1003)

Decay: Transformation of atoms of a radioactive element to atoms of another by emission of alpha or beta particles (positive or negative), or gamma rays from its nucleus. The resulting decay product may be radioactive or stable.

Department or DEP: The Pennsylvania Department of Environmental Protection.

Dose Equivalent: The dose of an ionizing radiation that will cause the same biological effect as one rad of x rays or gamma-rays. In the older conventional system, the unit is the rem. In the SI system, the unit is the sievert (Sv), 1Sv = 100 rem. Dose equivalent is calculated by multiplying absorbed dose (rad, Gy) by a quality factor (QF) that accounts for the effectiveness of the radiation, relative to gamma or x rays, in causing a biological effect, i.e., rem = rad x QF; Sv = Gy x QF. (*Note: For this guidance, and x ray or gamma radiation, rem = rad = R.)*

DOT: The U.S. Department of Transportation.

DOE: The U.S. Department of Energy.

EPA: The U.S. Environmental Protection Agency. *(Note: According to the revised Federal Radiation Emergency Response Plan (FRERP), EPA is responsible for providing assistance to states in managing incidents involving radioactive material of unknown origin that is found outside of Nuclear Regulatory Commission (NRC) licensed facilities unless the radioactive material is clearly associated with a NRC licensee, in which* *case the NRC assumes responsibility for assistance. In general, federal agencies provide assistance at the request of the state.)*

Exposure Rate: An older measurement quantity of intensity for x ray or gamma radiation causing ionization of air. It is still in practical use in the U.S.A.; measured in roentgen (R) or microroentgen (µR) per unit time, usually an hour, as in Rh^{-1} or μRh^{-1}. 1 R = 2.58 E-4 C/kg of air.

Half-life: The time required for half the atoms of a quantity of a radioactive material to decay or become transformed to another nuclide.

Isotope: A chemical element with the same atomic number (i.e., number of protons), but different atomic mass.

Multichanne Analyzer (MCA): An electronic instrument which, when coupled with an appropriate detector, can determine the energy associated with various radiations and thereby identify the radioactive material emitting the radiation.

NARM: Naturally occurring or accelerator-produced radioactive material. The term does not include byproduct, source or special nuclear material.

NORM: Naturally occurring radioactive material is a radioisotope that is radioactive in its natural physical state, not man-made, but does not include source or special nuclear material.

NRC: The U.S. Nuclear Regulatory Commission, which is the federal agency responsible for the regulation of power and research reactors, and radioactive materials produced in nuclear reactors, and certain quantities of uranium and thorium.

Radioactive Material(RAM): A material – solid, liquid or gas - which emits radiation spontaneously.

Radiation: The ionizing particles (alpha, beta, others) or photons (x or gamma ray) emitted by radioactive materials in the process of decay or nuclear transformation.

Radioisotope: A radioactive isotope of an element.

Source Material: (1) Uranium or thorium or any combination of uranium and thorium in any physical or chemical form; or (2) ores which contain, by weight, 0.05 percent or more, of uranium, thorium, or any combination of uranium and thorium. Source material does not include special nuclear material. (10 CFR § 20.1003)

Special Nuclear or Material: (1) Plutonium, uranium-233, uranium enriched in the isotope 233, in the isotope 235, and in any other material that the Nuclear Regulatory Commission, pursuant to the provisions of Section 51 of the Atomic

Energy Act of 1954 determines to be special nuclear material, but does not include source material; or (2) any material artificially enriched by any of the foregoing but does not include source material. The term "Department" shall be substituted for the term "Commission" when the Department assumes Agreement State status from the Nuclear Regulatory Commission. (10 CFR §20.1003)

TEDE:	Total effective dose equivalent. Means the sum of the deep dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures). (10 CFR § 20.1003.)
TENORM:	Technologically enhanced naturally occurring radioactive materials. It is naturally occurring radioactive material not specifically subject to regulation under the laws of the Commonwealth or Atomic Energy Act (Public Law 83-703, 68 Stat. 921, 42 U.S.C. §2011 et seq.), but whose radionuclide concentrations or potential for human exposure have been increased above levels encountered in the undisturbed natural environment by human activities.
Transuranic (TRU) Radioactive Material:	The term "transuranic radioactive material" means material contaminated with elements that have an atomic number greater than 92, including neptunium, plutonium, americium and curium. TRU waste disposal is strictly regulated by the NRC and DOE.

TECHNICAL GUIDANCE

Background

The Department has the responsibility of protecting the health and safety of the citizens of the Commonwealth and the environment from toxic and hazardous materials in the environment. This includes most sources of radiation. With increasing frequency, radioactive materials have been detected in the municipal waste stream by monitors installed at waste processing and disposal facilities. Radioactive material (RAM) can also appear in the residual waste stream. Sometimes the radiation comes from naturally occurring radioactive material (NORM), but most often it comes from man-made radioactive materials. Man-made radioisotopes are regulated by the U.S. Nuclear Regulatory Commission (NRC) and/or the individual states. Accelerator-produced radioactive materials are regulated by the Commonwealth. Naturally occurring radioactive materials (NORM) are not regulated in Pennsylvania unless resulting radiation doses exceed the limits set forth in Title 25, Chapter 219 of the Pennsylvania Code. However, in the case of radium-226, the Commonwealth can regulate individual discrete sources above 0.1 microcurie (µCi), as set forth in Chapter 217. Thus, one can have RAM that is regulated (through specific or general license), unregulated, deregulated, or exempted from regulation by a variety of federal and state regulatory authorities, and yet the material may cause a solid waste facility radiation monitor to alarm.

Almost everything in the world contains small amounts of radioactive elements, which in turn emit radiation. Most radiation found in the natural environment comes from NORM and cosmic radiation from space, with minor amounts from past above ground testing of nuclear weapons, the nuclear fuel cycle, and perhaps effluents from medical and industrial uses of radioisotopes. Most of the alarm events with radiation monitoring of the municipal waste stream in Pennsylvania have been from short-lived isotopes often used in medical procedures. However, a number of very dangerous RAM sources have been recovered in recent years (e.g., 4.2 Ci Ir-192 and 20 mCi radium-beryllium neutron sources). It is possible that the medical isotopes are getting into the waste stream directly from the medical facilities via contaminated items getting into general trash by mistake. Alternately, the contaminated items are discarded in municipal waste from homes of patients who have had nuclear medicine procedures and been discharged from the treating facility. Other credible routes to the waste stream include contaminated items being discarded in regular trash containers by mistake from clinical or research laboratories, industrial facilities, misplaced encapsulated RAM sources, and construction, residual or industrial waste containing NORM, TENORM or other types of radioactive material.

State and federal regulations require that those who are licensed to handle radioactive materials will maintain strict controls relative to the use and disposal of the material, and will take appropriate actions to prevent unauthorized releases of radioactive materials in solid waste. Nonetheless, for some radioactive materials licensed by NRC or state regulations, once radioisotopes have been administered to patients, and are not likely to cause a dose to an individual above the proscribed public dose limit, the RAM is no longer regulated and patients can be discharged from the treating facilities. The potential amount of radioisotope in a patient's body that may be released from a medical facility is noted in NRC Regulatory Guide 8.39.[1] It should be noted, even small amounts of radioisotopes used for diagnostic tests or radioactivity retained on items touched by patients may emit enough radiation to set off a facility radiation monitoring alarm. Licensees are encouraged to investigate ways of effectively monitoring institutional waste streams coming from facilities using radioactive material before the waste leaves the

[1]Regulatory Guide 8.39, Release of Patients Administered Radioactive Materials. U.S. Nuclear Regulatory Commission, Washington, DC April 1997. A copy of the relevant table from Regulatory Guide 8.39 is attached to this document as Exhibit B.

facility. The NRC has recently issued guidance to RAM licensees for the "Management of Wastes Contaminated with Radioactive Materials" in Information Notice 99-33.

Additionally, there are a number of consumer and industrial items containing RAM in general use that are distributed under a regulatory "exemption" or "general license;" that is, the fabricator or distributor must be licensed but the individual owner/user does not have a "specific license." Examples of exempt RAM include some types of smoke detectors, self-luminous watches or clocks, and many others. Some of these consumer items, like smoke detectors are assumed by the NRC to be discarded in municipal waste during their normal life cycle, however return to the manufacturer is recommended. Other RAM is supposed to be returned to the manufacturer for proper recycle or low-level radioactive waste disposal (e.g., self-luminous tritium EXIT signs). For the more hazardous higher activity sources, the NRC and the Department are presently developing registration requirements to inventory generally licensed (GL) devices used in industry and other areas.

It is interesting to note the first time an alarm went off at one large landfill in Pennsylvania, the cause was a load of sludge containing TENORM (specifically radium- 226) from a facility that treated oil and gas well brine. Similarly, most rocks, bricks, gypsum wall board, slag from metal processing, waste from coal ash or coke processing, and similar residuals contain some natural radioactivity. Depending on their origin, these materials may emit enough radiation to set off the radiation alarms at solid waste facilities. These are all examples of NORM or TENORM.

Given the above examples of RAM that may set off waste facility radiation alarms, materials that are regulated, deregulated, exempt or unregulated, there are no current standards for radiation monitor alarm set points, and the potential for serious impact on human health and the environment - the DEP Bureaus of Radiation Protection and Land Recycling and Waste Management have recommended to the Department's Solid Waste Advisory Committee and the Environmental Quality Board, that the Department promulgate regulations requiring monitoring for radiation and radioactive materials at the following types of facilities:

- Municipal waste landfills. (25 Pa. Code Ch. 273)
- Construction/demolition waste landfills. (25 Pa. Code Ch. 277)
- Municipal Waste transfer facilities. (25 Pa. Code Ch. 279)
- Commercial municipal waste composting facilities that will receive sewage sludge or unseparated municipal waste, or both. (25 Pa. Code Ch. 28)
- Resource recovery and other municipal waste processing facilities. (25 Pa. Code Ch. 283)
- Commercial infectious or chemotherapeutic waste processing facilities. (25 Pa. Code Ch. 284) Noncaptive residual waste landfills. (25 Pa. Code Ch. 288)
- Noncaptive residual waste disposal impoundments. (25 Pa. Code Ch. 289)
- Noncaptive residual waste transfer facilities. (25 Pa. Code Ch. 293)
- Noncaptive residual waste composting facilities. (25 Pa. Code Ch. 295)
- Noncaptive residual waste incinerators and other noncaptive residual waste processing facilities. (25 Pa Code Ch. 297)

Operators of these facilities must comply with the new regulatory requirements as they are adopted and phased in. Requirements may be implemented by following the recommendations of this guidance document. Briefly, the facilities will have to be equipped with suitable gamma radiation detection devices to monitor incoming loads of waste for radioactive materials in the waste, and will be required to have an appropriate Action Plan that is approved by the Department. These, and the other applicable requirements and recommendations, are discussed herein. It is the Department's belief that these regulations and guidance will be a model for all solid waste facility operators that monitor for radioactive material in incoming waste loads. For Pennsylvania solid waste facilities not required to monitor, but wish to do so as a best management practice, this guidance document should be followed.

General Considerations

Detecting radiation and dealing with radioactive materials in the waste stream is a multiple phase process, including:

- Monitoring and detection of gamma radiation,
- Personnel Training,
- Awareness of items that may contain RAM,
- Initial response to the detection of RAM,
- Notifications - within the company, to DEP, and to others as necessary,
- Characterization,
- Disposition, and
- Record keeping.

The details of these phases may vary somewhat with the type of facility; but in most respects they are similar, except for disposition of the radioactive material. In some cases the facility may have the option of onsite processing or disposal with Department concurrence or pre-approval. Alternately, the waste load may be rejected. However, once RAM has been identified in the waste, it may not be transported on public roads without an evaluation for compliance with DOT regulations. The Department has the authority to exempt carriers from DOT regulations with the scenario of RAM in waste if certain conditions are satisfied.

Action Plans

The Department's regulations require specified facilities to have an approved Action Plan to give direction to operating staff and facility users regarding procedures for detecting and dealing with radioactive material in the waste stream. Action Plans will be part of the solid waste facility permit by modification, and must be approved by the Department. Guidance for preparation of Action Plans and their content is described below, and is also provided in Appendix D. As part of the submission of a proposed Action Plan, the Department may approve the processing and/or disposal of short lived RAM (e.g., I-131, Tc-99m, Tl-201, etc.) from a patient having undergone a medical procedure, small quantities of TENORM, and consumer products containing RAM. This will require providing appropriate justification and/or pathway analysis for modeling potential public and facility staff doses.

Dose Limits for Public and Workers

The public and occupational annual dose limits that will be utilized by the Department in evaluating proposed Action Plans are as follows:

Facility staff -	5,000 mrem	(considered as "occupationally" exposed)
Facility staff -	100 mrem	(if considered member of the "public")
Vehicle driver -	100 mrem	(considered member of the public)
General Public -	4 mrem	(for the drinking water pathway)
General Public -	10 mrem	(for the air pathway)
General Public -	25 mrem	(all pathways combined).

The above public radiation dose limits are all TEDE, where an external deep dose and internal committed dose is summed. It is important to emphasize that all public and facility staff exposure to radiation should be maintained as-low-as-reasonably-achievable (ALARA). As stated above, some facility staff may be considered members of the public, if it is unlikely they will exceed the 100 mrem per year dose limit. However, certain personnel may be considered occupationally exposed workers if higher exposures are anticipated (e.g., the individual that may be performing vehicle surveys). The Action Plan should include consideration of relevant requirements outlined in the Department's Standards for Protection Against Radiation (25 Pa Code Ch. 219) and Notices, Instructions and Reports to Workers (25 Pa Code Ch. 220) if personnel are to be considered occupationally exposed.

In all reviews of proposed Action Plans, the Department will perform evaluations to ensure solid waste processing or disposal does not endanger the environment, facility staff and public health and safety. Therefore proposed Action Plans should describe the potential exposure pathways for members of the general public, and how these expected doses were modeled. For certain solid waste facilities where processing solid waste may release RAM to the environment, the Department recommends the use of basic and conservative regulatory computer codes for such pathway analysis and dose modeling, e.g., the EPA's CAP88 or DOE/NRC's RESRAD codes. These codes and support documentation can be downloaded from various internet web sites. However, valid manual calculations using dispersion equations and published dose conversions factors are equally acceptable to the Department.

Detection of Radiation

The Department's revised solid waste regulations require radiation monitoring and response at the solid waste facilities specified above. Additionally, the regulations state that the radiation detector elements shall be as close as practical to the waste load, and in an appropriate geometry to monitor the waste. The Action Plan should require notification to the Department for conditions specified in the regulations (i.e., radiological conditions noted below in Action Level Two), the detection of prohibited RAM, or the case when a waste load is rejected and a DOT Exemption Form must be issued. Action Plans should address the two basic scenarios, or Action Levels, when radiation is detected from a truck or waste container:

1. Action Level One: A radiation monitor alarm at the facility indicating the potential presence of radioactive material in a waste load.

(Note: The regulations require a gamma exposure rate from a cesium –137 source, at a level no higher that 10 μR h^{-1} above the average local background, at any detector element, shall cause an alarm at the facility. Instrument background shall be kept below 10 μR h^{-1} using shielding if needed, and the system shall be set to detect gamma ray energies of 50 kiloelectron volts and higher.)

2. Action Level Two: Radiation dose rates of 20 μSv h^{-1} (2 mrem h^{-1}) or greater in the cab of the waste transport vehicle, 500 μSv h^{-1} (50 mrem h^{-1}) or greater from any other surface, or the detection of contamination on the outside of the vehicle shall require immediate notification of the Department, and isolation of the vehicle.

Measurements should be made in accordance with guidance provided in Appendix D

IDENTIFICATION AND DISPOSITION OF RADIOACTIVE MATERIAL FOUND IN THE WASTE STREAM

1. Landfill or Disposal Impoundment

A. RAM from Patients Having Undergone a Nuclear Medicine Procedure

If the gamma spectroscopy or other measurement indicates the radiation is from a radioisotope with a half-life of 65 days or less, the DEP Area Health Physicist may authorize the contents of the waste load to be processed and/or disposed of immediately. (See Appendix A for telephone numbers during normal and non-business hours.) This is provided there is a high likelihood, through radioisotope identification, the RAM is from a patient having undergone a medical procedure, and the disposal does not endanger the health or safety of the facility staff, the public or the environment. Alternately, as noted above, the facility may provide justification (e.g., considering the facility's engineered barriers, all the RAM will decay in place) in the proposed Action Plan, and apply for a blanket approval to dispose of short lived RAM from patients treated with radioisotopes.

For reference, the total estimated radioactivity that may be released in a patient is detailed in NRC Regulatory Guide 8.39, which is duplicated in Appendix B as Table 1. The solid waste facility operator will always have the option to reject any waste load causing an alarm; however, no vehicle containing RAM shall leave the facility without written approval and an authorized DOT Exemption Form issued by the Department.

Upon formal request and appropriate environmental analysis, the Department's Director of the Bureau of Radiation Protection may authorize disposal of RAM with a half-life greater than 65 days, if the material is not under state or federal regulatory controls and/or disposal restrictions. (See Appendix D for additional guidance.)

B. Naturally Occurring Radioactive Material

If the gamma spectroscopy or other measurement indicates the radiation is from NORM or TENORM, the Action Plan should outline an approach to determine the nature of the waste, or perhaps cover material, entering the facility. If the radiation source is determined to be from the undisturbed natural environment of the Commonwealth (e.g., cover material soil or rock with elevated NORM levels), then there are no disposal restrictions and the material can be accepted at the facility. Similarly, if the source is determined to be potassium or any related compound (e.g., potassium permanganate used for odor control), with a natural abundance K-40, there are no processing or disposal restrictions.

In the case where process knowledge would indicate the presence of TENORM, the DEP Area Health Physicist may authorize immediate disposal. However, the following conditions must be satisfied: a) the volume of waste does not exceed one cubic meter, b) the gamma radiation level at a distance of 5 cm from any source surface does not exceed 0.5 $\mu Sv\ h^{-1}$ (50 $\mu rem\ h^{-1}$), and c) the concentration of combined radium isotopes does not exceed 5.0 $pCi\ g^{-1}$. A facility may submit, in their proposed Action Plan, to obtain a blanket approval for disposal of such small quantities of waste with TENORM. For a blanket approval, the applicant shall provide appropriate justification (e.g., presence of engineered barriers) in the proposed Action Plan. Disposal of waste with TENORM of higher volumes, emitting higher radiation levels, or at higher radium concentrations, may be approved by the Department's Director of the Bureau of Radiation Protection. Such evaluations shall require the appropriate environmental assessment and pathway analysis to demonstrate that the annual dose to any member of the public is unlikely to exceed those values noted above. (See Appendix D for additional guidance.)

Again, the facility operator may reject any waste load causing an alarm, however, no vehicle containing RAM shall leave the facility without written Department approval and an authorized DOT exemption form.

C. Consumer Products Containing Radioactive Material

If certain consumer products containing radioactive material are observed in waste or cause an alarm - and are subsequently identified through a visual means to be an individual commodity smoke detector, radium dial watch/clock, exempt thorium metal alloy (e.g., welding rod), or uranium glaze/glass product – a facility may propose in their Action Plan that such an individual waste product be disposed of immediately. A recent life cycle analysis of these exempt RAM sources by the NRC notes that the above public dose limits will not be exceeded in such a disposal scenario (see NRC NUREG-1717). The facility Action Plan could have such an allowed disposal scenario for the specific individual items noted above, but should prohibit the disposal of aggregate quantities of these exempt devices or other products without written approval by the Department. It is recommended that smoke detectors, when found, be returned to the manufacturer for appropriated disposal. If a "generally licensed" tritium EXIT sign is found in any waste stream, it shall be returned to a licensed manufacturer for recycle or shipped for proper low-level radioactive waste disposal.

Consumer products containing exempt radioactive materials may be recovered by the facility, and stored for ultimate disposal as low level radioactive waste by the operator. Alternately, the facility operator may reject any waste load causing an alarm; however, no vehicle containing RAM shall leave the facility without written Department approval and an authorized DOT exemption form.

2. Other Facilities

A. RAM from Patients Having Undergone a Nuclear Medicine Procedure

If the gamma spectroscopy or other measurement indicates the radiation is from a radioisotope with a half-life of 65 days or less, the DEP Area Health Physicist may authorize the contents of the waste load to be processed and/or disposed of immediately. (See Appendix A for telephone numbers during normal and non-business hours.) This is provided there is a high likelihood, through radioisotope identification, the RAM is from a patient having undergone a medical procedure, and the disposal does not endanger the health or safety of the facility staff, the public or the environment. Alternately, the facility may provide in the proposed Action Plan, the justification through modeling that the above general public dose limits are met, and apply for a blanket approval to dispose of short lived RAM from patients treated with radioisotopes.

For reference, the total estimated radioactivity that may be released in a patient is detailed in NRC Regulatory Guide 8.39, which is duplicated in Appendix B as Table 1. The solid waste facility operator will always have the option to reject any waste load causing an alarm, or forward the waste load to a solid waste facility that will process or dispose of the material. However, no vehicle containing RAM shall leave the facility without written approval and an authorized DOT Exemption Form issued by the Department.

Upon formal request and appropriate environmental analysis, the Department's Director of the Bureau of Radiation Protection may authorize processing or disposal of RAM with a half-life greater than 65 days, if the material is not under state or federal regulatory controls and/or disposal restrictions. (See Appendix D for additional guidance.)

B. Naturally Occurring Radioactive Material

If the gamma spectroscopy or other measurement indicates the radiation is from NORM or TENORM, the Action Plan should outline an approach to determine the nature of the waste entering the facility. If the radiation source is determined to be from the undisturbed natural environment of the Commonwealth (e.g., soil or rock with elevated NORM levels), then there are no processing or disposal restrictions and the material can be accepted at the facility. Similarly, if the source is determined to be potassium or any related compound (e.g., potassium permanganate used for odor control), with a natural abundance K-40, there are no processing or disposal restrictions.

In the case where process knowledge would indicate the presence of TENORM, the DEP Area Health Physicist may authorize immediate disposal. However, the following conditions must be satisfied: a) the volume of waste does not exceed one cubic meter, b) the gamma radiation level at a distance of 5 cm from any source surface does not exceed 0.5 μSv h^{-1} (50 μrem h^{-1}), c) the concentration of combined radium isotopes does not exceed 5.0 pCi g^{-1}, and d) the processing or disposal of such material will not cause any above stated general pubic dose limit to be exceeded. A facility may submit, in their proposed Action Plan, to obtain a blanket approval for disposal of such small quantities of waste with TENORM. For a blanket approval, the applicant shall provide appropriate justification and modeling in the proposed Action Plan.

Processing or disposal of waste with TENORM of higher volumes, emitting higher radiation levels, or at higher radium concentrations, may be approved by the Department's Director of the Bureau of Radiation Protection. Such evaluations shall require the appropriate environmental assessment and pathway analysis to demonstrate that the annual dose to any member of the general public is unlikely to exceed those values noted above. (See Appendix D for additional guidance.)

Again, the facility operator may reject, or forward to a landfill that will accept it, any waste load causing an alarm. However, no vehicle containing RAM shall leave the facility without written Department approval and an authorized DOT Exemption Form.

C. Consumer Products Containing Radioactive Material

If certain consumer products containing radioactive material are observed in waste or cause an alarm - and are subsequently identified through a visual means to be an individual commodity smoke detector, radium dial watch/clock, exempt thorium metal alloy (e.g., welding rod), or uranium glaze/glass product – a facility may propose in their Action Plan that such an individual waste product be processed or disposed of immediately. A recent life cycle analysis of these exempt RAM sources by the NRC notes that the above public dose limits should not be exceeded in such processing or disposal scenario (see NRC NUREG-1717). The facility Action Plan could have such an allowed processing or disposal scenario for the specific individual items noted above, but should prohibit the processing or disposal of aggregate quantities of these exempt devices or other products without written approval by the Department. It is recommended that smoke detectors, when found, be returned to the manufacturer for appropriated disposal. If a "generally licensed" tritium EXIT sign is found in any waste stream, it shall be returned to a licensed manufacturer for recycle or shipped for proper low-level radioactive waste disposal.

Consumer products containing exempt radioactive materials may be recovered by the facility, and stored for ultimate disposal as low level radioactive waste by the operator. Alternately, the facility operator may reject, or forward to a landfill that will accept it, any waste load causing an alarm. However, no vehicle containing RAM shall leave the facility without written Department approval and an authorized DOT exemption form.

3. Records and Reports

A. Each person or municipality who operates a waste processing or disposal facility which has detected radioactive materials in any manner or radiation levels in excess of Action Level One to cause an alarm shall maintain records of each incident, containing the information set forth in section b, below, in the facility's daily operational record.

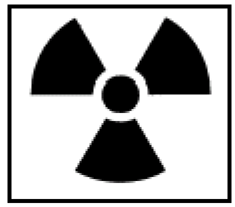
B. The daily operational record should include information required by regulation, such as the following:

1) Date, time and location of the occurrence,
2) A brief narrative description of the occurrence,
3) Specific information on the origin of the material, if known,
4) A description of the RAM involved, if known,
5) The name, address and telephone number(s) of the supplier, handler or transporter of the RAM contaminated waste, the name of the driver, and
6) The final disposition of the material (processed, disposed, or rejected).

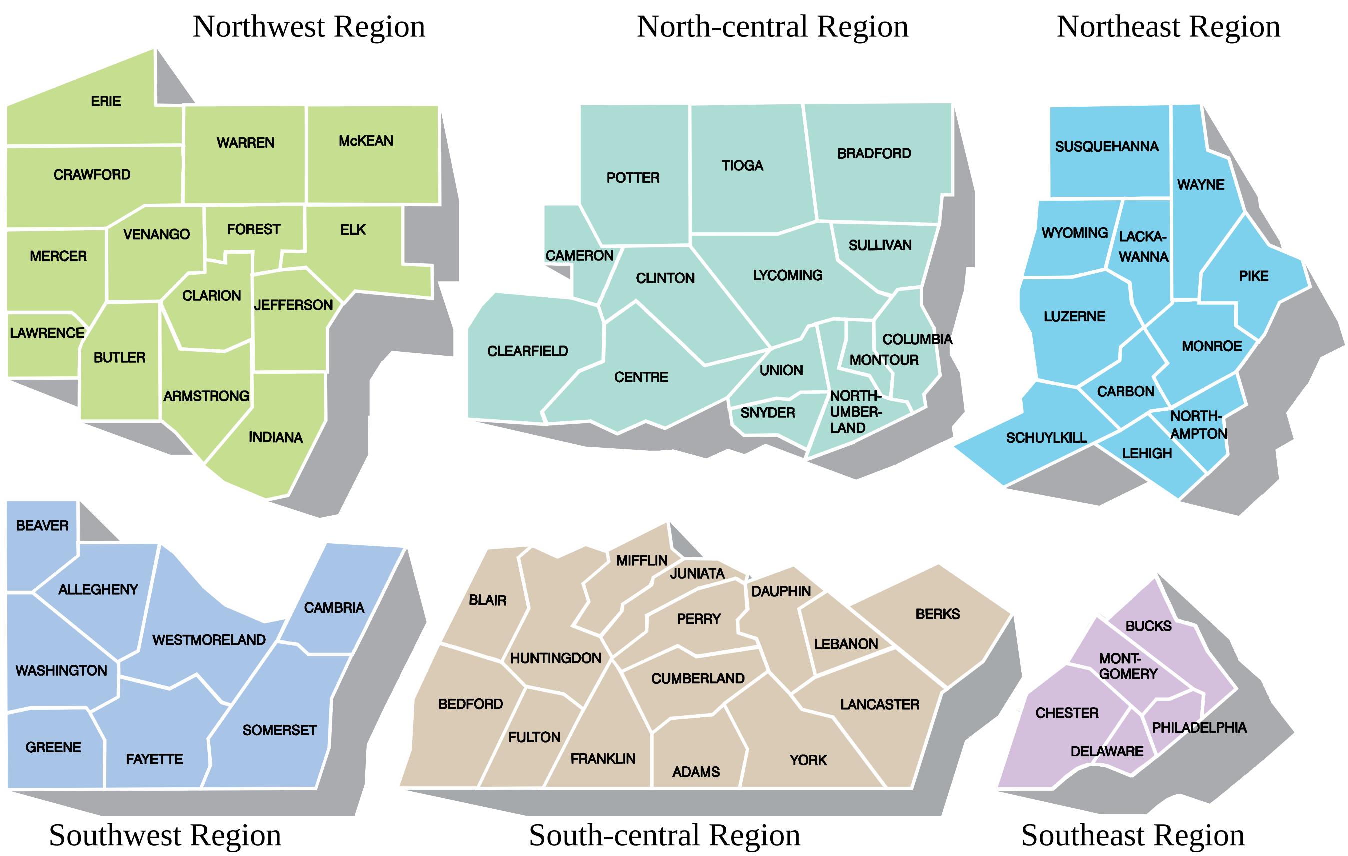
C. The facility's annual report should include a record of detected RAM summarizing the above information.

4. Monitoring and Equipment Facilities monitoring for radiation emitted from radioactive material must have appropriate monitoring equipment onsite. (See Appendix C for more information). Employees should be trained on proper use of all fixed and portable equipment. Additionally, facility operational staff should be trained to visually monitor waste during transfer or unloading for the potential presence of RAM. Specifically, they should be able to identify the caution "radiation symbol" on containers, and items that may not be detected by gamma monitors (e.g., tritium "EXIT" signs).

RADIATION SYMBOL



APPENDIX A. NOTIFICATION OF INCIDENTS OF RAM IN SOLID WASTE AND/OR REQUEST FOR DOT EXEMPTION FORM (Rev. 2-1-01)



Department of Environmental Protection		
Area Health Physicist Business hours: (412) 442-4227 **Northwest Region:** Armstrong, Butler, Clarion, Crawford, Elk, Erie, Forest, Indiana, Jefferson, Lawrence, McKean, Mercer, Venango, and Warren Counties. Emergency Coordinator Non-business hours: (800) 373-3398 **Southwest Region:** Allegheny, Beaver, Cambria, Fayette, Greene, Somerset, Washington, and Westmoreland Counties. Emergency Coordinator Non-business hours: (412) 442-4000	Area Health Physicist Business hours: (717) 705-4712 **North central Region:** Bradford, Cameron, Clearfield, Centre, Clinton, Columbia, Lycoming, Montour, Northumberland, Potter, Snyder, Sullivan, Tioga and Union Counties. Emergency Coordinator Non-business hours: (570) 327-3696 **South central Region:** Adams, Bedford, Berks, Blair, Cumberland, Dauphin, Franklin, Fulton, Huntingdon, Juniata, Lancaster, Lebanon, Mifflin, Perry and York Counties. Emergency Coordinator Non-business hours: (877) 333-1904	Area Health Physicist Business hours: (484) 250-5900 **Northeast Region:** Carbon, Lackawanna, Lehigh, Luzerne, Monroe, Northampton, Pike, Schuylkill, Susquehanna, Wayne and Wyoming Counties. Emergency Coordinator Non-business hours: (570) 826-2511 **Southeast Region:** Bucks, Chester, Delaware, Montgomery and Philadelphia Counties. Emergency Coordinator Non-business hours: (484) 250-5950

APPENDIX B. ACTIVITIES AND DOSE RATES FOR AUTHORIZING PATIENT

RELEASE FROM MEDICAL FACILITIES[2]

Table 1. Activities and Dose Rates for Authorizing Patient Release†

Radioactive Material	**COLUMN 1 Activity at or Below Which Patients May Be Released**		**COLUMN 2 Dose Rate at 1 Meter, at or Below Which Patients May Be Released***	
	(GBq)	**(mCi)**	**(mSv/hr)**	**(mrem/hr)**
Ag-111	19	520	0.08	8
Au-198	3.5	93	0.21	21
Cr-51	4.8	130	0.02	2
Cu-64	8.4	230	0.27	27
Cu-67	14	390	0.22	22
Ga-67	8.7	240	0.18	18
I-123	6.0	160	0.26	26
I-125	0.25	7	0.01	1
I-125 implant	0.33	9	0.01	1
I-131	1.2	33	0.07	7
In-111	2.4	64	0.2	20
implant	0.074	2	0.008	0.8
Pd-103 implant	**	**	**	**
Re-186	1.5	40	0.03	3
Re-188	28	770	0.15	15
Sc-47	29	790	0.20	20
Se-75	11	310	0.17	17
Sm-153	0.089	2	0.005	0.5
Sn-117m	26	700	0.3	30
Sr-89	1.1	29	0.04	4
Tc-99m	**	**	**	**
Tl-201	28	760	0.58	58
Y-90	16	430	0.19	19
Yb-169	**	**	**	**
	0.37	10	0.02	2

† The activity values were computed based on 5 millisieverts (0.5 rem) total effective dose equivalent.

* If the release is based on the dose rate at 1 meter in Column 2, the licensee must maintain a record as required by 10 CFR 35.75(c) because the measurement includes shielding by tissue. See Regulatory Position 3.1, "Records of Release," for information on records.

** Activity and dose rate limits are not applicable in this case because of the minimal exposures to members of the public resulting from activities normally administered for diagnostic or therapeutic purposes.

[2] **Source:** Regulatory Guide 8.39, Release of Patients Administered Radioactive Materials. U.S. Nuclear Regulatory Commission, Washington, D.C. April 1997.

APPENDIX C. GUIDELINES FOR RADIOLOGICAL MONITORING EQUIPMENT

1. General Information About Radiation Detectors

In general, radiation detection equipment consists of a detector and electronics to convert the signal received by the detector into meaningful values. The passage of radiation through the detector (or probe) causes an impulse to be generated within the detector, which is converted into a preset unit, usually counts per minute (cpm). There are two general types of detectors likely to be used in municipal and residual waste monitoring. The first, called a Geiger-Muller (G-M) counter with thin window probe, converts electrical discharge pulses into counts, which are displayed on a meter. This is the best type of detector for detecting beta particles, because most of the beta particles that pass into the detector will register. However, certain low-energy beta particles will not penetrate through the outer wall of the detector and, therefore, will not be detected. Examples of radioactive materials emitting such low-energy beta particles include carbon-14 and tritium (hydrogen-3), which are commonly used in medical research programs and may inadvertently be disposed of in waste. This type of detector is gas-filled and is less efficient at detecting gamma radiation because most pass through the detector without causing a pulse to be generated. Nevertheless, G-M counters are normally used in hand-held instruments, and a “pancake” type thin window G-M probe can be used for alpha, beta, and gamma measurements when properly calibrated.

The second type of radiation detector also uses a probe that converts the impulses caused by the radiation striking the detector surface into counts, which are recorded on the meter. However, this type of detector differs from the G-M counter in that the signal transferred to the meter is dependent on the radiation type and energy striking the detector. Typically, this type of radiation detector is called a scintillation detector. Scintillation detectors convert the radiation energy into a light impulse within the probe. The amount of light generated is based on the amount of radiation that strikes the probe. This light impulse is then converted to a measurement that may be used to determine the energy of the radiation and the total amount of radiation. Because of this capability, scintillation detectors are useful in determining the type of radioactive material present in the waste as well as the relative radiation hazard associated with the material. Scintillation detectors are also more efficient at detecting gamma radiation than a G-M counter because they are solid material (i.e., a greater number of interactions occur between the detector and the radiation yielding a greater number of counts). Zinc sulfide scintillation detectors may be used to quantify the amount of alpha particle radiation from contamination materials, although this is often conducted in laboratories rather than field settings. In addition, the scintillation medium may be liquid, thus allowing greater contact of the medium with the radioactive material and further increasing the efficiency of the measurement. Liquid scintillation is often used to quantify the amount of radioactive materials that emit low-energy beta particles, such as carbon-14 and tritium. However, this technique is employed exclusively in laboratories, rather than in the field.

Sodium iodide (NaI) crystals, germanium crystals, zinc sulfide coatings, and specially formulated plastic materials are the most common media used in solid scintillation detectors. Plastic scintillation detectors may be more sensitive to beta/gamma radiation than NaI detectors due to size and window thickness, however neither detect alpha radiation. In addition, plastic detectors are usually more resistant to environmental stresses than NaI detectors and can be purchased in larger sizes, allowing better geometry for detection of radioactive material in waste. However, though plastic detectors may be less expensive than NaI detectors, they may not offer the same degree of discrimination in terms of identifying the energies of the gamma radiation. Solid state germanium detectors are often used in laboratories for precise determination of the type and amount of radioactive materials present. Although some germanium detectors are sufficiently rugged to be used in the field, most are designed for use in laboratories.

2. Facility Monitoring Equipment

Many solid waste facilities have installed radiation detection equipment at the entrance portal to the facility or in conjunction with other onsite facilities, such as scales. In such installations, the radiation detector elements (e.g., NaI crystals) are typically installed to screen incoming waste and should be installed, operated, and maintained in a manner that ensures that the measurements are meaningful and fulfill the objectives for detecting radiologically contaminated waste. The detectors should be positioned as close as practical to the waste load, and calibrated so that they measure radiation [in µR h^{-1}, or equivalent counts per unit time] emitted from vehicles that are used to haul the solid waste into or out of the facility. The waste load portal detectors are normally scintillation type detectors. In the scenario where time permits (i.e., waste loads are infrequent) or fixed portal monitors become inoperable, hand-held microR meters may be used to scan incoming waste loads.

Both fixed and portable scintillation and G-M detectors can be calibrated to display radiation in units of exposure rate (µR h^{-1}), or dose equivalent rate (µrem h^{-1}). Equipment that display in counts per unit time should have calibration factors that can be related to these qualities. The radiation unit displayed by the detector is less important than the selection of the appropriate type of radiation detector element or probe, and the proper subtraction of background radiation is made. Factors that should be considered when developing radiation detection and monitoring programs are:

- Area background radiation level,
- Detector efficiency and ruggedness,
- Detector calibration and response checks,
- Detector positioning and shielding,
- Detector element physical protection,
- Counting time,
- Alarm set point,
- Overall system sensitivity, and
- Alarm response procedures and training.

Because of the complex nature of radiation detection instrumentation and the multiple objectives for which such instruments may be deployed, facility staff should be trained to determine the appropriate type of instrument and/or detector probe to be used at a facility based on the established operational objectives. In addition, it is recommended that only individuals with proper experience and training (e.g., manufacturer’s representative or knowledgeable health physicist) should be permitted to initially install, calibrate fixed radiation detection equipment.

3. Monitoring Equipment – General Recommendations

Facilities shall comply with specific regulatory requirements, but the following general recommendations for monitoring equipment may be used for initial detection of radioactive material at solid waste facilities:

A. Monitoring equipment should consist of both portable (hand-held) and fixed radiation monitoring equipment. Portable instrumentation should have multiple probes for contamination and a range of gamma dose rate measurements (i.e., 10 μR h^{-1} to over 50 mrem h^{-1}).

B. Fixed monitoring equipment should be capable of detecting and displaying ambient background radiation levels. For both portable and fixed instrumentation, the equipment should provide a visual readout of the μSv h^{-1}, μrem h^{-1}, μR h^{-1} or count rate (e.g., cpm) level. Should the background radiation level be above 10 μR h^{-1}, the detector elements will require shielding to maintain the rate below this level.

C. The readout on the instrumentation should allow either scale multiplying factors or logarithmic scales to display higher radiation levels.

D. Portable instrumentation should be powered either by replaceable batteries or power cells with charging units and provide indication if battery/power cell capacity is not at levels for proper unit function. Fixed instrumentation should be line operated (e.g., 110 volt AC).

E. Waste monitors should be installed according to the manufacturers recommendations, with the radiation detectors as close as practicable to the waste load (i.e., close as possible and preventing physical damage). The alarm set-point for fixed monitoring equipment shall be no higher than 10 μR h^{-1} above background, with a cesium-137 gamma radiation field at the radiation detector element(s). The ambient gamma background in Pennsylvania ranges from about 5 μR h^{-1} to 25 μR h^{-1}. Instrument readings in microroentgen per hour (μR h^{-1}), or equivalent counts per unit time (e.g., cpm), will need to be averaged during calibration to determine the appropriate alarm set point. If capable of energy discrimination, the radiation monitor shall be set to detect gamma rays of a 50 kiloelectron volt (keV) energy or higher. The alarm should provide an audible signal to the operator and may provide a visible signal that the alarm set point has been exceeded. The operator should be able to reset the audible signal from the readout position. Written indication of radiation levels, such as by a data log print out or chart recording, may be available as an option for the readout.

F. The detector element assemblies for fixed monitoring may be located at or near the weigh scale for vehicles. Provision should be made to stop or slow the vehicle during the monitoring for radioactive material, with a geometry and collimation of the radiation detectors to maximize system sensitivity. It is recommended an appropriate housing and other barriers be installed to protect the detector assembly from physical damage due to vehicles and from environmental conditions, such as precipitation, high humidity, and thermal variation.

G. If the detector assembly for fixed monitoring equipment is supplied with electrical power other than the monitoring unit, provision should be made to display power condition or availability to the detector assembly.

H. The range of readout for portable (hand-held) monitoring equipment and various probes should be 0.01 to approximately 100 mrem h^{-1}, and have a known gamma energy response. A "pancake" type G-M probe will be adequate for gross counting of wipes taken for gross contamination evaluations of vehicles. Again, hand-held micoR meters would be suitable for temporary vehicle monitoring if fixed systems become inoperable.

I. The monitoring equipment used at solid waste facilities should be calibrated no less frequently than annually, and (if utilized) its function should be tested on a daily basis using a check source for which the instrument's expected response has been previously determined.

4. Evaluation Equipment

If a radiation alarm is determined to be valid, evaluation of waste may require supplies, calibrated survey meters with capabilities similar to those specified above, and may require any of the following to determine the specific radioisotope, and if contamination is present:

A. Portable multichannel analyzer (MCA) coupled to a sodium iodide (NaI) detector or solid state detector. Appropriate calibration source(s) will also be needed to check the library of spectra.

B. Probes for survey meter capable of detecting beta and gamma radiation. Depending on the survey meter and probe(s) used for beta/gamma monitoring, a different probe could be obtained for alpha monitoring, if desired.

C. Supplies for taking samples for laboratory analysis, such as wipes (or smears), containers for water and soil/waste samples, plastic bags, indelible markers, trowels, tongs, etc. would be useful to have on hand.

D. Plastic tarps, disposable protective clothing and gloves for personnel handling potentially contaminated waste. *(Note: the use of some types of protective mask requires that the employing firm have an approved respirator qualification program.)*

E. A supply of radiation warning signs, rope, tape, etc.

F. Supplies and information for data analysis, e.g., scientific calculator, survey forms, tables of radioisotopes with half-life, etc.

APPENDIX D. GUIDELINES FOR ACTION PLANS FOR DETECTION AND HANDLING OF RADIOACTIVITY AT SOLID WASTE FACILITIES

1. Procedures for Development and Review of Action Plans

A. Qualifications of Persons Preparing the Action Plan

Plans should be prepared by individuals having, at a minimum, the following qualifications:

1) Two years of on-the-job training in health physics; or one year of on-the-job training in health physics plus one year of formal college level study in health physics, physics, chemistry, biology, engineering, or radiation science.

2) Experience with radiation detection and measurement, and in developing radiation safety procedures and plans.

Comprehensive certification by the American Board of Health Physics satisfies numbers 1 and 2, above. It is recommended that facilities employ a certified health physicist (CHP) as a consultant for developing and implementing their Action Plan.

B. Implementation of the Action Plan

The provisions of the Action Plan should be activated whenever situations arise in which the pre-established action levels are exceeded.

C. Persons Responsible for Implementation of the Action Plan

Each facility should designate an individual responsible for implementation of the Action Plan. This individual should have adequate authority to implement the plan. In the event that the individual(s) implementing the Action Plan is/are different from the individual who prepared the Action Plan, the Action Plan should specify a minimum one day training session in the fundamentals of radiation safety and detection.

(Note: Provided onsite operational facility personnel are able to appropriately respond to the radiological scenarios at Action Levels One and Two, the Action Plan may reference the use of corporate or consultant health physics support staff for further RAM characterization.)

D. Revision of the Plan

The plan should be reviewed and updated periodically by the permittee. At a minimum, this should occur when any of the following occurs:

1) Applicable Department regulations or policies are revised.

2) The Action Plan fails during an incident.

3) The facility operation changes in a manner that would interfere with implementation of the Action Plan.

4) The individual responsible for implementing the plan changes.

5) The monitoring equipment used is changed.

6) The designated area for vehicles in which RAM has been detected changes.

7) As otherwise required by the Department.

2. Content and Format of Action Plans

A. General Instructions

The main elements of the Action Plan should cover all the appropriate regulatory requirements, and are described in this basic guidance document. Details are outlined below. Certain Action Plan elements may not be entirely applicable or appropriate for a specific facility or type of incident. In these cases, the person preparing the Action Plan should act accordingly and provide a brief explanation as to why the Action Plan element(s) in question are not applicable or appropriate.

The most important thing to remember in developing an Action Plan is that the actual effectiveness of the plan will depend upon its simplicity, readability and summary instructions for facility operational staff.

B. Action Levels

The Action Plan must be designed to address two radiological scenarios or action levels, namely:

<u>Action Level One</u>: A radiation monitor alarm at the facility indicating the potential presence of radioactive material in a waste load.

(Note: The regulations require a gamma exposure rate from a cesium –137 source, at a level no higher that 10 µR h^{-1} above the average local background, at any detector element, shall cause an alarm at the facility. Instrument background shall be kept below 10 µR h^{-1} using shielding if needed, and the system shall be set to detect gamma ray energies of 50 kiloelectron volts and higher.)

<u>Action Level Two</u>: Radiation dose rates of 20 µSv h^{-1} (2 mrem h^{-1}) or greater in the cab of the waste transport vehicle, 500 µSv h^{-1} (50 mrem h^{-1}) or greater from any other surface, or the detection of contamination on the outside of the vehicle shall require immediate notification of the Department, and isolation of the vehicle.

The Action Plan should provide for notification of the Department.

1) For Action Level One, notification and request for DOT Exemption Form prior to rejection of a waste load, or request for disposal or processing approval of RAM in solid waste if blanket approval was not requested.

2) For Action Level Two, notification must be made immediately.

C. Detection and Initial Response

Fixed and portable radiation monitoring systems shall be calibrated annually to a traceable cesium-137 source. This radiation standard shall be traceable to the U.S. National Institute of Standards and Technology. Radiation monitors may be response checked daily on a relative basis. If the alarm level of 10 $\mu R\ h^{-1}$ over background is exceeded when a vehicle is at the monitoring location, the following procedures are recommended:

1) Reset the monitor alarm and evaluate the vehicle or container a second time.

2) If the alarm level is still exceeded, promptly survey the vehicle surfaces at a distance of 5 cm with a portable radiation survey meter to determine if Action Level Two levels are exceeded, and if an area of highest radiation level can be determined. Mark this location with chalk if other gamma spectroscopy measurements are to be performed.

3) If surveying the vehicle with a portable survey meter at 5 cm fails to reveal the presence of radioactive material, scan the driver with a portable survey meter (or have him/her stand between the monitor detectors) to determine if the driver has triggered the alarm. Alarms have been triggered by drivers who have undergone nuclear medicine procedures involving radioactive material. If this is the case, and the driver alone has triggered the alarm, no further action under this guidance document is necessary.

4) **Action Level One:** If the radiation monitor alarmed on a second count, the following procedures are recommended:

   a) Remove the vehicle to the Designated Area for vehicles found to contain RAM. (See D below.) Contact the individual responsible for supervising response to alarms at the facility. If the waste load is to be rejected, contact the appropriate DEP Area Health Physicist for approvals. If disposal or processing is considered, keep the load onsite until the nature of the RAM and proper actions are determined. Do not allow the vehicle or container to leave the facility without the permission of the Department, and the driver being issued a DOT Exemption Form signed by the Department's Area Health Physicist or their authorized representative. If a driver leaves the facility with a contaminated waste load, they must carry a copy of the signed DOT Exemption Form. *(Note: once a solid waste* *facility has an approved Action Plan, it is anticipated that facility survey data and DOT Exemption Form can be exchanged via fax to allow for immediate action on the part of the Department.)*

b) If the driver leaves with the vehicle without a DOT Exemption Form and before the RAM can be evaluated, contact the Pennsylvania State Police and provide them with any information you may have on the vehicle such as make, model, color, company name, license plate number, time left and the direction in which the vehicle was traveling and, if possible, the intended destination. This is to ensure that the driver does not dispose of the contaminated waste improperly. Notify the appropriate DEP Area Health Physicist listed in Appendix A and apprise that individual of the situation.

5) **Action Level Two:** If the dose rates indicated by a radiation survey at a distance of 5 cm equal or exceed either limit in this Action Level on the exterior or in the cab of the vehicle, remove the driver and all other personnel from the immediate area. Similarly, if contamination is detected by wiping vehicle areas that may have contacted the waste during loading, or seams that may leak liquid, isolated the vehicle and call the Department's Area Health Physicist for your location as listed in Appendix A. Proceed as directed by the Area Health Physicist.

D. Designated Area

The Action Plan should include the location of a Designated Area for vehicles found to contain RAM. This area is to be used for surveys, and if needed, to isolate a vehicle or container to maintain personnel radiation exposure ALARA. If surveys show that either exterior dose rate limit in Action Level Two is exceeded, but there is no removable contamination on the exterior of the vehicle and the dose rate in the cab is below 50 mrem/hr, the vehicle should be promptly moved to the Designated Area for an addition characterization or evaluation by facility or Department staff. The area should be appropriate for the various types of RAM potentially found in waste, size of facility, size of truck, employees in the proximity of the truck, and any other suitable steps warranted by the potential situation at hand and site-specific facility layout. Protection of the health and safety of facility operators, and the environment, may be achieved through consideration of time, distance, shielding, and contamination containment.

E. Characterization

If blanket approval is requested for immediate disposal or processing of short lived RAM from patients, NORM, TENORM, or individual consumer products containing RAM (as described above), the Action Plan must have procedures for characterizing the radioactive material present in the waste. Characterization is best executed under the direct supervision of the person who prepared the Action Plan, or another similarly trained and qualified individual. The Action Plan should address steps to confirm the radiation level detected by the monitoring device and identify the radioisotope(s).

At Action Level One, the procedure to identify the radioisotope must include means to determine the gamma ray spectrum. Procedures used in the characterization phase should be situation specific and will be determined by many factors including the type of truck and how it is loaded, the nature of the waste, radiation levels indicated by the survey, highest dose rate, location of RAM in the load, instrumentation, personnel available, weather, and other factors.

At Action Level Two, radiation protection personnel from DEP, and perhaps federal agencies, may come onsite to provide additional guidance and assistance.

In general, appropriate characterization procedures should include the following:

1) If the cab radiation level is over 2 mrem/hr, vehicle surface is over 50 mrem/hr, or contamination is detected - immediately notify the Department's Area Health Physicist. If there is no contamination and the cab radiation level is less than 50 mrem/hr, promptly relocate the vehicle or container to the Designated Area. Using appropriate instrumentation and measurement set-up, identify the radioisotope (i.e., via gamma spectroscopy).

   If the gamma spectroscopy indicates the radiation is from RAM with a half-life of 65 days or less and is most likely from a patient having undergone a medical procedure, the DEP Area Health Physicist may authorize the contents to be processed or disposed of immediately in the facility, provided there is minimal risk to workers. Alternately, the waste load may be rejected. As noted above, a solid waste facility may apply for a blanket approval to process or dispose of certain RAM in waste (i.e., short lived radioisotopes form patients, NORM, TENORM and individual consumer products).

2) Survey the exterior of the vehicle with a portable survey meter set at the most sensitive setting and holding the survey meter no more than two inches (5 cm) from all vehicle surfaces. Mark areas where radiation levels appear to be the highest. If containerized, monitor the waste during unloading from the vehicle. If the radiation levels from the vehicle or any container exceeds 50 mrem/hr at any time during unloading, stop removing the waste, remove personnel from the area and call the DEP Health Physicist at the numbers provided in Appendix A.

3) If contamination is found or the dose rate on the vehicle or cab exceed Action Level Two, Department staff will oversee the surveying the waste vehicle or containers (if waste is containerized in the vehicle). Personnel who are handling the waste to isolate the source should have appropriate training, wear radiation monitoring devices, protective clothing, including coveralls, boots, gloves and dust masks to avoid skin contamination, inhalation, or ingestion with the radioactive material or other potentially hazardous material. The Action Plan and facility should provide for personal protective equipment for facility or consultant personnel if waste off-loading is anticipated.

4) If the waste is containerized, remove the individual waste containers (if not contaminated) from the vehicle and survey each with a survey meter. Look for signs and container labels that might identify the radioactive material or other hazards and the point of origin. Caution should be exercised to ensure that injuries do not occur during removal of the waste containers. Do not attempt to open containers and sort through the waste. The waste may contain sharps, biological waste, and other pathological or hazardous waste that could cause immediate, and more significant risks to the workers.

5) If the waste load is in bulk form and can not be processed or disposed of in the facility or rejected, remove the bulk waste until the estimated location of the radioactive source is approached. Survey bulk waste removed with the portable meter to isolate the RAM. When the source is located, attempt to separate the RAM from the waste, provided it can be done without jeopardizing the health and safety of workers due to other hazards present in the waste. The Action Plan should specify precautions to be taken to monitor external exposure and prevent workers from becoming contaminated by the radioactive material in this process. The contaminated material should be placed in containers and taken to the Designated Area where it can be stored safely and in a manner that protects facility staff, and prevents environmental contamination (e.g., due to runoff, infiltration, pests, etc.) until the means of disposition is determined.

6) If radiation is detected at more than 0.5 mSv h^{-1} (50 mrem h^{-1}) above background levels on the surface of any container, isolate this area within the facility property and contact the DEP Area Health Physicist.

7) The area(s) where radioactive material is identified per (5) and (6) above, should be roped off or otherwise secured to prevent persons from entering areas where radiation levels exceed 0.02 mSv h^{-1} (2 mrem h^{-1}), and labeled with appropriate signs. Radiation levels in areas occupied by operational staff should be kept ALARA. The contaminated waste should be physically secured against removal or inadvertent disposal or else be under observation by facility staff at all times.

8) If radioactive material is not detected in any of the waste containers or in the bulk waste, resurvey the exterior of the vehicle. Mark any areas where radiation levels exceed background levels. The source of the radiation may be the transport vehicle itself (i.e., contamination or a small sealed source).

F. Determination of Origin.

The plan should include procedures to determine the place where the waste originated that contained RAM. These procedures should be thorough (e.g., interview driver) and capable of providing the best attempt to determine the origin of the waste. This effort is most likely to be successful with monitoring at the transfer station.

G. Disposition and/or Storage.

The plan should have procedures for rejection, disposition, or perhaps storage for decay of the waste containing RAM in accordance with the requirements and recommendations set forth in this guidance document. The procedures must take into account the radiation level, the type and amount of waste involved, the radioactive material present in the waste, the form in which the radioactive material is present, availability of the storage option at the waste processing site, and the health and safety of personnel handling such waste or present in the immediate area.

Experience to date indicates that many, if not most, alarms at solid waste facilities involve radioactive materials used in medical procedures which have half-lives sufficiently short (i.e., less than 65 days) that it is practical to either process or dispose of the waste immediately, or to store the waste in a secure area until it has decayed to a non-radioactive form. If the waste is contaminated with short-lived radioisotopes from medical procedures, and the facility operator requests blanket approval to disposed or processed at a solid waste facility immediately, the proposed Action Plan should contain a justification and/or pathway analysis indicating that the RAM will decay in place or not cause a radiation dose to the general public above respective limits noted above. Similarly, for NORM, TENORM or individual consumer products containing RAM, the disposal or processing shall not cause a radiation dose to the general public above applicable limits.

H. Training

The Action Plan should provide for training of individuals responsible for implementing the plan in the areas of:

1) Fundamentals of radiation safety.

2) Operation of the monitoring instrumentation used by the facility, including daily operation and other response checks.

3) All aspects of the Action Plan.

I. Other Items to be Included

1) Provision for written alarm procedures to be posted where they can be seen by the personnel performing the waste monitoring. The alarm procedures should be coordinated in advance with facility personnel, including appropriate notification of DEP or other applicable state or local agencies and authorities.

2) Posting of notices so that waste haulers will be aware of the procedures that will be followed if radiation and radioactive material is detected in their vehicle, including notification of out-of-state radiation protection authorities and declaration of where the waste will be returned. Again, any rejected waste load must have an approved DOT Exemption Form from the Department.

3) Procedures to ensure that at least one individual per shift is trained in and responsible for the implementation of response procedures in the event an alarm is activated.

4) Informing customers in advance of the procedures in the event that an alarm point is exceeded, especially if the procedures include “waste load rejection” provisions under which the suspect waste may be promptly returned to the shipper.

5) Instructing facility personnel on the appropriate procedures to be followed in the event the alarm is activated. The instructions should include graduated contingency plans in the event that RAM in waste is detected, or criteria of Action Level Two is exceeded.

APPENDIX E. BACKGROUND INFORMATION ON RADIOACTIVE MATERIAL IN SOLID WASTE

1. Introduction

Radioactive material is used for a variety of beneficial purposes in the United States, including medical diagnosis and treatment and materials testing. The use and disposal of most types of radioactive material are regulated by the Nuclear Regulatory Commission (NRC) and individual states. Other types of radioactive material are regulated by the Environmental Protection Agency (EPA) and the States. Although low-level radioactive waste must be disposed of in a licensed radioactive waste disposal facility, occasionally unregulated RAM (e.g., from patients having undergone a medical procedure) is found at solid waste processing sites that are not licensed by the NRC or states for the control radiation hazards. Additionally, with increasing frequency, NORM, TENORM or consumer products are detected, as well as less frequent lost or improperly discarded higher hazard radioactive sources.

Radioactive materials in municipal waste have been detected with increasing frequency at landfills, incinerators, transfer stations, and associated facilities. This increase can be partially attributed to increased use of radiation detection instruments at the solid waste facilities. The operators of facilities have been installing such instruments in response to concerns by regulatory agencies and the public or in an attempt to limit liability for potentially costly remedial actions for radioactive contamination. When radioactive contamination is detected, it often prompts an emergency response until the potential hazards posed by the waste are determined and the material is properly controlled.

2. Sources of the Contamination

It should be noted just about everything contains some trace amount of radioactivity, and the earth is continually bathed in cosmic radiation from space. Radioactive materials exist naturally in soil, rocks, and water. There are a great many of these radioactive materials in construction materials, food, and waste. These materials may also be concentrated artificially above naturally occurring levels in their use or production (i.e., TENORM). In addition to these naturally occurring radioactive materials, municipal waste may also contain radioactive materials that have been introduced in consumer products (e.g., most domestic smoke detectors contain the radioactive material americium-241). These detectors enter the waste stream when consumers dispose of them in municipal waste.

Although the NRC and the Agreement States (States that have assumed regulatory control over certain nuclear materials through an agreement with NRC) strictly control the possession, use, storage, transportation and disposal of certain radioactive materials through their licensing and inspection activities, on occasion, radioactive material can find its way into municipal solid waste streams. Over the last several years, the Department and NRC have monitored event reports involving detection of radioactive materials in municipal wastes. Based on reported incidents, the principal man-made sources of radioactively contaminated waste in municipal waste landfills are medical facilities, private and university laboratories and radiopharmaceutical manufacturers.

The radioactive materials reported in contaminated waste have consisted primarily of the following radioisotopes: iodine-131, technetium-99, thallium- 201, gallium-67,iodine-123, indium-111, etc. In most cases, such RAM has been legitimately released within patients in accordance with the NRC and state requirements. However, in other cases the event has been caused in violation of applicable requirements, such as lost sealed sources of cobalt-57 and iridium- 192.[3]

In the practice of nuclear medicine, radioactive materials are administered to patients for the diagnosis or treatment of illnesses such as thyroid cancer or dysfunction. NRC and Agreement State regulations allow patients receiving radiopharmaceuticals to leave the hospital or clinic when the amount of radioactive material present in their bodies has dropped to certain levels or they present a low exposure potential to members for their family and the public. (See Appendix B). After these patients leave the hospital, they may inadvertently contaminate ordinary trash that is then disposed of in municipal solid waste disposal facilities. Contaminated materials that have been generated by nuclear medicine practices and detected at municipal solid waste facilities include diapers, bed linen, disposable medical supplies and general trash (for example, food, plastic and paper dishes and utensils, newspapers and magazines). Again, these items often become contaminated with radioactive materials when they are contacted by patients that have received the nuclear medicine administration, either while the patient is in the hospital or after the patient has returned home. Although the amount of radioactivity in the municipal waste is often small, detection systems used by solid waste facilities are often sensitive enough to detect the radioactive contamination.

Hospital, clinics, laboratories and universities use radioactive materials in research, including the marking and detection of molecules in genetic research, the study of human and animal organ systems, and in the development of new drugs. There is a potential that municipal wastes may become contaminated with radioactive materials when contaminated laboratory trash is inadvertently mixed with municipal waste. Contaminated materials may include contaminated glass or plastic, gloves, animal bedding, or paper lab countertop protectors. Waste from radiopharmaceutical manufacturers is similar to the waste produced by laboratories and universities. On rare occasions, sealed sources are mistakenly discarded from such facilities, and shall be retrieved when detected.

In addition to radioactive material that may inadvertently be included in municipal solid waste, solid waste facilities may detect NORM, which is found in a variety of common household or construction materials. NORM, such as radium, thorium or uranium is often found in bricks, wall board or building rubble containing these construction materials. It should be noted, this NORM was present in the base material that was used to produce these construction materials. Natural potassium also contains trace amounts of the radioisotope potassium-40 (K-40). In sufficient quantities, NORM potassium salts may trigger radiation alarms. In no case, because of radiological concerns, shall the presence of potassium or any related compound (with K-40 at natural abundance levels) prevent the immediate disposal or processing of solid waste.

[3] Of particular note and concern is an incident that occurred in Pennsylvania when an high activity iridium-192 source used in cancer treatment was inadvertently disposed of as medical or “red bag” waste - see NRC document number NUREG-1480 for more information.

The NRC and most Agreement States allow licensees with waste contaminated with radioactive material having a short half-life (e.g., less than 65 days), to be held for at least ten half-lives onsite at licensed facilities. After this period, the licensees are allowed to dispose of the decayed waste, if it is indistinguishable from background radiation levels based on an appropriate survey. There have been occasions when municipal waste becomes contaminated when a licensee fails to properly monitor radioactively contaminated waste before releasing it for disposal as ordinary trash. In other reported detection incidents, licensees may have properly managed the waste, but the disposal facility's detection equipment was more sensitive than the licensee's equipment.

The NRC and some Agreement State regulations also allow small quantities of specific radioactive materials used in clinical or laboratory tests to be disposed of as if they were not radioactive. Although no incidents involving the disposal of these types of radioactive material have been reported, incidents involving medical waste have shown that detection systems are capable of detecting the low levels of radioactivity associated with these exempted materials.

Some radioactive materials that could contaminate solid waste include:

Radioisotope	Half-Life	Radiation Type
Iodine-131	8 days	beta, gamma
Iodine-125	60 days	Gamma
Iodine-123	13 hours	Gamma
Technetium-99m	6 hours	Gamma
Indium-111	2.8 days	Gamma
Thallium-201	73 hours	Gamma
Gallium-67	3.3 days	Gamma
Cobalt-57	270 days	Gamma
Hydrogen-3	12 years	Beta
Iridium-192	74 days	beta, gamma
Potassium-40	$1.3x10^{9}$ years	beta, gamma
Radium-226	1600 years	alpha, gamma
Uranium-238	$4.5x10^{9}$ years	alpha, gamma
Thorium-232	1.4×10^{10} years	alpha, gamma
Americium-241	432 years	alpha, gamma

Lastly, under NRC and Agreement State regulations, some sources and devices may be possessed under a General License. These items include industrial gauging equipment, tritium “EXIT” signs, etc. There is a real potential for such items to be present in solid waste streams. When they are identified through radiation alarms, or visual observation of a GL device or radiation warning symbol, the waste processing facility shall investigate, isolate the item, and contact the Department if needed. Action Plans should contain procedures for the appropriate response if a tritium (hydrogen-3) EXIT sign, or other package with a caution radiation symbol, is observed during processing or disposal of solid waste.

3. What is Radioactivity and Radiation?

The term “radiation” as it relates to “radioactive materials” means the energetic emissions given off by the material as it decays. Ionizing radiation produces charged particles, or ions, in the material that it encounters. Potential adverse effects from radiation on humans are caused by these charged particles, and the energy they deposit in tissues and organs.

Detailed information on radioactivity and radiation is provided in Appendix F.

If you have questions about radiation or require more information, please contact the Bureau of Radiation Protection at the Department of Environmental Protection in Harrisburg (717) 787-2480 or the Area Health Physicist listed in Appendix A for your location.

APPENDIX F. RADIATION PROTECTION FUNDAMENTALS

1. What is Radiation?

Radiation is energy that comes from a source and travels through any kind of material and through space. Light, radio, and microwaves are types of radiation. The kind of radiation discussed in this appendix is called *ionizing radiation* because it can produce charged particles (ions) in matter.

Ionizing radiation is produced by unstable atoms. Unstable atoms differ from stable atoms because unstable atoms have an excess of energy or mass or both. Radiation can also be produced by high voltage devices (e.g., x-ray machines).

Unstable atoms are said to be *radioactive*. In order to reach stability, these atoms give off, or emit, the excess energy or mass. These emissions are called *radiation*. The kinds of radiation are electromagnetic (like light) and particulate (i.e. mass given off with the energy of motion). Gamma radiation and x rays are examples of electromagnetic radiation. Beta and alpha radiation are examples of particulate radiation.

Interestingly, there is a "background" of natural radiation everywhere in our environment. It comes from space (i.e., cosmic rays) and from naturally occurring radioactive materials contained in the earth and in living things. Background radiation levels are typically 5 to 10 $\mu R\ h^{-1}$ depending on location, but may be as high as 25 $\mu R\ h^{-1}$.

Radiation from Various Sources

External Background Radiation	60 mrem/yr, U.S. Average
Natural K-40 Radioactivity in Body	40 mrem/yr
Air Travel Round Trip (NY- LA)	5 mrem
Chest X-ray Internal Dose	10 mrem per film
Radon in the Home	200 mrem/yr (variable)
Man-made (medical x rays, etc.)	60 mrem/yr (average)

2. Types of Radiation

The radiation one typically encounters is one of four types: alpha radiation, beta radiation, and gamma (or X) radiation.

A. Alpha Radiation

Alpha radiation is a heavy, very short range particle, and actually an ejected helium nucleus. Some characteristics of alpha radiation are:

1) Alpha radiation is not able to penetrate human skin.

2) Alpha emitting materials can be harmful to humans if the materials are inhaled, swallowed, or absorbed through open wounds.

3) A variety of instruments have been designed to measure alpha radiation.

Special training in the use of these instruments is essential for making accurate measurements.

4) A thin window Geiger-Mueller (GM) probe can detect the presence of alpha radiation.

5) Instruments cannot detect alpha radiation through even a thin layer of water, dust, paper, or other material, because alpha radiation is not penetrating.

6) Alpha radiation travels only a short distance (a few inches) in air, but is not an external hazard.

7) Alpha radiation is not able to penetrate clothing.

Examples of some alpha emitters: radium, radon, uranium, thorium.

B. Beta Radiation

Beta radiation is a light, short range particle, and actually an ejected electron. Some characteristics of beta radiation are:

1) Beta radiation may travel several feet in air and is moderately penetrating.

2) Beta radiation can penetrate human skin to the "germinal layer," where new skin cells are produced. If high levels of beta emitting contaminants are allowed to remain on the skin for a prolonged period of time, they may cause skin injury.

3) Beta emitting contaminants may be harmful if deposited internally.

4) Most beta emitters can be detected with a survey instrument and a thin window G-M probe (e.g., "pancake" type). Some beta emitters, however, produce very low energy, poorly penetrating, radiation, that may be difficult or impossible to detect. Examples of these difficult to detect beta emitters are hydrogen-3 (tritium), carbon-14, and sulfur-35.

5) Clothing provides some protection against beta radiation.

Examples of some pure beta emitters: strontium-90, carbon-14, tritium, and sulfur-35.

C. Gamma (or X) Radiation

Gamma radiation or x rays are very long range, penetrating electromagnetic radiation. Some characteristics of gamma radiation are:

1) Gamma radiation or x rays are able to travel many feet in air, and many inches in human tissue. It readily penetrates most materials, and is sometimes called "penetrating" radiation.

2) X rays are like gamma rays. X rays, too, are penetrating radiation. Sealed radioactive sources and machines that emit gamma radiation and x rays respectively constitute mainly an external hazard to humans.

3) Gamma radiation and x rays are electromagnetic radiation like visible light, radiowaves, and ultraviolet light. These electromagnetic radiations differ only in the amount of energy they have. Gamma rays and x rays are the most energetic of these.

4) Dense materials are needed for shielding from gamma radiation. Clothing provides little shielding from penetrating radiation, but will prevent contamination of the skin by these materials.

5) Gamma radiation is easily detected by survey meters with a sodium iodide detector probe.

6) Gamma radiation and/or characteristic x rays frequently accompany the emission of alpha and beta radiation during radioactive decay.

Examples of some gamma emitters are: iodine-131, cesium-137, cobalt- 60, radium-226, technicium-99m.

3 How is Radiation Measured?

In the United States, radiation dose or exposure is often measured in the older units called rad, rem, or roentgen (R). For practical purposes with gamma and x rays, these units of measure for exposure or dose are considered equal.

Smaller fractions of these measured quantities often have a prefix, such as, milli (m) means 1/1000. For example, 1 rad = 1,000 mrad. Micro (µ) means 1/1,000,000. So, 1,000,000 µrad = 1 rad, or 10 µR = 0.000010 R.

The “System International” of units (SI system) for radiation measurement is now the official system of measurement, and uses the “gray” (Gy) and “sievert” (Sv) for absorbed dose and equivalent dose respectively.

1 Gy = 100 rad
1 mGy = 100 mrad
1 Sv = 100 rem
1 mSv = 100 mrem

With radiation counting systems, radioactive transformation events can be measured in units of “disintegrations per minute” (dpm) and because instruments are not 100% efficient, “counts per minute” (cpm). Background radiation levels are typically less than 10 µR h^{-1}, but due to differences in detector size and efficiency, the cpm reading on a fixed portal monitor and various hand-held survey meters will vary considerably.

4. How Much Radioactive Material is Present?

The size or weight of a quantity of material does not indicate how much radioactivity is present. A large quantity of material can contain a very small amount of radioactivity, or a very small amount of material can have a lot of radioactivity.

For example, uranium-238, with a 4.5 billion year half life, has only 0.00015 curies of activity per pound, while cobalt-60, with a 5.3 year half life, has nearly 513,000 curies of activity per pound. This "specific activity," or curies per unit mass, of a radioisotope depends on the unique radioactive half-life, and dictates the time it takes for half the radioactive atoms to decay.

In the U.S., the amount of radioactivity present is traditionally determined by estimating the number of *curies* present. The more curies present, the greater amount of radioactivity and emitted radiation.

Common fractions of the curie are the millicurie (1 mCi = 1/1000 Ci) and the microcurie (1 µCi = 1/1,000,000 Ci). In terms of transformations per unit time, 1 µCi = 2,220,000 dpm.

The System International of units (SI system) uses the unit of becquerel (Bq) as its unit of radioactivity. One curie is 37 billion Bq. Since the Bq represents such a small amount, one is likely to see a prefix noting a large multiplier used with the Bq as follows:

37 GBq = 37 billion Bq = 1 Curie
1 MBq = 1 million Bq = ~ 27 microcurie
1 GBq = 1 billion Bq = ~ 27 millicuries
1TBq = 1 trillion Bq = ~ 27 Curies

5. How Can You Detect Radiation?

Radiation cannot be detected by human senses. A variety of instruments are available for detecting and measuring radiation

The most common of these are:

Geiger-Mueller (G-M) Tube or Probe -- A gas-filled device that creates an electrical pulse when radiation interacts with the gas in the tube. These pulses are converted to a reading on the instrument meter. If the instrument has a speaker, the pulses also give an audible click. Common readout units are: roentgens per hour (R/hr), milliroentgens per hour (mR/hr), rem per hour (rem/hr), millirem per hour (mrem/hr) and counts per minute (cpm). G-M probes (e.g., "pancake" type) are most often used with hand-held radiation survey instruments.

Sodium Iodide Detector -- A solid crystal of sodium iodide creates a pulse of light when radiation interacts with it. This pulse of light is converted to an electrical signal, which gives a reading on the instrument meter. If the instrument has a speaker, the pulses also give an audible click. Common readout units are: microroentgens per hour (µR/hr), and counts per minute (cpm). Sodium iodide detectors are often used with hand-held instruments and large stationary radiation monitors. Special plastic “scintillator” materials are also used in place of sodium iodide.

(Note: For practical purposes, consider the rad, roentgen, and the rem to be equal with gamma or x rays. So, 1 mR/hr is equivalent to 1 mrem/hr.)

6. How Can You Keep Radiation Exposure Low?

Although some radiation exposure is natural in our environment, it is desirable to keep radiation exposure as low as reasonably achievable (ALARA) in an occupational setting. This is accomplished by the techniques of time, distance, and shielding.

Time: The shorter the time in a radiation field, the less the radiation exposure you will receive. Work quickly and efficiently. Plan your work before entering the radiation field.

Distance: The farther a person is from a source of radiation, the lower the radiation dose. Levels decrease by a factor of the square of the distance. Do not touch radioactive materials. Use shovels, or remote handling devices, etc., to move materials to avoid physical contact.

Shielding: Shielding behind a massive object (such as a truck, dumpster, or pile of dirt) provides a barrier that can reduce radiation exposure.

7. What is Radioactive Contamination?

If radioactive material is not in a sealed source container, it might be spread onto other objects. Contamination occurs when material that contains radioactive atoms is deposited on materials, skin, clothing, or any place where it is not desired. It is important to remember that radiation does not spread or get “on” or “in” people; rather, it is radioactive *contamination* that can be spread. A person contaminated with radioactive material will receive radiation exposure until the source of radiation (the radioactive material) is removed.

-- A person is *externally* contaminated if radioactive material is on the skin or clothing.

-- A person is *internally* contaminated if radioactive material is breathed in, swallowed, or absorbed through wounds.

-- The *environment* is contaminated if radioactive material is spread about or is unconfined.

8. How Can You Work Safely Around Radiation or Contamination?

You can work safely around radiation and/or contamination by following a few simple precautions:

A. Use time, distance and shielding to reduce exposure. B. Avoid contact with the contamination.

C. Wear protective clothing that if contaminated, can be removed.

D. Wash with non-abrasive soap and water any part of the body that may have come in contact with the contamination.

E. Assume that all materials, equipment, and personnel that came in contact with the contamination are contaminated. Radiological monitoring is recommended before leaving the scene.

9. Is it Safe to be Around Sources of Radiation?

A single high-level radiation exposure (i.e., greater than 10,000 mrem) delivered over a very short period of time may have potential health risks. From follow-up of the atomic bomb survivors, we know acutely delivered very high radiation doses can increase the occurrence of certain kinds of disease (e.g., cancer) and possibly negative genetic effects. To protect the public, radiation workers (and environment) from the potential effects of chronic low-level exposure (i.e., less than 10,000 mrem), the current radiation safety practice is to prudently assume similar adverse effects are possible with low-level protracted exposure to radiation. Thus, the risks associated with low-level medical, occupational and environmental radiation exposure are conservatively calculated to be proportional to those observed with high-level exposure. These calculated risks are compared to other known occupational and environmental hazards, and appropriate safety standards have been established by international and national radiation protection organizations (e.g., ICRP and NCRP) to control and limit potential harmful radiation effects.

Annual Radiation Dose Limits- TEDE

Facility staff -	5,000 mrem	(considered as "occupationally" exposed)
Facility staff -	100 mrem	(if considered member of the "public")
Vehicle driver -	100 mrem	(considered member of the public)
General Public -	4 mrem	(for the drinking water pathway)
General Public -	10 mrem	(for the air pathway)
General Public -	25 mrem	(all pathways combined)

Both public and occupational dose limits are set by federal (i.e., EPA and NRC) and state agencies (i.e., DEP) to limit cancer risk.

(Note: It is important to remember when dealing with radiation sources in other materials or waste that there may be chemical or biological hazards separate and distinct from the radiation hazard. These chemical or biological hazards are often more dangerous to humans than the radiation hazard.)