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~~Draft Protective Action Guide (PAG) for Drinking Water~~

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~~**for Drinking Water**~~

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~~Draft Protective Action Guide (PAG) for Drinking Water~~

~~1.0 INTRODUCTION~~

1.1 ~~This proposal presents the protective action guide (PAG) and planning~~PROTECTIVE ACTION GUIDANCE FOR FOOD AND DRINKING WATER

Information on food and animal feeds protective action guidance is contained in FDA's "Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations for State and Local Agencies" (FDA 1998).

EPA developed a new drinking water PAG as non-regulatory guidance to ~~help~~ protect the public in the event of a radiological incident that affects drinking water ~~sources. A~~supplies. The drinking water PAG will help federal, state, local and public water system officials make decisions about use of water during radiological emergencies.

The drinking water PAG is ~~the projected dose to~~for use only during an ~~individual from a release of radioactive material at which~~emergency; it is not a ~~specific protective~~substitute for compliance with EPA's National Primary Drinking Water Regulations (NPDWRs) for Radionuclides. EPA expects that any drinking water system adversely impacted during a radiation incident will take action to ~~reduce or avoid that dose is recommended.~~ return to compliance as soon as possible.

1.1.1 Protective Action Guide for Drinking Water

The purpose of the protective action for the drinking water exposure pathway is to restrict the use of contaminated water for drinking ~~purposes~~ and to provide recommendations for local communities to consider in providing alternative drinking water for the affected community during a nationally significant radiological incident, such as a disaster at a nuclear power plant, an RDD or an IDD. The drinking water PAGs apply during the intermediate phase of an incident, which may last for weeks to months~~[1].~~ but not longer than one year.[2] This guidance only provides recommendations and does not confer any legal rights or impose any legally binding requirements upon any member of the public, states, or any other federal agency.[3]~~.~~

~~[1] The intermediate phase is defined as the period beginning after the source and releases have been brought under control (has not necessarily stopped but is no longer growing) and reliable environmental measurements are available for use as a basis for decisions on protective actions and extending until these protective actions are no longer needed. The intermediate phase includes protective action recommendations for relocation of the public, worker exposure, reentry, food interdiction, and water interdiction. This phase may last from weeks to months and could also overlap the early phase (hours to days) and late phase (months to years).~~

[2] The intermediate phase is defined as the period beginning after the source and releases have been brought under control (has not necessarily stopped but is no longer growing) and reliable environmental measurements are available for use as a basis for decisions on protective actions and extending until these protective actions are no longer needed. The intermediate phase includes protective action recommendations for relocation of the public, worker exposure, reentry, food interdiction, and water interdiction.

[3] This guidance does not address or impact actions occurring under other statutory authorities such as the United States Environmental Protection Agency's (EPA) Superfund program, the Nuclear Regulatory Commission's (NRC) decommissioning program, or other federal or state programs. As indicated by the use of non-mandatory language such as "may," "should" and "can," this guidance only provides recommendations and does not confer any legal rights or impose any legally binding requirements upon any member of the public, states, or any other federal agency.

~~2.0 THE DRINKING WATER PAG~~

~~Currently there is no intermediate PAG for drinking water. Drinking water is an essential necessity for all people. The~~ EPA ~~determined, given the drinking water contamination that occurred in Japan following the Fukushima event, that a drinking water PAG is necessary. This proposal intends to provide the necessary tools to inform the level at which local emergency responders should restrict consumption of drinking water contaminated during a radiological emergency. In addition, based on public comment received in response to the revised interim PAG manual (2013), EPA believes that this proposal will make the overall PAG document a more robust and complete tool to be used by emergency responders.~~

~~EPA is proposing~~recommends a two-tier drinking water PAG ~~that would be used~~for use during the intermediate phase following a nationally significant radiation incident: ~~500 millirem ((mrem)~~500mrem (5 ~~millisievert (~~mSv~~))~~ or 0.5 rem) projected dose[4] for the general population (defined as anyone over age 15, excluding pregnant women and nursing women), and 100 mrem (1 mSv or 0.1 rem) projected dose for pregnant women, nursing women and children age 15 and under.[5]~~.~~

This guidance does not in any way affect public water systems' compliance obligations under applicable NPDWRs promulgated under the Safe Drinking Water Act (SDWA). EPA expects that the responsible party for any drinking water system adversely impacted during a radiation incident will take action to return to compliance with ~~Safe Drinking Water Act (~~SDWA~~)~~ maximum contaminant levels (MCLs) as soon as practicable. The ~~proposed~~ drinking water PAG provides a level of protection for the general population consistent with PAGs currently in place for other media in the intermediate phase (i.e., ~~the Food and Drug Administration's~~the FDA's 500 mrem PAG for ingestion of food[6,7]) and provides an additional level of protection for the most sensitive life stages. Intermediate phase doses can be projected using a ~~one~~1-year duration and compared to the PAG so that actions can be taken to avoid the exposure. PAG levels were calculated based on a maximum 1-year exposure and provide a level of protection roughly equivalent to applicable NPDWRs for radiation, which are based on 70 years of exposure.

The ~~already promulgated~~ FDA food PAG and ~~this proposed EPA~~the drinking water PAG are designed to complement each other, and allow emergency response officials to account for and address doses from both eating contaminated food and drinking contaminated water. The food ingestion and drinking water pathways are inherently related because both address exposure through ingestion. In addition, water may be used in the preparation of some food products, and radionuclides in water may

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[4] All dose values are expressed as Committed Effective Dose ~~(CED)~~ projected over a person's lifetime based on one year~~. The CED, as defined in FGR-13 (1999) and ICRP 103 (2007), is the sum~~ of ~~the product of all organ doses times their tissue weighting factors~~intake.

[5] Emergency management officials may consider whether it is appropriate to extend the lower tier to individuals beyond age 15 or to women who are trying to get pregnant or who believe they might be pregnant.

[6] Food and Drug Administration (FDA). 1998. *Accidental Radioactive Contamination of Human Food and Animal Feeds: Recommendations to State and Local Agencies.* Available online at: http://www.fda.gov/downloads/MedicalDevices/.../UCM094513.pdf.

[7] FDA. 2004. Supporting Document for Guidance Levels for Radionuclides in Domestic and Imported Foods. Docket No. 2003D-0558.

affect crops and ultimately enter the food supply. The FDA food PAG accounts for water intrinsic in food as purchased and EPA's ~~proposed~~water PAG accounts for drinking water, including water added to foods during preparation.[8] ~~.~~

PAGs for both food and drinking water are needed because a radiological incident may affect the food supply and drinking water differently. In addition, because drinking water is usually locally controlled and food is frequently shipped in from distant locations, different and separate interdiction approaches would be appropriate. ~~Finally, as explained in the revised interim PAG manual (2013)~~[9]Finally, the various PAGs are designed to work in concert, allowing emergency responders to choose the exposure reduction strategies that match the exposure scenario, community needs, and resources available in the particular emergency.

While ~~FDA~~food safety and ~~EPA~~drinking water personnel would work closely together in a radiological response, the ~~two agency's~~ authorities related to food and drinking water safety are separate~~ so~~, and different strategies may be needed to protect drinking water and the food supply.

A PAG is intended as a point of reference to aid emergency response managers in their decision-making. After ~~a particular~~an emergency situation stabilizes and becomes more clearly defined, local authorities may wish to modify the PAG level they consider to be appropriate in order to implement longer-term dose reduction strategies. EPA expects that the responsible party for any drinking water system adversely impacted during a radiation incident will take action to return to compliance with ~~maximum contaminant levels (~~SDWA MCLs~~)~~ as soon as practicable.

Should a major radiological event occur, emergency response officials should consider potential doses from all affected pathways (e.g., airborne plume, ground contamination, drinking water, foods) when making protective action decisions. The drinking water PAG is focused solely on drinking water exposures and does not take into account other exposure pathways; decision makers may want to adjust to account for cumulative doses (see Section 1.4.3). Consideration of the specific conditions facing a community should be used in determining how each PAG should be implemented. Protective actions might include restrictions on consumption of garden produce, locally produced foods or an embargo on sales of certain products, as well as drinking water actions described in Section 4.6.~~0~~5 of this ~~proposal~~guidance. Local decision makers will need to determine the appropriate ~~PAGs~~protective actions depending on projected ~~risk. For the PAGs, exposure routes are divided up by time and circumstance~~dose. Guidance in this Manual is intentionally flexible to allow the many different potential protective actions to be tailored to the specific risks that must be addressed. ~~The full PAG Manual addresses all of the other pathways (plume inhalation, immersion, ground shine, skin and thyroid doses in particular, long term exposure to contamination, reentry and return to complete cleanup work, etc.) but always within parameters appropriate to a corresponding PAG.~~

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[8] Liquid beverages as well as milk are covered under the FDA food PAG.

~~[9] EPA. 2013. Draft PAG Manual for Interim Use and Public Comment. Available online at: http://www2.epa.gov/sites/production/files/2014-11/documents/pag-manual-interim-public-comment-4-2-2013.pdf.~~

Section ~~7.0~~4.6.6 explains how to calculate Derived Response Levels (DRLs) for radionuclides likely to appear in drinking water following a radiological contamination incident.[10]~~.~~ DRLs are concentrations of radionuclides in drinking water that correspond to EPA's ~~proposed PAG~~recommended PAGs of 100 mrem and 500 mrem. DRLs are essential because a PAG identifies a radiation dose rather than a quantity of radionuclides that can be measured directly in drinking water. DRLs are expressed in units of picocuries per liter (pCi/L) or becquerel per liter (Bq/L), and can be directly compared to measured radionuclide concentrations in finished drinking water. In most situations, by the intermediate phase, responders will have enough information about the source of radiation to develop site-specific DRLs. In the absence of ~~site-specific DRLs developed by emergency responders acquainted with~~information about local ~~conditions~~emissions sources and isotopes, particularly in the early phase, EPA recommends using ~~these DRLs~~conservative assumptions to fill information gaps, which ~~are indicative of a worst case scenario in which there is~~might include assuming no decay of isotopes over the calculated 1-year exposure period, to guide actions to protect the public in the event of a major radiological incident that affects drinking water sources.

~~1.1.1~~1.1.2 Factors EPA considered when establishing the drinking water PAG

Section 1.3.2 of ~~the revised interim~~this PAG manual ~~(2013)[11]~~ provides the following three principles for establishing PAGs.

1. Prevent acute effects.
2. Balance protection with other important factors and ensure that actions result in more benefit than harm.
3. Reduce risk of chronic effects.

EPA crafted the drinking water PAG with these same principles in mind. Specifically, consideration was given to the acute effects of exposure to radiation and lifetime risk of cancer based on age and drinking water intake. EPA made use of the risk conversion factors set forth in Federal Guidance Report ~~No.~~ #13 (~~FGR-13~~EPA 1999)[12] and considerations of risk to the unborn set forth in ~~National Council on Radiation Protection and Measurements (~~NCRP~~)~~ Report No. 174.[13]

~~In preparing this proposal, EPA gave careful consideration to public feedback received on the revised interim PAG manual (2013) request for comments on adopting a drinking water PAG.[14]~~

[10] EPA selected I-131, Sr-90/Y-90, and Cs-137 as indicator isotopes likely to appear in water following a radiation contamination incident, these were selected based on previous documented experience. However, DRLs can be calculated for different isotopes by using dose conversion factors included in Federal Guidance Report No. 13.

~~[11] EPA. 2013. Draft PAG Manual for Interim Use and Public Comment. Available online at: http://www2.epa.gov/sites/production/files/2014-11/documents/pag-manual-interim-public-comment-4-2-2013.pdf.~~

[12] EPA. 1999. Cancer Risk Coefficients for Environmental Exposure to Radionuclides. Federal Guidance Report #13. Available online at: http://www.epa.gov/rpdweb00/docs/federal/402-r-99-001.pdf.

[13] Brent, R.L., Frush, D.P., Harms, R.W., and M.S. Linet. 2013. *Preconception and Prenatal Radiation Exposure: Health Effects and Protective Guidance.* National Council on Radiation Protection. Report #174.

~~[14] Public feedback on the draft PAG Manual was requested in the Federal Register Notice Vol. 78, No. 72, p. 22257, April 15, 2013.~~

~~This proposed~~The drinking water PAG was developed based on reducing risks associated with ingesting drinking water contaminated with radionuclides. EPA also considered the potential radiation dose people could receive from various other uses of contaminated water, including showering, bathing, and dishwashing. In the United States, people typically shower, bathe, and wash dishes using the same source of water that they use to drink, but, for the radionuclides of interest, dermal and inhalation exposures from these activities generally represent much smaller risk than drinking contaminated water. Protection of a community's drinking water supply based on assumptions about ingestion will also protect the population from undue risk from contaminated drinking water by other routes of exposure.

~~1.1.2~~1.1.3 Rationale for a two-tier Drinking Water PAG

The two-tier PAG consists of 500 mrem (5 mSv or 0.5 rem) for the general population ~~(i.e., anyone over age 15, excluding pregnant women and nursing women),~~, and a more stringent PAG of 100 mrem (1 mSv or 0.1 rem) to inform protective actions for pregnant women, nursing women, and children age 15 and under. Fetuses, infants and children are at greater risk from radiological exposures than adults due to the greater sensitivity of the developing body to the potential harmful effects of radiation and the longer dose commitment period for the longer-lived radionuclides that clear slowly from the body. A newborn that ingests radioactive material in water (e.g., through formula) would be expected to be subject to the effects of that radiation for a longer period of time than if the same dose was experienced by an adult.

~~There are precedents for establishing a more protective threshold for radiological risks for younger members of the population due to the greater radiosensitivity of children versus adults. Following the Fukushima nuclear plant releases in 2011, the Japanese authorities set an emergency drinking water standard for infants that was one-third of the value for adults.[15]~~

~~PAGs and other guidance materials established by FDA for thyroid blocking with potassium iodide[16] and for ingestion of food[17] both include separate thresholds for more sensitive age groups.~~

For the sake of establishing clear and executable decisions in the intermediate phase of emergency response, EPA ~~proposes~~recommends a uniform PAG for fetuses, infants~~,~~ and children, even though there may be considerable differences in the transmission of radiological drinking water contaminants to a fetus via the placenta, to an infant via formula or breast milk, and to a child via direct consumption. Specifically, we have ~~proposed~~developed a PAG level designed to ~~protect~~provide additional protection to the most sensitive of the three subgroups from exposure to radioactivity in drinking water

~~[15] World Health Organization (WHO). 2011. FAQs: Japan nuclear concerns. Page 9, water contamination. September 2011. Available online at: http://www.who.int/hac/crises/jpn/faqs/en/index8.html.~~

~~[16] FDA. 2001. *Guidance: Potassium Iodide as a Thyroid Blocking Agent in Radiation Emergencies*. Available online at: http://www.fda.gov/downloads/Drugs/.../Guidances/ucm080542.pdf.~~

~~[17] FDA. 1998 *Accidental Radioactive Contamination of Human Foods and Animal Feeds: Recommendations for State and Local Agencies*. http://www.fda.gov/downloads/MedicalDevices/.../UCM094513.pdf~~

following a radiological incident. Keeping PAGs relatively simple helps to minimize confusion during their implementation~~. Therefore, DRLs provided in Section 7.0 were selected by assessing risks to all age groups and choosing the most conservative concentration to the most sensitive age group.~~; however, Federal, state, and local officials should consider resource availability as they determine when and how to apply either of these guidelines.

The PAG of 500 mrem (5 mSv or 0.5 rem) for the general population is designed to be used in concert with the FDA food PAG[18] since many of the considerations for a food PAG also apply to drinking water. It is also consistent with the guidance value of 500 mrem over one year established by the ~~Department of Homeland Security~~DHS as an intermediate-phase PAG for drinking water interdiction.[19] A PAG of 100 mrem ~~provides~~ (1 mSv or 0.1 rem) for the most sensitive members of the population ~~a reasonable level of~~provides them with a significant additional protection from exposure to radioactivity in drinking water following a radiological incident.

Other Standards

~~The current~~NRC regulations (i.e., 10 CFR Part 20.1301) have established a public radiation protection standard of 100 mrem per year effective dose ~~is set forth in Nuclear Regulatory Commission (NRC) regulations (i.e., 10 CFR Part 20.1301). The International Commission on Radiation Protection~~. The ICRP[20] recommends reference levels in the range of 2,000 to 10,000 mrem (20 to 100 mSv) for protection of human health in emergencies, and in the range of 100 to 2,000 mrem (1 to 20 mSv) for occupational exposure, exposure by caregivers, or residential radon exposure. Based on a risk reduction approach, EPA ~~is proposing its~~ recommends that the drinking water PAGs be set at the lower (more stringent) end of the latter range ~~as an added layer~~to ensure protection of ~~precaution~~public health.

~~Following the Fukushima nuclear plant releases in 2011, there was concern about levels of radioactive iodine-131 (I-131) in drinking water. The Japanese authorities applied a two-tier set of provisional emergency standards to I-131 in water: 300 Bq/L (about 8,100 pCi/L) for adults and 100 Bq/L (about 2,700 pCi/L) for infants (specifically for drinking water used to prepare baby formula). According to informational materials assembled by the World Health Organization in the wake of the incident,[21] these emergency drinking water standards were provisional regulation values established by the Japanese Food Sanitation Act, as indicated by the Nuclear Safety Commission of Japan. These standards were precautionary and took international guidance into consideration, including recommendations of the International Atomic Energy Agency and the International Commission on Radiological Protection. The infant standard, furthermore, was equivalent to the international guideline set by Codex Alimentarius[22] for infant food.~~

[18] FDA. 1998 *Accidental Radioactive Contamination of Human Foods and Animal Feeds: Recommendations for State and Local Agencies*. http://www.fda.gov/downloads/MedicalDevices/.../UCM094513.pdf

[19] See Planning Guidance for Protection and Recovery Following Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND), Table 1 in 73 FR 45029, August 2008, http://www.gpo.gov/fdsys/pkg/FR-2008-08-01/pdf/E8-17645.pdf.

[20] International Commission on Radiological Protection (ICRP). 2007. *The 2007 Recommendations of the International Commission on Radiological Protection*, Annals of the ICRP, Volume 37, Nos.2-4, 2007, Publication 103, ISSN 0146-6453, ISBN 978-0-7020-3048-2, pp. 96-98

~~[21] WHO. 2011.~~

~~[22] http://www.codexalimentarius.org/about-codex/en/.~~

Under the ~~Safe Drinking Water Act (~~SDWA~~)~~,, EPA established ~~maximum contaminant levels (~~MCLs~~)~~ for radiological contaminants in drinking water. ~~The National Primary Drinking Water Regulations (~~The NPDWR~~)~~ for Radionuclides, set forth in 40 CFR Part 141, effectively ~~adopt~~adopted a dose-based limit of 4 mrem~~/yr~~ per year for beta particle and photon radioactivity. These requirements are based on lifetime exposure criteria, which assume 70 years of continued exposure to contaminants in drinking water. The Agency determined that it may not be ~~appropriate~~possible to base protective actions during short-term emergency incidents on lifetime exposure criteria. While the SDWA framework is appropriate for day-to-day normal operations, it does not provide the necessary tools to assist emergency responders with determining the need for ~~potentially ongoing~~prioritizing protective actions during the intermediate phase of a response. However, regardless of the cause of an incident, EPA expects that actions will be taken to return the ~~responsible party for any~~ impacted drinking water system ~~impacted during a radiation incident will take action to return~~ to compliance with the NPDWR levels by the earliest feasible time.

~~1.1.3~~1.1.4 Interpreting and Applying the PAG

The drinking water PAG is intended primarily to guide planning and decision-making efforts by local and state officials, including drinking water providers, during the intermediate phase of a radiological emergency when surface water sources are particularly vulnerable to contamination from deposition of radioactive material from the atmosphere. Actions to protect water sources may be implemented at other levels and at any time following a radiological incident, and even before an anticipated release occurs. The goal is to keep the dose to the public as low as reasonably achievable. Radiation doses should be reduced to below SDWA MCLs as soon as practicable.

Interpreting the Two-tier PAG

EPA ~~is proposing~~recommends a two-tier PAG: 500 mrem (5 mSv or 0.5 rem) for the general population (anyone over age 15, excluding pregnant women and nursing women) and 100 mrem (1 mSv or 0.1 rem) for pregnant women, nursing women and children.

Authorities have flexibility on how to apply the PAG. In some cases they may find it ~~prudent~~feasible to use the PAG of 100 mrem as a target for the whole population, while in other circumstances, authorities may find that it makes sense to use both targets simultaneously. For example, emergency managers can use a two-tiered approach to focus on protecting the most sensitive population with limited alternate water resources. If bottled water must be rationed, for example, authorities may make the bottled water available to children, pregnant women and nursing women, and instruct the rest of the population to use a public drinking water supply that will not trigger the 500 mrem PAG.

As stated above, the PAGs are intended as guidance only, and local authorities should take into account local circumstances (e.g., incident scope and community needs) when implementing ~~a~~any course of action to protect the public.

~~Operationalizing~~Converting PAGs ~~as~~into Derived Response Levels (DRLs)

The PAG specifies a radiation dose to avoid via drinking water exposure projected over one year. In order to determine whether a PAG should be implemented, authorities will need to establish a relationship between the measured concentration of one or more radionuclides in finished drinking water and the radiation dose members of the population might experience as a result of drinking contaminated water. Incident-specific factors that may be taken into consideration include:

1. The particular radionuclides being emitted in this ~~particular~~ emergency situation

2. The rate and timing of entry of the radionuclides into ~~a~~the drinking water supply, via atmospheric deposition or by other means

3. The rate of natural attenuation of the radionuclides

4. The estimated potential duration of public exposure to contaminated drinking water

5. The estimated daily consumption of contaminated drinking water.

Those responsible for implementing PAGs will need to convert PAGs into Derived Response Levels (DRLs) in units of Bq/L or pCi/L~~.~~ for each radionuclide of interest. Section ~~7.0~~4.6.6 of this ~~document~~Manual provides DRLs and explains how they can be calculated. Selected dose conversion factors and standard estimates of daily drinking water consumption for various age groups are also provided, along with references to informational resources.

While the PAG Manual is primarily for advance planning, there are specific radionuclides, including cesium-137 (Cs-137), iodine-131 (I-131) and strontium/yttrium-90 (Sr-90/Y-90) that are of particular interest for major radiological incident scenarios where drinking water sources might be contaminated. Section ~~7.0~~4.6.6 presents default DRLs for these radionuclides to aid emergency managers in making water restriction decisions involving these contaminants. DRLs for these radionuclides are presented as examples for purpose of illustration. If other radionuclides are present, DRLs should be calculated using the same methodology, as discussed in Section ~~7.0.~~4.6.6.

Practical Considerations

After deposition has ended, radionuclide concentrations present in a water supply may decline at rates determined by the half-lives of the individual nuclides,~~ or~~ may decline faster by dilution with uncontaminated water, or may even increase after rainfall and seasonal thaw events~~.~~ in an affected watershed. The concentration of radionuclides in drinking water as a function of time after the incident can be measured, estimated or modeled based on knowledge of the incident, including radionuclide sources and the properties of the drinking water supply. ~~Such~~Models and estimates should be validated by monitoring or sampling, as discussed in Section ~~6.1.~~4.6.5.

Unlike naturally-occurring radionuclide contamination of drinking water from minerals present in geological formations, for a radiation release incident, ground water sources are expected to be less vulnerable to contamination than surface water sources, but this should be confirmed by monitoring or sampling. The potential for ground water to become contaminated will greatly depend on whether the ground water resource is close to the surface or is from a deep aquifer bounded by an aquitard, as well as on rainfall rate and the composition of the overlying soil (which will affect the rate at which contaminants deposited on soil will migrate to the ground water resource).

Section ~~6.3~~4.6.5 discusses actions that authorities can take to minimize radiation doses from drinking water. Because radionuclides decay over time, early interventions such as restricting use of contaminated water immediately after the incident may be most effective in reducing radiation dose to the population. Such decisions may need to be made based on limited information. Authorities may find it prudent to take such action even before field sample measurements or modeled estimates of radiation dose have been calculated and validated.

~~1.1.4~~1.1.5 Planning and Taking Action

This section discusses actions that state and/or local authorities and drinking water utilities can take to protect the public in the event that a water supply is affected by a nationally significant radiological contamination incident. Different actions described here may be appropriate for initial and intermediate phases depending on local resources. This section does not constitute a complete handbook for radiological emergency response, but it describes considerations that can be included in comprehensive emergency planning at the state, local and utility level. Actions that public authorities and drinking water providers should take ~~include~~are described below, including water monitoring~~ (described in Section 6.1)~~, public notification~~ (described in Section 6.2)~~, and mitigation measures to protect the water supply and the water-consuming public~~ (described in Section 6.3)~~.

Preventive action, such as temporary closure of water system intake valves to prevent a contaminant plume from entering the system, may be taken in advance of an anticipated release; it is not necessary to wait until drinking water contamination is detected. Emergency response plans need to consider whether sufficient storage capacity is available to support the community's fire suppression and sanitation needs while the intake valves are closed.

Emergency planning provides the opportunity to develop state, local and utility-specific plans and implementation procedures that reflect the unique needs of a particular community. Advance planning can provide clarity and facilitate the decision-making process during a radiological emergency.

Monitoring and Characterization of Contaminants

A comprehensive radiological surveillance program to monitor concentrations of radionuclides of interest in both source water (including both upstream and downstream of intakes, as applicable) and finished drinking water would provide an indication of whether any adjustments are necessary or if the actions being taken are effective.

The NPDWR for radionuclides requires community water systems (CWSs) to conduct monitoring at each entry point to the distribution system to ensure that every customer's water does not exceed the MCLs for radionuclides.[23] All CWSs are required to monitor for gross alpha, radium-226/228, and uranium. In addition, CWSs designated by the state as "vulnerable"[24] and those using waters "contaminated"[25] by effluents from nuclear facilities must also conduct monitoring for beta particle and photon radioactivity. If a water system is directed by the primacy agency to collect samples for compliance purposes, approved analytical methods must be used.

In the event of a radiological contamination incident, state officials may require public water systems to immediately collect additional samples for radionuclides, including beta particle and photon activity. However, EPA recognizes that during an emergency situation it may be necessary to identify alternative sampling and analytical approaches to obtain data to inform short-term actions by emergency response personnel. Many states have established Radiological Emergency Preparedness[26] programs designed to guide sample collection and analysis and to advise emergency managers in a radiological emergency. Additionally, the Federal Radiological Monitoring and Assessment Center (FRMAC)[27] can deploy monitoring and sampling field teams and provide dose assessment expertise to assist states and local

[23] For more information about monitoring requirements for the Radionuclides Rule see the "Radionuclides Rule: A Quick Reference Guide" (EPA 816-F-01-003, June 2001) or "Implementation Guidance for Radionuclides" (EPA 816-F-00-002, March 2002).
[24] For more information see 40 CFR 141.26(b)(1).
[25] For more information see 40 CFR 141.26(b)(2).
[26] http://www.fema.gov/radiological-emergency-preparedness-program
[27] The Federal Radiological Monitoring and Assessment Center (FRMAC) is a federal asset available on request by the Department of Homeland Security (DHS) and state and local agencies to respond to a nuclear or radiological incident.

communities in responding to an emergency. See the National Response Framework, Nuclear/Radiological Incident Annex[28] for information on roles and capabilities.

~~Once the situation is better characterized and systems are working towards returning to compliance, monitoring should be conducted at entry points to the distribution systems using approved analytical methods.~~ EPA provides rapid laboratory analysis methods for selected radionuclides to expedite the analytical turnaround time while simultaneously meeting measurement quality objectives.[29] Samples should be collected from entry points to the distribution system. Challenges may arise from variability in environmental matrices. Advance emergency planning can help to achieve sample representativeness and homogeneity relative to routine samples.

Once the situation is better characterized and systems are working towards returning to compliance, monitoring should be conducted at entry points to the distribution system using only approved analytical compliance methods.

If members of the public are served by drinking water from household cisterns or private wells, local officials should consider how monitoring should be undertaken to determine levels of target radionuclides and assess the risks posed to these populations.

Public Notification

An emergency response plan should include a strategy for keeping the community informed of the actions being taken by authorities and clearly delineate roles and responsibilities of local officials and emergency responders. This includes communicating to customers of CWSs and (if applicable) to those who rely on household cisterns and private wells. It is critical for water utilities to participate in the emergency response planning activities.

If compliance monitoring indicates that contamination levels exceed the MCL for any radionuclide, water systems are required to issue public notice on a “Tier 2” time frame (i.e., as soon as practical, but no later than 30 days after the system learns of the violation). CWSs should be able to issue repeat notices as required. However, states may determine that the notification requirement should be elevated to a “Tier 1” Public Notification (i.e., as soon as practical, but no later than 24 hours) based on a significant potential for serious adverse effects on human health due to short-term exposure.[30]

During a response to a major radiological incident, water systems may have difficulty with issuing public notifications in addition to managing the response to the contamination event. The state may issue public notification on behalf of the water system (40 CFR 141.210(a)). This would allow the state to deliver a consistent message to all affected customers and allow the system to concentrate its efforts on returning to operation or returning to compliance in the event of ~~a radionuclides~~radionuclide(s) MCL violation~~.~~(s). For more information see the Revised Public Notification Handbook (EPA 816-R-09-013, March 2010).

State and local authorities should be proactive in communicating about risks and uncertainties and providing clear instructions to the public. For any incident response requiring coordinated federal support,

[28] Document is available online at: http://www.fema.gov/media-library/assets/documents/25554
[29] EPA. 2014a. Rapid Radiochemical Methods Applicable to Selected Radionuclides for Environmental Remediation Following Radiological Incidents. Third Edition. Front matter available online at: http://www.epa.gov/narel/Docs/Preface%20to%203rd%20Edition%20%28Online%29%2004-16-14.pdf. Rapid methods are available online at: http://www.epa.gov/narel/rapid_methods.html
[30] For more information see 40 CFR 141.202(a), Table 1(9), Special public notices: Occurrence of a waterborne disease outbreak or other waterborne emergency.

refer to the National Response Framework and Emergency Support Function 15, External Affairs Annex, for roles and response protocols.

Additional Actions to Reduce Levels of Contamination

In the initial phase following a radiological incident, officials should take reasonable precautionary measures (i.e., closing intake valves) to protect water sources as soon as notification of a radiological release or impending release is received. Moving into the intermediate phase, as data are obtained from monitoring programs (including sampling and analysis of water upstream and downstream of a water system intake structure and within the distribution system), officials should benchmark observed concentrations against the default DRLs discussed in Section ~~7.0~~4.6.6 or situation~~-~~-specific DRLs that account for specific isotopes present, release patterns, and decay. Officials would then be in a position to make informed decisions about the need to implement protective actions. Water system officials should be in close communication with their ~~primacy~~drinking water regulatory agency (e.g., state~~/county regulators~~) prior to taking protective actions.

Options available to water systems to reduce radiation dose to drinking water customers include applying treatment technologies, relying on back-up storage, blending water, accessing alternative water sources, and rationing of uncontaminated water or a combination of these actions. Examples of these options are described briefly below. Technical and economic burden on smaller systems may be reduced by pooling resources with other water systems (e.g., establishing interconnections, sharing technical and operator staff, and sharing of supplies and equipment). As part of emergency planning efforts, local officials should consider the possibility of temporary rationing of uncontaminated or treated water if supplies are inadequate to meet normal demand.

All of these options require advanced planning and should be evaluated and included in ~~States~~State's plans as appropriate. Guidance on developing emergency drinking water supplies is available from EPA.[31] The ~~Centers for Disease Control and Prevention~~CDC also ~~provide~~provides resources and guidance for establishing emergency water supplies and communicating water advisories to the public.[32]

- **Treating Contaminated Water**

Systems with the appropriate technology in place can treat contaminated water to reduce elevated radionuclide levels. Four treatment technologies are classified by EPA as Best Available Technologies (BATs) for removing radionuclides from drinking water: coagulation/filtration, ion exchange, lime softening and reverse osmosis. EPA has also listed these BATs as Small System Compliance Technologies (SSCTs) for radionuclides treatment, along with less commonly used techniques such as green sand filtration, co-precipitation with barium sulfate, electrodialysis/electrodialysis reversal, pre-formed hydrous manganese oxide filtration and activated alumina. Further information on radionuclide treatment options is available from EPA.[33]

Removal efficiency for specific radionuclides will vary across available technologies and may depend on technology-specific parameters (e.g., ion exchange effectiveness depends on pH, resin selected and

[31] EPA. 2011b. *Planning for an Emergency Drinking Water Supply,* EPA 600/R-11/054, June 2011.
[32] CDC. 2014. Drinking Water Advisory, Planning, & Emergency Response Resources. Available on the Internet at: http://www.cdc.gov/healthywater/emergency/drinkingwateradvisory.html. Last updated December 2, 2014.
[33] EPA. 2015a. Radionuclides in Drinking Water -- Compliance Options: Treatment Technology Descriptions. Available on the Internet at: http://cfpub.epa.gov/safewater/radionuclides/radionuclides.cfm. See also EPA. 2002a. *Radionuclides in Drinking Water: A Small Entity Compliance Guide.* EPA 815-R-02-001, 2002.

presence of other ions). In addition, liquid and solid treatment residuals with elevated radiation levels may have special disposal requirements. Disposal options may vary from one jurisdiction to another, and may depend on the type, concentration and volume of residuals. Further information on residual disposal considerations is available from EPA.[34]

- **Temporarily Closing Intake Valves**

If the deposition of radionuclides into a river is limited in duration, only a portion of the water may become contaminated. A water system with enough storage capacity can temporarily close its intake valves and allow the contaminants to flow past the intake to prevent contamination from entering the distribution system.

If stored water supplies are not sufficient to meet community fire suppression and sanitation needs while intake valves are closed, the system could take other actions discussed in this section, including supplementing water supplies with alternate sources or implementing water use restrictions.

- **Establishing Interconnections to Neighboring Systems**

If the water system is part of a larger, regional supply system, existing interconnections to ~~an~~ uncontaminated neighboring water ~~supply~~supplies could be activated. It might also be possible to construct temporary pipelines on an impromptu basis.

If this option is implemented, steps should be taken to prevent backflow from the contaminated system. Care will also need to be taken to ensure that the supply of water and treatment capacity at the uncontaminated system will adequately serve the larger population.

- **Blending Water Sources**

If a source of uncontaminated water is available, a water system may choose to blend water from contaminated and uncontaminated sources of drinking water to minimize radiation doses from drinking water. The water may be blended using storage tanks or a common header to allow for complete mixing prior to distribution to customers.

- **Importing Water in Tanker Trucks**

Under some circumstances (e.g., difficult terrain, urgent need), it may be more efficient or expedient to temporarily transport clean water by truck, rail or barge to distribution centers in the affected community than to lay down pipelines. State and local departments of public health, as well as emergency management agencies, typically have standards and requirements related to hauling water. Water systems would benefit from having procedures for importing water in tanker trucks documented in an emergency response plan. All water systems importing water by tanker should verify that their plan adheres to state and local requirements. If the water system's distribution system is not being used to provide the imported water, the needs of residents with limited transportation options and physical disabilities should be taken into account when selecting locations for distribution centers. The availability of suitable transport vehicles may limit use of this option.

- **Importing Bottled Water**

(http://www.epa.gov/safewater/radionuclides/pdfs/guide_radionuclides_smallsystems_compliance.pdf).

[34] EPA. 2006a. *A System's Guide to the Management of Radioactive Residuals from Drinking Water Treatment Technologies.* EPA 816-F-06-012, August 2006. See also EPA. 2006b. *A System's Guide to the Identification and Disposal of Hazardous and Non-Hazardous Water Treatment Plant Residuals.* EPA 816-F-06-011, August 2006.

Providing bottled water to the affected community is another possible option during an emergency situation. The water may come from a nearby water system or from a water bottling company. This option may be cost-effective during an emergency if water is needed quickly and if the length of the emergency does not require long-term action, such as the construction of an interconnecting pipe.

~~1.1.5~~1.1.6 Derived Response Levels (DRLs)

~~EPA developed the radionuclide-specific default DRLs by calculating the radionuclide concentrations in drinking water that would result in projected radiation doses of 100 and 500 mrem, assuming one year of continuous exposure and average drinking water intake rates for children and adults.~~

~~Several considerations should be kept in mind when using these pre-calculated DRLs. The DRLs presented in Table 1 are calculated on the assumption that each radionuclide is the only radionuclide present in drinking water. DRLs are additive. In situations where multiple radionuclides are present, DRLs should be combined using a sum of fractions approach to ensure that the projected dose does not exceed the PAG of 100 or 500 mrem. (An example calculation is provided in Section 7.1.) Table 1 does not present DRLs for all radionuclides that may occur in drinking water following a contamination incident.~~

~~These default DRLs were calculated using a simplifying and conservative assumption that radionuclide levels will remain constant over the course of one year. This assumption would cover the most serious situations in which continuous release and replenishment of isotopes is ongoing. As such, the assumption provides an added level of protection in light of the many unknowns involved in an emergency. In fact, after the initial deposition event has occurred, concentrations may decline at rates determined by the half-lives of individual isotopes, or decline faster due to dilution with uncontaminated water, or could even increase after rainfall or subsequent deposition events. Some nuclides, like I-131, have half-lives measured in days, while others, like Cs-137, have half-lives measured in years.~~

~~The default DRLs in the PAGs are provided for convenience to allow local entities to make decisions about drinking water provided by public water systems quickly in the event of a radiological emergency. As one moves further into the intermediate phase, when~~Once the incident characteristics have been assessed, ~~assumptions~~information regarding duration of the radiological release and the half-life of nuclides involved as well as other factors may be considered by local decision makers in projecting ~~risks~~doses and adapting mitigation measures. All radionuclides are covered by the assessment tools provided by FRMAC. For instance, if an alpha emitting isotope was of concern following a radiation contamination incident, it would be included in any calculations regarding protective actions for drinking water. As such, local officials may choose to work with FRMAC to calculate situation-specific DRLs that are based on information gained during the intermediate phase, including identification of specific isotopes, release patterns, and associated decay functions.

In the unlikely scenario where radioactive isotopes are continuously replenished, EPA recommends using the conservative assumption that radionuclide levels will remain constant over the course of one year. Such an assumption provides an added level of protection in light of the many unknowns involved in an emergency. In fact, after the initial deposition event has occurred, concentrations usually decline at rates determined by the half-lives of individual isotopes, or decline faster due to dilution with uncontaminated water, or could even increase after rainfall or subsequent deposition events. Some nuclides, like I-131, have half-lives measured in days, while others, like Cs-137, have half-lives measured in years.

Table 4-3 provides default DRLs for those unlikely scenarios. They provide for convenience to allow local entities to make quick decisions about drinking water provided by public water systems in the event of a radiological emergency.

Early exceedance of the default DRL does not ~~preclude the possibility~~suggest that doses will stay at that level. In most cases, levels will drop below PAGs as radionuclide concentrations in water decline by a combination of radioactive decay and natural attenuation. If the concentrations of radionuclides do not exceed DRLs over the course of one year, doses will remain below the PAG.

~~Table 1. Default derived response levels (DRLs)[35] -- drinking water concentrations corresponding to specified doses (mrem) of select radionuclides, assuming one year of exposure at constant levels[36]~~

	~~DRLs for pregnant women, nursing women and children age 15 and younger – 100 mrem dose~~ Table 4-3. Default Derived Response Levels (DRLs)[37] – Drinking Water Concentrations Corresponding to Specified Doses (mrem) of Select[38] Radionuclides, Assuming One Year of Exposure at Constant Levels[39]	~~DRLs for adults (excluding pregnant women and nursing women) – 500 mrem dose~~
Isotope	**DRLs for pregnant women, nursing women and children age 15 and younger – 100 mrem dose**	**DRLs for the general population – 500 mrem dose**
Sr-90/Y-90[40]	1,000 pCi/L	7,400 pCi/L
Cs-137	6,~~140~~200 pCi/L	~~16,570~~17,000 pCi/L

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~~[35] Values provided in this table have been rounded.~~

~~[36] The calculated values provided in this table are intended to illustrate the methodology and conservative assumptions EPA believes are adequate to provide a reasonable level of protection to sensitive populations. Dose conversion factors, calculation methodologies as well as other comprehensive information regarding DRL development will be available and updated as needed in the FRMAC Assessment Manual.~~

[37] The DRLs in Table 1 indicate the concentration of each radionuclide which results in the corresponding radiation dose value if such radionuclide was the radiation emitter in drinking water. Values provided in this table have been rounded to two significant figures.

[38] Table 1 does not present DRLs for all radionuclides that may occur in drinking water following a contamination incident, however DRLs can be calculated for any isotope of interest by using the provided reference documents and calculation methodology.

[39] The calculated values provided in this table are intended to illustrate the methodology and conservative assumptions EPA believes are adequate to provide a reasonable level of protection to sensitive populations. Dose conversion factors, calculation methodologies as well as other comprehensive information regarding DRL development will be available and updated as needed in the FRMAC Assessment Manual.

[40] Y-90 is a radioactive decay product of Sr-90 and will normally be found alongside Sr-90 in the case of a Sr-90 release; therefore they are treated together. Solubility differences may cause less yttrium to be present, however it is a conservative assumption to include both in DRLs. When calculating the combined DRL, note that the dose coefficients (see ~~Table 3)~~Table 4-5) are additive.

I-131	~~1,310~~820 pCi/L	10,~~350~~000 pCi/L

The DRLs provided in ~~Table 1~~Table 4-3 were derived by calculating life stage-specific DRLs (as described ~~in section 7.2)~~below) for ~~six~~eight different ages (fetus, breastfed infant, infant, 1, 5, 10, 15, and adults). For the most sensitive life-stages, concentrations of individual radionuclides yielding a 100 mrem dose were calculated for each age group, then the most protective/lowest radioactivity concentration was selected as the DRL for the entire sensitive life-stage group, including pregnant and nursing women. The calculated values differ across individual life-stages because each age group has a different dose conversion factor and drinking water ingestion ~~rate~~rates.

For example, the sensitive life-stage group DRL for I-131 was derived by calculating the concentration of I-131 which yields a 100 mrem dose for each age group. In this case the resulting concentrations were: fetus (2,500 pCi/L), breastfed infants (~~2,110~~820 pCi/L), infants (2,100 pCi/L), 1 ~~yr~~year (1,~~860~~900 pCi/L), 5 ~~yr~~years (1,~~310~~300 pCi/L), 10 ~~yr (1,950~~years (2,000 pCi/L), and 15 ~~yr~~years (2,~~410~~400 pCi/L). Since the lowest calculated concentration ~~corresponds to~~is that of the ~~5-year old (1,310~~breastfed infant (820 pCi/L), this value is the DRL that will be applied to be the most protective for the entire sensitive life-stage group.

Calculation of Default DRLs

DRLs may be calculated with the help of the following equations.

The dose (mrem or Sv) due to the ingestion of radionuclide *i* to age group *a* over time period *T* is calculated as follows:

$$D_{iaT} = I_{iaT} \times DCF_{ia}$$

Where:

D_{iaT} = Dose (in mrem or Sv) due to the ingestion of radionuclide *i* to age group *a* over time period *T*.

I_{iaT} = The total intake of radionuclide *i* for age group *a* (in pCi or Bq) over time period *T*.

DCF_{ia} = The dose conversion factor (also referred to as dose coefficient) for the ingestion of radionuclide *i* in drinking water and age group *a* (in mrem/pCi or Sv/pCi, or mrem/Bq or Sv/Bq). See ~~section 7.4~~below for guidance on dose conversion factors (DCFs~~.~~).

The quantity of radionuclide *i* ingested by age group *a* over a given time period, *T*, is calculated as follows.

$$I_{iaT} = C_i \times Ing_a \times T$$

Where:

I_{iaT} = The total intake of radionuclide *i* for age group *a* (in pCi or Bq) over time period *T*.

C_i = The concentration of radionuclide *i* in drinking water (in pCi/L or Bq/L). A simplifying assumption is made that the concentration of the radionuclide is constant over the time period *T*.

Ing_a = The daily ingestion rate of water for age group *a*, in L/day. ~~See Section 7.3~~See below for guidance on daily water ingestion rates.

T = The time period that the population is drinking contaminated water (days). In this analysis, the time period of interest for fetus exposure is 280 days, for all other age groups the exposure timeframe is 365 days.

For each age group *a* and radionuclide *i*, substituting the applicable PAG for the dose D_{iaT} and then solving for C_i yields the applicable DRL.

For example, the DRL for iodine-131 for an adult is calculated as follows:

$$DRL = PAG / (Ing_a * T * DCF_{ia})$$

$$DRL = 500 \text{ mrem} / (1.643 \text{ L/day} * 365 \text{ days} * 8.05 \text{ E-05 mrem/pCi})$$

$$= 500/4.83 \text{ E-02}$$

$$= 10{,}352 \text{ pCi/L}$$

Which is ~~best~~ rounded to 10,~~350~~000 pCi/L ~~considering~~(two significant figures) in consideration of the uncertainties involved.

Combining Default DRLs for Multiple Radionuclides

If multiple radionuclides are present in the water supply, ~~then it is recommended that~~ the ~~obtained~~measured concentrations of each radionuclide should be divided by the provided DRL values~~.~~ ~~This provides~~ and summed. Each quotient represents a fraction of the allowed concentration (~~and~~ the ~~projected dose) for each~~ radionuclide~~.~~-specific DRL) and the permissible dose (the PAG). If the sum of the fractions is less than 1, the total dose ~~is assumed to be below~~does not exceed the PAG ~~values~~value. Emergency response personnel may need to calculate the sum of fractions on an ongoing basis, as the concentrations of individual radionuclides may change over time.

The sum of the fractions is expressed as follows:

$$F = \sum (C_i / DRL_i)$$

Where:

F = sum of the fractions

C_i = the concentration of radionuclide *i* in the water supply (pCi/L or Bq/L)

$DRL_{i\ (100 \text{ or } 500 \text{ mrem});}$ = derived response level for the i^{th} radionuclide (pCi/L or Bq/L)

For example, if Sr-90/Y-90 and Cs-137 are the only radionuclides present in the drinking water, and Sr-90/Y-90 are present at ~~1,540~~900 pCi/L and Cs-137 is present at ~~10,600~~4,500 pCi/L, the combined dose exceeds the PAG of 100 mrem for fetuses, infants, and children:

$$F = \sum (C_i / DRL_i)$$

$$= (\cancel{1{,}540}900 \text{ pCi/L} / 1{,}000 \text{ pCi/L}) + (\cancel{10{,}600}4{,}500 \text{ pCi/L} / 6{,}\cancel{140}200 \text{ pCi/L})$$

$$= \cancel{1.54 + 1}0.90 + 0.73$$

$= \cancel{3.27}1.63$

$\cancel{3.27}1.63 > 1$, so the PAG is exceeded.

The same concentrations do not exceed the PAG of 500 mrem for ~~adults~~the general population:

$$F = \sum (C_i / DRL_i)$$

$$= (\cancel{1,540}900 \text{ pCi/L} / 7,\cancel{415}400 \text{ pCi/L}) + (\cancel{10,600}4,500 \text{ pCi/L} / \cancel{16,570}17,000 \text{ pCi/L})$$

~~= 0.21 + 0.64~~

$= 0.\cancel{85}$

$12 + 0.\cancel{85}26$

$= 0.38$

$0.38 < 1$, so the PAG is not exceeded.

Water Ingestion Rates

~~Table 2~~Table 4-4 presents mean values for tap water consumption taken from the CD supplement to ~~FGR-~~Federal Guidance Report #13~~.~~ (EPA 1999).[41] Other sources of estimated drinking water ingestion rates are available (e.g., EPA's Exposure Factors Handbook[42]), but the ingestion rates presented in ~~FGR-13~~Federal Guidance Report #13 (EPA 1999) were specifically designed with corresponding age ranges to be used in conjunction with other data from ~~FGR-13.~~Federal Guidance Report #13 (EPA 1999). Values are provided for males and females in various age groups. Since the ingestion rates for males are higher (and therefore more conservative) than those for females, EPA elected to use the intake values for males to represent each age group in the calculation of DRLs in ~~Table 1.~~Table 4-3. In addition, for the calculation of the DRLs for the pregnant women (fetus), nursing women (breastfed infant) and adult ~~DRL~~, EPA made the conservative ~~assumption that the~~choice of assigning the drinking water ingestion rate ~~would be assigned the highest value~~ within the adult category~~, the 50 year old male~~, at an estimated 1.643 L/day.

~~**Table 2. Mean Drinking Water Ingestion Rates from FGR-13**~~

Table 4-4. Mean Drinking Water Ingestion Rates from Federal Guidance Report #13

Age (years)	Tap Water (L/day)	
	Male	**Female**
0	0.191	0.188
1	0.223	0.216
5	0.542	0.499
10	0.725	0.649

[41] EPA.~~ 2002b.~~ Federal Guidance Report 13. Cancer Risk Coefficients for Environmental Exposure to Radionuclides: CD Supplement, EPA-402-C-99-001, Rev. 1~~.~~ (2002).
[42] ~~EPA. 2011a.~~ EPA. Exposure Factors Handbook: 2011 Edition. EPA 600-R-09-052F (2011). https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252.

15	0.900	0.712
20	1.137	0.754
50	1.643	1.119
75	1.564	1.179

~~Source: CD Supplement to FGR-13, Table 3.1.~~

Source: CD Supplement to Federal Guidance Report #13 (EPA 1999), Table 3.1.

Dose Coefficients, or Dose Conversion Factors (DCF) (Sv/Bq Ingested)

The effective whole body dose per Bq ingested of various radionuclides in water, for various age groups, can be found on the CD supplement to ~~FGR-~~Federal Guidance Report #13~~.~~[43] (EPA 1999). These DCF values apply to both males and females. ~~Table 3~~In addition, DCFs used to calculate DRLs for the fetus[44] and the breastfed infant[45] are taken from ICRP Publications 88 and 95 respectively. Table 4-5 presents DCFs for a few representative radionuclides of interest, converted to U.S. units for convenience.

~~**Table 3. Dose Conversion Factors**~~[46]

Table 4-5. Dose Conversion Factors[47]

Age	DCFs (mrem per pCi ingested), from ~~FGR-~~Federal Guidance Report #13 (EPA 1999)			
	Sr-90	**Y-90**	**Cs-137**	**I-131**
Infant (100 day old)	8.40E-04	1.16E-04	7.79E-05	6.82E-04
1 year old	2.68E-04	7.41E-05	4.58E-05	6.62E-04
5 year old	1.73E-04	3.69E-05	3.58E-05	3.83E-04
10 year old	2.21E-04	2.18E-05	3.75E-05	1.94E-04
15 year old	2.92E-04	1.24E-05	4.95E-05	1.27E-04
Adult	1.02E-04	9.94E-06	5.02E-05	8.05E-05

~~Source: CD Supplement to FGR-13.~~

Source: CD Supplement to Federal Guidance Report #13 (EPA 1999).

~~43 EPA. 2002~~

44 International Commission on Radiation Protection (ICRP) Publication 88, *Doses to the Embryo and Fetus from Intakes of Radionuclides by the Mother*

45 International Commission on Radiation Protection (ICRP) Publication 95, *Doses to Infants from Ingestion of Radionuclides in Mother's Milk*

~~46 The DCFs in this table show the variation across age groups and nuclides and are provided to illustrate the conservative methodology and assumptions EPA believes are adequate to provide a reasonable level of protection to sensitive populations. Additional information including updated dose conversion factors, calculation methodologies as well as other comprehensive information regarding DRL development will be appended to the FRMAC Assessment Manual.~~

47 The DCFs in this table show the variation across age groups and nuclides and are provided to illustrate the conservative methodology and assumptions EPA believes are adequate to provide a reasonable level of protection to sensitive populations. Additional information including updated dose conversion factors, calculation methodologies and other comprehensive information regarding DRL development, will be appended to the FRMAC Assessment Manual.