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DEVELOPMENT OF A TECHNICAL GUIDE FOR THE IDENTIFICATION OF RADIOLOGICAL SOURCES OF POTENTIAL EXPOSURE AND/OR CONTAMINATION

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Abstract

Radiological assessment of sites with radioactive residues starts with the identification of potential sources. The U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) has developed a technical guide that summarizes sources of potential radiological exposures of both civilian and military origin. These sources include those found in the natural environment, in the nuclear fuel cycle, in medical and industrial settings, in the transportation of radioactive materials, in U.S. Army commodities and foreign materiel, and in the use and storage of nuclear weapons. This technical guide is intended to foster awareness of radiological hazards and to provide the reader with the knowledge necessary to take the first step in radiological health risk assessment: recognition of the hazard. Furthermore, this guide can be used in conjunction with other technical guides for performing radiological surveys and field dose assessments in war or peacetime operations.

Background

The nature of recent military deployments, remediation exercises, and the increasing concerns about radiological contamination of the environment has driven research and development in an effort to identify and quantify the potential hazards from radioactive residues in the deployed forces' operating environments. The traditional perception of a hazard in the military is that which will cause tactical or operational performance decrement. Therefore, environmental radiological contamination concerns are usually not considered since at low levels, they do not produce an immediate reduction in performance.

However, one would be remiss for not considering the byproducts of a modern industrial society as threats to be managed with all the other hazards that may be encountered. For example, radiological assessment when planning for deployments near an industrial city should account for threats from exposures to radiological sources from hospitals, nuclear power plants and other industrial sources. The hazards from encountering these sources, as well as their potential use in devices that enhance exposure/contamination or in dispersal weapons, must be considered in the overall hazard management framework.

Acknowledging there may be potential radiological threats in an area of deployment will then permit radiological assessments to be incorporated into the hazard minimization (avoidance, prevention, reduction of effects in the event of exposure and contingency plans for dealing with such hazards) planning process. Hence, the USACHPPM determined the need for a Technical Guide that identifies potential radiological sources, forewarns of radiological hazards that may be

encountered, and provides knowledge to identify such hazards and apply appropriate procedures for general precaution levels *[1]*.

Introduction

The USACHPPM developed Technical Guide 238 (TG-238) in an effort to identify radiological sources of potential exposure and/or contamination *[1]*. This technical guide provides guidance on the explicit identification of many radiological hazards from diverse sources with the intent of familiarizing users with the potential sources that may be encountered. This technical guide has identified sources found in nature, the nuclear fuel cycle, biomedical sources, in Army commodities and military foreign materiel, industrial sources, sources from the transportation of radioactive material, and sources from the production of nuclear weapons.

Technical Guide 238 sets the stage for further investigation of identified sources in the form of surveys or sampling of suspected radiological sources. Therefore, it can be considered the initial step in the process of radiological risk assessment of sites with radioactive residues.

Development of Technical Guide 238

The process of developing a technical guide that would be used by civilians as well as military personnel to identify radiological sources started with an extensive literature search. The technical guide was then broken down into a set of chapters and appendices that contain a vast collection of pictures and diagrams, as well as tabulated lists of potential sources, that may lead to exposure or contamination from radioactive residues. Internal and external reviews recommended changes that included the addition of precautions levels, which were then linked to each specifically identified source.

Chapter One is a brief overview of the technical guide. Chapters Two through Seven summarize sources of radiation exposure and contamination found in nature, the nuclear fuel cycle, the medical field, in Army commodities and foreign materials, industry, the transportation of radioactive materials, and the production of nuclear weapons.

The appendices contain precautions for reducing or avoiding radiation exposure and contamination, as well as supplemental material that describes nuclear power reactors around the world, radioactive waste, accelerators and generators. Brief descriptions of accidental radiation exposures and radiological accidents and their consequences are also included in the appendices.

Postings for the Nuclear, Biological, and Chemical (NBC) environment may be indicative of being in proximity to a radiation source, chemical or biological agent. Therefore, the technical guide includes an appendix that shows the most common postings and signs in a nuclear environment used by the U.S. and other countries that would help caution personnel that they are in the possible proximity or the presence of radioactive residues.

Familiarity with potential and actual exposure scenarios is useful in understanding potential exposure from similar situations. Therefore, the technical guide includes an appendix with descriptions of accidents that relate to nuclear power plants, sources in accelerators and sources in

clinical radiation generator facilities. A case study that illustrates a potential radiation contamination accident and other examples are also included.

Summary of Identified Potential Sources

Table I is a summary of the identified radiological sources that may cause radioactive residues. Radiation sources, identified as potential radioactive residues, are broadly classified as natural or manmade sources. Natural sources include cosmic radiation and radiation from naturally radioactive elements that are present in the air, ground and water. The nuclear fuel cycle has a subset of radioactive sources; most of which are concentrated natural sources but some manmade sources are also found in the cycle.

The majority of sources used in medicine is produced in reactors or accelerators. Medical sources are commonly used in diagnostic and therapeutic clinical procedures. Industrial and academic sources can be natural or manmade and are used at universities, research institutes, and laboratories. In industry, sources are used in such applications as radiography, gauging devices, gas chromatography, well logging, and smoke detectors. Radiation sources are also found throughout the construction and use of nuclear weapons, the transportation of radioactive material, and in military commodities, such as in land-mine detectors.

Development of Precaution Levels

An innovative approach in addressing identified radioactive residues is to develop general precaution levels that would apply to groups of sources previously categorized by the type of emission and by the potential for exposure or contamination. Precaution levels are defined in Appendix A of the technical guide to facilitate immediate and appropriate responses to recognized radioactive residues. The defined levels encompass radiological protection principles applicable to specific types of radiation sources. The precautions were developed by evaluating the different types of radionuclides and grouping them by their potential to become an external radiation exposure threat or both external and internal contamination hazards. Specific attention was given to tritium (^{3}H) and depleted uranium (DU**Error! Bookmark not defined.**) because of their important role in Army commodities. Table II shows the precaution levels addressed in this technical guide. Precautions E and I are detailed in the technical guide and may be common to identified sources that are both external and internal contamination threats.

Examples of specific scenarios illustrated in TG-238 include internal contamination and external exposure from uranium and plutonium. The results were linked to the Radiation Exposure State (RES) categories[1] in the process of assessing the dose or potential risk *[2]*.

[1] Radiation Exposure State (RES) categories are defined in NATO Ace Directive No. 80-63 *[2]*. Draft on STANAG report 2473, Commander's guide on low level radiation exposure in military operations, also addresses the concept of RES categories.

Table I. Summary of Identified Radiological Sources

Natural radiation	Nuclear fuel cycle	Biomedical	U.S. Army commodities and foreign materiel	Industry and transport	Production of nuclear weapons
^{3}H, ^{7}Be, ^{14}C, ^{40}K, ^{87}Rb, $^{232}Th$and its daughters, ^{220}Rn and its daughters, ^{235}U and its daughters, ^{238}U and its daughters ^{222}Rn and its daughters, ^{241}Pu and its daughters Other primordial radionuclides (^{40}K, ^{50}V, ^{87}Rb, ^{113}Cd, ^{115}In, ^{123}Te, ^{138}La, ^{142}Ce, ^{144}Nd, ^{147}Sm, ^{152}Gd, ^{174}Hf, ^{176}Lu, ^{187}Re, ^{190}Pt, ^{192}Pt, and ^{209}Bi) Other nuclides found in the Earth's crust (^{115}In, ^{138}La, ^{142}Ce, ^{144}Nd, ^{147}Sm, ^{148}Sm, ^{149}Sm, ^{152}Gd, ^{174}Hf, ^{176}Lu, ^{204}Pb) Other cosmogenic radionuclides (^{10}Be, ^{18}F, ^{22}Na, ^{24}Na, ^{26}Al, ^{31}Si, ^{32}Si, ^{32}P, ^{33}P, ^{37}Ar, ^{39}Ar, ^{34m}Cl, ^{36}Cl, ^{38}Cl, ^{39}Cl, ^{35}S, ^{38}S, ^{80}Kr)	Mining and Milling ^{235}U and its daughters. ^{238}U and its daughters. ^{222}Rn and its daughters. Conversion Same radionuclides as above are found in the conversion process and in the low-level waste. Enrichment Same radionuclides as above. Two main concerns are the enriched product containing ^{235}U and depleted uranium. Fuel Fabrication Same radionuclides as above in low level radioactive waste (liquid and gas waste). Pu isotopes from the MOX fuel fabrication process, liquid waste and gasses. Reactor Operations Same radionuclides as above plus: ^{239}U, ^{240}U, ^{239}Np, ^{240}Np, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{243}Pu, ^{241}Am, and ^{243}Am. Fuel (core and spent fuel pool) Same as above and mainly U and Pu isotopes, plus fission products and activation products. Fission products (in fuel and reactor effluents): Gases: ^{3}H, ^{83m}Kr, ^{85m}Kr, ^{85}Kr, ^{87}Kr, ^{88}Kr, ^{133m}Xe, ^{133}Xe, ^{135m}Xe, ^{135}Xe, ^{138}Xe. Solids: ^{88}Rb, ^{89}Sr, ^{90}Sr, ^{90}Y, ^{91}Y, ^{95}Zr, ^{95}Nb, ^{106}Ru, ^{129}Te, ^{131m}Te, ^{131}Te, ^{133}Te, ^{131}I, ^{133}I, ^{135}I, ^{134}Cs, ^{136}Cs, ^{137}Cs, ^{138}Cs, ^{140}Ba, ^{140}La, ^{144}Ce, ^{144}Pr. Neutron activation products (in systems, core components, reactor coolant system): Gases: ^{13}N, ^{16}N, ^{41}Ar Solids: ^{51}Cr, ^{54}Mg, ^{56}Mg, ^{58}Co, ^{60}Co, ^{59}Fe. Waste / Reprocessing Most of radionuclides with longer half-lives.	Nuclear Medicine equipment Isotopic generators Therapy Units Equipment used in brachytherapy ^{198}Au ^{18}F ^{67}Ga ^{123}I ^{125}I ^{131}I ^{111}In ^{99}Mo ^{32}P ^{226}Ra ^{99m}Tc ^{201}Tl ^{192}Ir ^{127}Xe ^{133}Xe	^{3}H ^{14}C ^{60}Co ^{63}Ni ^{85}Kr ^{90}Sr ^{90}Y ^{131}I ^{137}Cs ^{133}Ba ^{147}Pm ^{204}Tl ^{210}Pb ^{210}Bi ^{226}Ra ^{232}Th ^{234}Pa ^{235}U ^{238}U DU ^{239}Pu ^{241}Am	Industrial accelerators Radioactive waste Transportation of radioactive materials to include spent fuel, ^{235}U, ^{238}U, ^{239}Pu, and others. ^{3}H, ^{14}C, ^{36}Cl, ^{210}Pb, ^{46}Sc, ^{0}Co, ^{82}Br, ^{85}Kr, ^{90}Sr, ^{110m}Ag, ^{137}Cs, ^{140}La, ^{144}Ce, ^{147}Pm, ^{51}Cr, ^{54}Mn, ^{57}Co, ^{65}Zn, ^{99m}Tc, ^{169}Yb, ^{170}Tm, ^{192}Ir, ^{198}Au, $^{239}Pu^{241}Am$, ^{252}Cf	^{3}H ^{137}Cs ^{210}Po ^{234m}Pa ^{231}Th ^{232}Th ^{234}Th ^{234}U ^{235}U ^{238}U ^{234m}Pa ^{239}Pu ^{240}Pu ^{241}Pu ^{241}Am

Table II. Guidance for Recommended Precaution Levels

Precaution level	Application (Detailed in sections from Appendix A of Technical Guide)
X	Potential external exposure. (Apply precautions in section A.1.)
E	Potential external contamination. (Apply precautions in section A.2.)
I	Potential internal exposure and contamination. (Apply precautions delineated in section A.3.)
T	Potential tritium exposure. (Apply precautions in section A.4.)
U	Potential DUexposure. (Apply precautions in section A.5.)

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References

[1] U.S. Army Center for Health Promotion and Preventive Medicine, Radiological Sources of Potential Exposure and/or Contamination, Technical Guide 238, APG, MD (1999).

[2] NATO, ACE Policy for defensive measures against low level radiological hazards during military operations, No. 80-63, Brussels, Belgium (1996).