Chapter 4: Environmental Monitoring Programs – Air

CHAPTER 4

An estimated total of 357 Ci (1.32×10^{13} Bq) of radioactivity, primarily in the form of short-lived noble gas isotopes, was released as airborne effluents from Idaho National Laboratory (INL) Site facilities in 2022. The highest contributors to the total release were the Materials and Fuel Complex (MFC) at 73.7%, the Radioactive Waste Management Complex (RWMC) at 13.5%, the Radiological Response Training Range (RRTR) at 9.31%, and the Advanced Test Reactor (ATR) Complex at 2.78%. Other INL Site facilities contributed less than 0.67% per facility to the total. The estimated maximum potential dose to a member of the public from all INL Site air emissions (0.018 mrem/yr) is below the regulatory standard of 10 mrem/yr (see Chapter 8 for details).

The INL Site environmental surveillance programs emphasize measurements of airborne contaminants in the environment because air is the most important transport pathway from the INL Site to receptors living outside the INL Site boundary. Because of this pathway, samples of airborne particulates, atmospheric moisture, and precipitation were collected onsite, at INL Site boundary locations, and at offsite communities. These samples were analyzed for radioactivity in 2022.

Particulates were filtered from the air using a network of low-volume air samplers, and the filters were analyzed for gross alpha activity, gross beta activity, and specific radionuclides—primarily cesium-137, americium-241, plutonium-239/240, plutonium-238, uranium-234, uranium-238, zinc-65, and strontium-90. Results were compared to detection levels, background measurements, historical results, and radionuclide-specific Derived Concentration Standards (DCSs) established by the U.S. Department of Energy (DOE) to protect human health and the environment. Gross alpha and gross beta activities were used primarily for trend analyses, which indicated fluctuations were observable that correlate with seasonal variations in natural radioactivity.

Specific gamma-emitting (primarily cesium-137) radionuclides were not detected by the INL contractor during 2022. Strontium-90 was detected in six quarterly composited samples during 2022. Plutonium-239/240 and americium-241 were detected in a quarterly composited samples collected during the fourth quarter. All concentrations were within historical measurements made during the past ten years (2012-2021) and well below the DCSs for these radionuclides. Plutonium-238 was not detected in any quarterly composite samples during 2022.

Airborne particulates were also collected biweekly around the perimeters of the Subsurface Disposal Area (SDA) at the RWMC and the Idaho Comprehensive Environmental Response, Compensation, and Liability Act Disposal Facility at the Idaho Nuclear Technology and Engineering Center (INTEC). Gross alpha and gross beta activities measured on the filters were comparable with historical results, and no new trends were identified in 2022. Americium and plutonium isotopes were detected within levels measured in previous years. The results were three to four orders below the DCS values established for those radionuclides.

Atmospheric moisture and precipitation samples were analyzed for tritium. Tritium was detected in some samples and was most likely from natural production in the atmosphere rather than INL Site releases. All measured results were below health-based regulatory limits.

4. ENVIRONMENTAL MONITORING PROGRAMS – AIR

Although all INL Site facilities are carefully managed and controlled the potential exists to release radioactive and nonradioactive hazardous constituents in amounts above regulatory limits during an operational upset or emergency incident situation. In such an event, pathway vectors, such as air, soil, plants, animals, and groundwater, may transport these constituents to nearby populations. Figure 4-1 is a conceptual model showing potential routes of exposure for these potential releases. Reviews of historical environmental data and environmental transport modeling indicate that air is a key pathway from INL Site releases to members of the general public. The ambient air monitoring network operates constantly and is a critical component of the INL Site's environmental monitoring programs. It monitors for routine and unforeseen releases, provides verification that the INL Site complies with regulatory standards and limits, and can be used to assess impact to the environment over time.

This chapter presents results of radiological analyses of airborne effluents and ambient air samples collected on and off the INL Site. The results include those from the INL and the Idaho Cleanup Project (ICP) contractors. Table 4-1 summarizes the radiological air monitoring activities relative to INL's major radiological sources as well as the minor onsite and offsite radiological sources. Details may be found in the INL Site Environmental Monitoring Plan (DOE-ID 2021).

4.1 Organization of Air Monitoring Programs

The INL and ICP contractors document airborne radiological effluents at all INL Site facilities in an annual report prepared in accordance with the 40 CFR 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities." Section 4.2 summarizes the emissions reported in *National Emission Standards for Hazardous Air Pollutants—Calendar Year 2022 INL Report for Radionuclides* (DOE-ID 2023), referred to hereafter as the National Emission Standards for Hazardous Air Pollutants (NESHAP) Report. The report also documents the estimated potential dose received by the general public due to INL Site activities.

Ambient air monitoring is conducted by the INL and ICP contractors to ensure that the INL Site remains in compliance with DOE O 458.1, "Radiation Protection of the Public and the Environment."

The INL contractor collects air samples primarily around the INL Site encompassing a region of 23,390 km^2 (9,000 mi^2) that extends to Jackson, Wyoming, as observed in Figure 4-2. In 2022, the INL contractor collected approximately 2,200 air samples (including duplicate samples and blanks) for various radionuclide analyses. The INL contractor collected air moisture at eight locations and precipitation samples at four locations for tritium analysis.

The ICP contractor collects air samples primarily on the INL Site at Low-Level Waste disposal facilities subject to DOE O 435.1, "Radioactive Waste Management," and downwind of facilities subject to an U.S. Environmental Protection Agency (EPA)-approved alternative for the NESHAP air monitoring method in accordance with 40 CFR 61.93(g). In 2022, the ICP contractor collected approximately 280 air samples (including duplicate samples) for various radionuclide analyses. While the INL contractor, being the operations and maintenance contractor for the INL Site, maintains a large network of onsite and offsite receptors, the ICP contractor's monitoring network is configured to identify potential releases from specific ICP facilities.

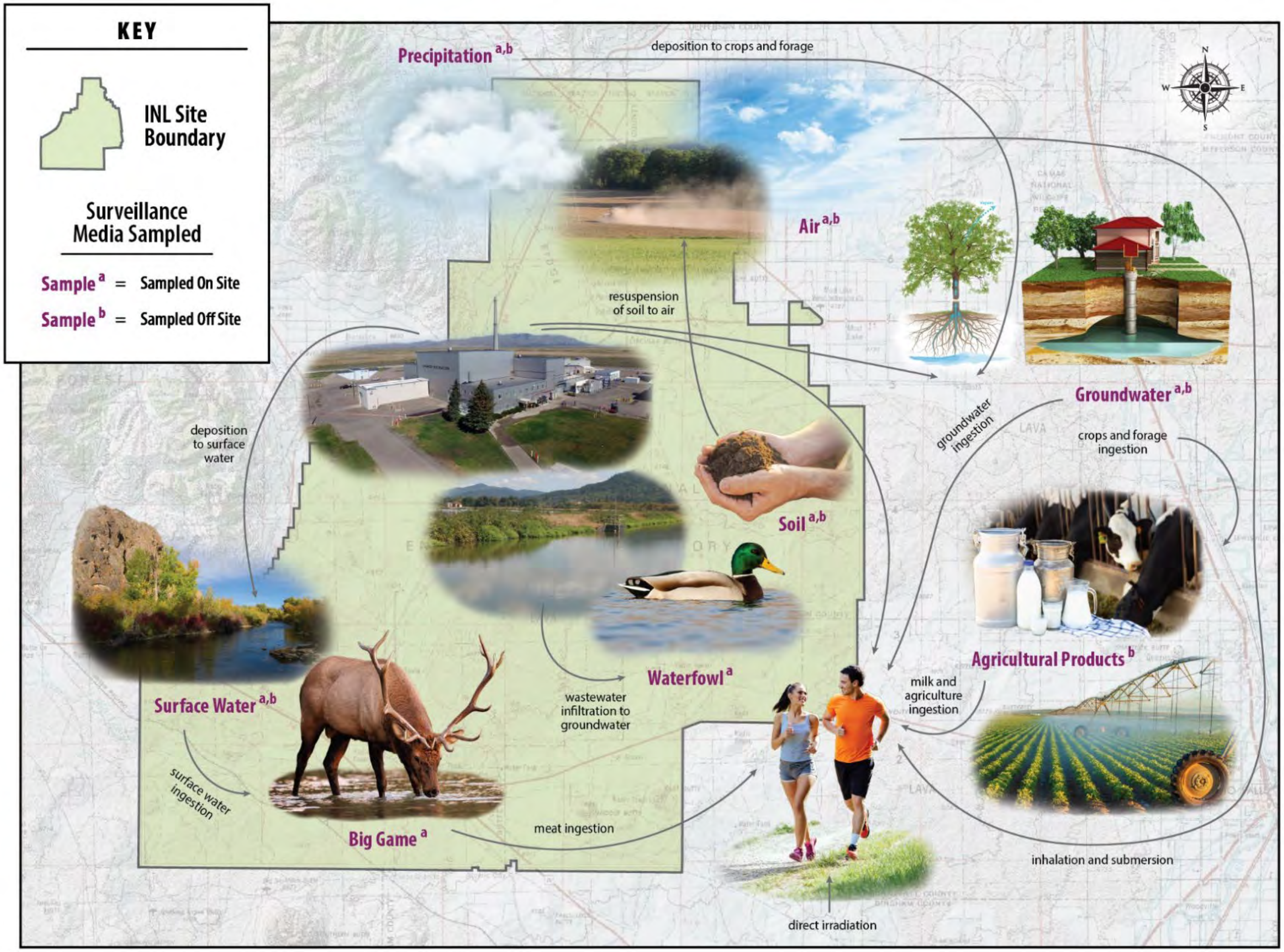


Figure 4-1. INL Site conceptual model.

Table 4-1. Radiological air monitoring activities by organization.

	AIRBORNE EFFLUENT MONITORING PROGRAMS	ENVIRONMENTAL SURVEILLANCE PROGRAMS					
AREA/FACILITY[a]	AIRBORNE EFFLUENTS[b]	LOW-VOLUME CHARCOAL CARTRIDGES (^{131}I)	LOW-VOLUME GROSS ALPHA	LOW-VOLUME GROSS BETA	SPECIFIC RADIONUCLIDES[c]	ATMOSPHERIC MOISTURE	PRECIPITATION
ICP CONTRACTOR[d]							
INTEC	●		●	●	●		
RWMC	●		●	●	●		
INL CONTRACTOR[e]							
MFC	●						
INL Site/Regional		●	●	●	●	●	●

a. ICP = Idaho Cleanup Project, INL = Idaho National Laboratory, INTEC = Idaho Nuclear Technology and Engineering Center, RWMC = Radioactive Waste Management Complex, MFC = Materials and Fuels Complex.

b. Facilities that required monitoring during 2022 for compliance with 40 CFR 61, Subpart H, “National Emissions Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities.”

c. Gamma-emitting radionuclides are measured by the ICP contractor monthly and by the INL contractor quarterly. Cesium-137, americium-241, plutonium-239/240, plutonium-238, uranium-234, uranium-238, zinc-65 and strontium-90 are measured by the INL and ICP contractors quarterly.

d. The ICP contractor monitors waste management facilities to demonstrate compliance with DOE O 435.1, “Radioactive Waste Management.” A combination of continuous monitoring and ambient air sampling are used to demonstrate compliance with 40 CFR 61, Subpart H.

e. The INL contractor monitors airborne effluents at MFC and also collects samples onsite, around, and offsite from the INL Site to demonstrate compliance with DOE O 458.1, “Radiation Protection of the Public and the Environment”.

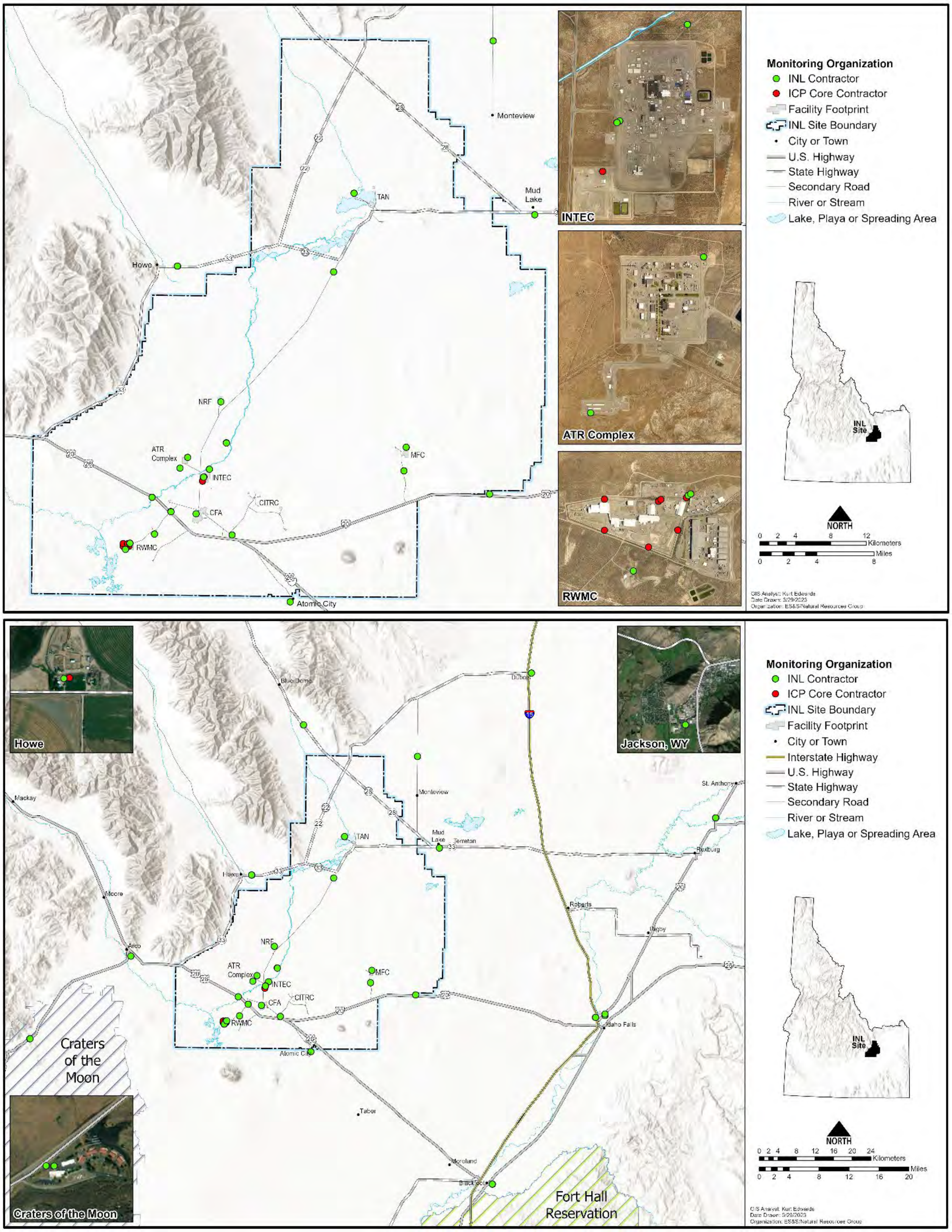


Figure 4-2. INL Site environmental surveillance radiological air sampling locations (regional [top] and onsite [bottom]).

The ICP contractor monitors air around waste management facilities to comply with DOE O 435.1, "Radioactive Waste Management." These facilities are the SDA at the RWMC and the Idaho Comprehensive Environmental Response, Compensation, and Liability Act Disposal Facility (ICDF) near the INTEC. These locations are shown in Figure 4-2. Section 4.4 discusses air sampling the ICP contractor performs in support of waste management activities. In 2022, the ICP contractor collected approximately 200 air samples (including duplicate samples) for various radiological analyses.

The National Oceanic and Atmospheric Administration (NOAA) has collected meteorological data at the INL Site since 1950. The data have historically been tabulated, summarized, and reported in several climatography reports and used by scientists to evaluate atmospheric transport and dispersion. The latest report, *Climatography of the Idaho National Laboratory*, 4th Edition (Clawson et al. 2018), was prepared by the NOAA Field Research Division (since renamed the Special Operations and Research Division) of the Air Resources Laboratory and presents over 20 years (1994–2015) of quality-controlled data from the NOAA INL mesonet meteorological monitoring network (https://niwc.noaa.inl.gov/climate/INL_Climate4th_Final2.pdf). More recent data are provided by the Special Operations and Research Division to scientists modeling the dispersion of INL Site releases (see Chapter 8 in this annual report and *Meteorological Monitoring*, a supplement to this annual report).

4.2 Airborne Effluent Monitoring

Each regulated INL Site facility determines airborne effluent concentrations from its regulated emission sources as required under state and federal regulations. Radiological air emissions from INL Site facilities are also used to estimate the potential dose to a hypothetical maximally exposed individual (MEI), who is a member of the public (see Chapter 8 of this report). Radiological effluents and the resulting potential dose for 2022 are reported in the NESHAP Modeling Report (INL 2023) and the NESHAP Report (DOE-ID 2023a).

The NESHAP Report includes three categories of airborne emissions:

- Sources that require continuous monitoring under the NESHAP regulation are primarily the stacks at the Materials and Fuels Complex (MFC), the Advanced Mixed Waste Treatment Project, and INTEC
- Releases from all other point sources (stacks and exhaust vents)
- Nonpoint—or diffuse—sources, otherwise referred to as fugitive sources, which include radioactive waste ponds, buried waste, contaminated soil areas, radiological test ranges, and decontamination and decommissioning operations.

INL Site emissions include all three airborne emission categories and are summarized in Table 4-2. The radionuclides included in this table were selected because they contribute 99.9% of the cumulative dose to the MEI estimated for each facility area. During 2022, an estimated 357 Ci (1.32×10^{13} Bq) of radioactivity was released to the atmosphere from all INL Site sources. The 2022 release is 67% lower than the estimated total of 1,076 Ci (3.98×10^{13} Bq) released in 2021. The reduction is primarily the result of the ATR shutdown during most of 2022 for refurbishment of the reactor core.

The following facilities were major contributors to the total emissions, as observed in Figure 4-3:

- ***MFC Emissions Sources (73.7% of total INL Site source term).*** Radiological air emissions are primarily associated with spent fuel treatment at the Fuel Conditioning Facility, waste characterization and fuel research development at the Hot Fuel Examination Facility, fuel research and development at the Fuel Manufacturing Facility, and post-irradiation examination at the Irradiated Materials Characterization Laboratory. To satisfy the requirements of 40 CFR 61 Subpart H, stack filters from the effluent streams of these four facilities are sampled and analyzed for particulate radionuclides on a regular basis because of their potential to discharge radionuclides into the air in quantities that could cause an effective dose of more than 1% of the standard. Other effluent streams with a smaller potential dose (less than 1% of the standard) such as the Transient Reactor Test Facility, are sampled and analyzed periodically to confirm the lower emissions. Gaseous and particulate radionuclides may also be released from other MFC facilities during laboratory research activities, sample analysis, waste handling and storage, and maintenance operations. While the ATR Complex is generally the greatest emissions contributor at the INL Site, the shutdown of its reactor during the core internal changeout operations resulted in reduced emissions reported from ATR. This reduction resulted in MFC being the greatest relative emissions contributor, however the actual amount in curies is still significantly lower than average ATR estimated annual emissions. While ATR emissions dropped from 827 Ci to 9.92 Ci in 2022, MFC emissions grew slightly from 188 Ci to 263 Ci from 2021 to 2022. Since overall emissions are down in 2022, the 263 Ci from MFC accounts for 73.74% of all estimated emissions.

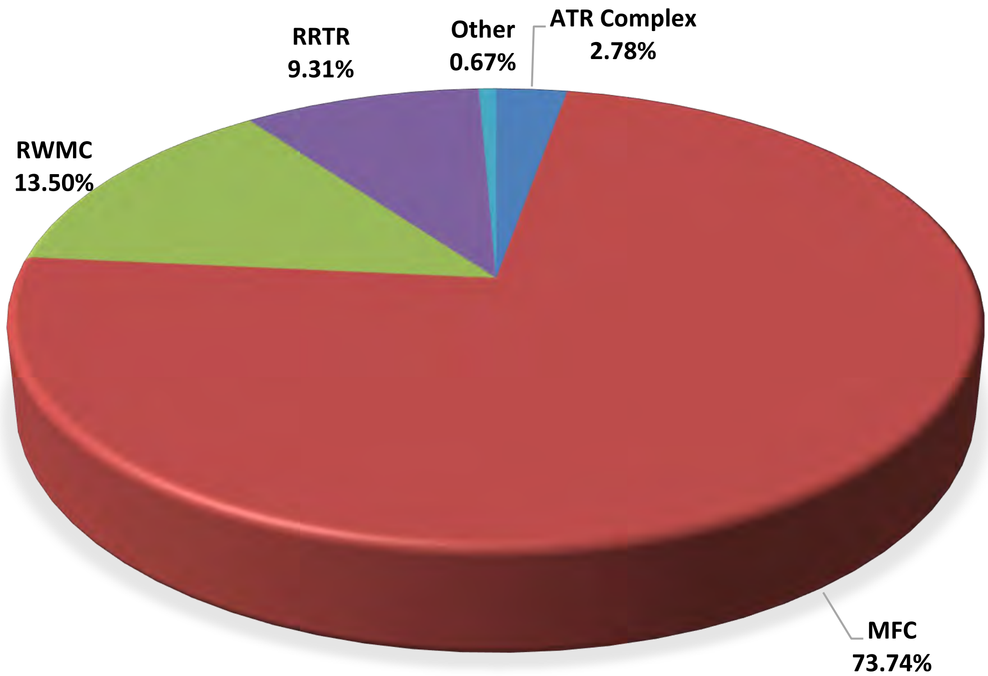


Figure 4-3. Percent contributions in Ci, by facility, to total INL Site airborne radiological releases (2022).

- ***RWMC Emissions Sources (13.5% of total INL Site source term).*** Emissions at RWMC result from various activities associated with the facility's mission to complete environmental cleanup of the area, as well as to store, characterize, and treat contact-handled transuranic waste and mixed low-level waste prior to shipment to offsite licensed disposal facilities. Various projects are being conducted to achieve these objectives: waste retrieval activities at the Accelerated Retrieval Projects (ARPs), operation of the Resource Conservation and Recovery Act permitted Sludge Repackage waste processing project, storage of waste within the Type II storage modules at Advanced Mixed Waste Treatment Project, storage and characterization of waste at the Drum Vent and Characterization facilities, storage of wastes at the Transuranic Storage Area-Retrieval Enclosure (WMF-636), and treatment of wastes at the Advanced Mixed Waste Treatment Facility (WMF-676). Data from 13 emission sources (both point and diffuse) at RWMC were reported in the 2022 NESHAP Report for Radionuclides (DOE-ID 2023), including three continuously monitored point sources. WMF-676 has two continuously monitored stacks, while WMF-636 had one continuously monitored stack, for which monitoring was ceased during 2022. Radionuclide emissions monitoring from the Comprehensive Environmental Response, Compensation, and Liability Act ARP facilities and the two Resource Conservation and Recovery Act facilities (WMF-1617 and WMF-1619) is achieved with the EPA-approved ambient air monitoring program, which has been in place since 2008. Radiological emissions at RWMC include tritium and carbon-14 associated with buried beryllium blocks at the SDA. Transuranic radionuclides releases from ARP facilities, including americium-241 (^{241}Am), plutonium-238 (^{238}Pu), plutonium-239/240 ($^{239/240}$Pu), and plutonium-241 (^{241}Pu) have declined in recent years as waste exhumation and processing activities progress to completion.
- ***RRTR Emissions Sources (9.3% of total INL Site source term).*** The north RRTR is located 1.6 km (1 mile) NNE of SMC and began operations in July 2011 to support federal agencies responsible for the nuclear forensics mission. These sites are used to train personnel, test sensors, and develop detection capabilities (both aerial and ground-based) under a variety of scenarios in which radioactive materials are used to create a radioactive field for training in activities such as contamination control, site characterization, and field sample collection activities. Previously,

emissions from RRTR were reported in combination with emissions from SMC. As described in INL/RPT-23-72759, *Update of Receptor Locations for INL NESHAP Assessments* (INL 2023b), a number of facilities that were once modeled as collocated emission sources are now modeled as separate sources, resulting in a more realistic modeling scenario. Estimated emissions from RRTR were greater in 2022 (33.2 Ci) compared to 2021 (10.6 Ci) due primarily to use of a new source (pellets containing Cu-64). Although the increase in emissions from RRTR was moderate in 2022, RRTR emissions as a percentage of total INL Site emissions increased due to the reduced emissions reported from ATR.

- ***ATR Complex Emissions Sources (2.78% of total INL Site source term).*** Radiological air emissions from the ATR Complex are primarily associated with the operation of the ATR. These emissions include noble gases, radioiodine, and other mixed fission and activation products. Other radiological air emissions are associated with sample analysis, site remediation, and research and development activities. The INL Radioanalytical Chemistry Laboratory, which has been in operation since 2011, is another emission source at the ATR Complex. Activities at the lab include inorganic, general purpose analytical chemistry, and wet chemical analysis for trace and high-level radionuclide determination. The laboratory contains high-efficiency particulate air-filtered hoods that are used for the analysis of contaminated samples. There are no sources at the ATR Complex that require continuous emissions monitoring due to the low dose contribution (see Section 8.2). On a regular basis, the ATR effluent stream is sampled and analyzed for particulate, radioiodine, and noble gas radionuclides. Effluent from the Safety and Tritium Applied Research Facility (TRA-666) is sampled and analyzed for tritium.

- ***INTEC Emissions Sources (0.37% of total INL Site source term).*** Radiological air emissions at INTEC are primarily from the operation of the ICDF landfill and ponds (located outside the fenced boundary of INTEC) and storage and containment of the Three Mile Island Unit 2 (TMI-2) core debris within the Independent Spent Fuel Storage Installation (CPP-1774), which is licensed under the U.S. Nuclear Regulatory Commission (NRC). These sources contribute gaseous radionuclides, including tritium, iodine-129, and krypton-85, with contributions of particulate radionuclides cesium-137 (^{137}Cs) and ^{90}Sr from ICDF. INTEC has one stack continuously monitored for radionuclide emissions (resulting from Waste Management activities) located outside of CPP-666. Additional sources include the INTEC Main Stack (CPP-708), which emits gaseous and particulate radionuclides associated with liquid waste operations, including effluents from the Tank Farm Facility, Process Equipment Waste Evaporator, and Liquid Effluent Treatment and Disposal facility. Other radioactive emissions are associated with remote-handled transuranic and mixed-waste management operations, dry storage of spent nuclear fuel, and maintenance and servicing of contaminated equipment.

- ***Central Facilities Area (CFA) Emissions Sources (0.20% of total INL Site source term).*** Minor emissions occur from CFA where work with small quantities of radioactive materials is routinely conducted. This includes sample preparation and verification and radiochemical research and development. Other minor emissions result from groundwater usage via evapotranspiration from irrigation or evaporation from sewage lagoons.

- ***Test Area North Emissions Sources (0.004% of total INL Site source term).*** Emissions sources at Test Area North are primarily from the New Pump and Treat Facility, which serves to reduce concentrations of trichloroethylene and other volatile organic compounds in the medial zone portion of the OU 1-07B contamination groundwater plume to below drinking water standards. Low levels of strontium-90 (^{90}Sr) and tritium are present in the treated water from the New Pump and Treat Facility and are released to the atmosphere by the treatment process.

- ***Specific Manufacturing Capability (SMC) Emissions Sources (0.000000038% of total INL Site source term).*** Operations at SMC include material development, fabrication, and assembly work to produce armor packages. The operation uses standard metal-working equipment in fabrication and assembly. Other activities include developing tools and fixtures and preparing and testing metallurgical specimens. Radiological air emissions from SMC are associated with processing depleted uranium. Potential emissions are uranium isotopes and associated radioactive progeny.

- ***Critical Infrastructure Test Range Complex (CITRC) Emissions Sources (0.000000013% of total INL Site source term).*** Emissions from CITRC are primarily the result of activity related to National and Homeland Security missions. Activities at CITRC include program and project testing for critical infrastructure resilience, nonproliferation, wireless test bed operations, power line and grid testing, unmanned aerial vehicles, explosives detection, and training radiological counter-terrorism emergency response. Radionuclide releases from CITRC were less in 2022 due to the curtailment of some activities because of COVID-19.

The estimated radionuclide releases (Ci/yr) from INL Site facilities, shown in Table 4-2, were used to calculate the dose to the hypothetical MEI member of the public, who is assumed to reside near the INL Site perimeter. To calculate dose to the MEI, radionuclides with very short half-lives must be converted to the first progeny with a suitable half-life for modeling. The estimated emissions are then scaled based on the difference in activity between the parent and progeny. The estimated dose to the MEI in calendar year 2022 was 0.018 mrem/yr (0.18 μSv/yr) which is below the regulatory standard of 10 mrem/yr. Seven radionuclides—uranium-238 (^{238}U), chlorine-36 (^{36}Cl), uranium-234 (^{234}U), americium-241 (^{241}Am), strontium-90, (^{90}Sr), cesium-137 (^{137}Cs), and tritium (^{3}H)—are responsible for more than 90% of the MEI dose. Potential radiation doses to the public are discussed in more detail in Chapter 8 of this report.

4.2.1 Hydrofluorocarbon Phasedown

Hydrofluorocarbons (HFC) are the third generation of refrigerants; they were developed to replace Class II ozone depleting substances. HFCs are used in the same applications in which ozone-depleting substances have historically been used, such as refrigeration and air conditioning, foam blowing agents, solvents, aerosols, and fire suppression. HFCs are non-ozone-depleting; however, they are also potent greenhouse gases with 100-year global warming potentials (a measure of the relative climatic impact of greenhouse gases) that can be hundreds to thousands of times more potent than carbon dioxide.

Atmospheric observations of most currently measured HFCs confirm their amounts are increasing in the global atmosphere at accelerating rates. Total emissions of HFCs increased by 23% from 2012 to 2016. The four most abundant HFCs in the atmosphere—in global warming potential-weighted terms—are HFC-134a, HFC-125, HFC-23, and HFC-143a (Federal Register Volume 86, Number 95 published May 19, 2021). The American Innovation and Manufacturing Act of 2020 included reductions for the production and the consumption of HFCs.

Additionally, the INL contractor is participating in the voluntary HFC Task Team led by AU-21, National Nuclear Security Administration. The goal of the task team is to better understand and address DOE's needs and determine next steps. The HFC Task Team wrote an Operating Experience Summary for the DOE complex that provides information on operational impacts to critical systems from these regulations that will decrease the amount of HFCs manufactured in the future (OES-2022-03, HFC Phasedown Impacts Critical Operations. The task team is currently exploring methods for documenting and sharing the review of alternatives with the DOE complex. HFC phasedown proactive measures being taken by the INL Site contractors are listed below.

4.2.1.1 INL Contractor

The INL contractor compiled a list of equipment at its facilities that contains HFCs and completed an impact analysis to better understand the potential impacts of this HFC phasedown. This list was obtained from a variety of sources: facility/operations personnel, laboratory personnel, fire protection personnel, research and development organizations, engineer personnel, maintenance personnel, and environmental support and services personnel. The list includes heating, ventilation, and air conditioning systems that contain 50 pounds or more of refrigerant and computer room air conditioning units that contain 50 pounds or more of refrigerant, fire protection systems, and laboratory equipment. Most of the laboratory equipment that contained HFCs were chillers used to cool specific pieces of equipment. Other laboratory equipment that contains HFCs includes environmental chambers, a microwave digester, non-rad and rad separator ion sources, non-rad and rad separator magnets, and a laser flash. The list does not include small heating, ventilation, and air conditioning equipment (units containing less than 50 pounds of refrigerant), refrigerators, drinking water fountains, or other small appliances. The INL contractor manages thousands of these small appliances at the facilities; most would be operated until failure and then replaced. The INL contractor identified 236 pieces of equipment and systems.

4.2.1.2 ICP Contractor

An inventory of refrigeration equipment at ICP facilities, using HFCs scheduled for phasedown, was conducted in December 2021. This activity identified two chillers (four circuits total) using HFC-134a at the Integrated Waste Treatment Unit. The total charge for both chillers is approximately 830 lbs. These units will continue to be used for the

Table 4-2. Radionuclide composition of INL Site airborne effluents (2022).[a]

		AIRBORNE EFFLUENT (Ci)[b]										
RADIONUCLIDE[c]	HALF-LIFE[d]	ATR COMPLEX[e]	CFA[e]	CITRC[e]	INTEC[e]	MFC[e]	NRF[e]	RRTR[e]	RWMC[e]	SMC[e]	TAN[e]	TOTAL
Americium-241	432.2 y	2.21E-05	NS[f]	–[g]	5.79E-04	2.11E-03	–	–	1.03E-04	–	–	2.81E-03
Argon-41	1.827 h	NS	NS	–	–	8.19E+01	–	NS	–	–	–	8.19E+01
Bromine-82	1.471 d	–	NS	–	–	–	–	6.02E+00	–	–	–	6.02E+00
Carbon-14	5700 y	NS	NS	–	NS	–	3.20E-01	–	2.22E-02	–	–	3.42E-01
Cadmium-109	461.4 d	NS	NS	–	–	5.28E-03	–	NS	–	–	–	5.28E-03
Californium-252	966.1 d	–	–	–	–	5.00E-05	–	–	–	–	–	5.00E-05
Cesium-137	30.16 y	5.36E-03	NS	–	3.39E-04	3.55E-03	NS	–	NS	–	–	9.24E-03
Chlorine-36	3.01E+05 y	–	–	–	NS	7.17E-03	–	NS	–	–	–	7.17E-03
Copper-64	12.7 h	–	NS	–	–	–	–	2.70E+01	–	–	–	2.70E+01
Cobalt-60	5.271 y	6.31E-03	NS	–	NS	NS	–	–	NS	–	–	6.31E-03
Europium-152	13.53 y	6.78E-05	NS	–	NS	–	–	–	–	–	–	6.78E-05
Hydrogen-3	12.32 y	9.88E+00	5.39E-01	–	NS	3.82E-01	NS	–	4.81E+01	–	NS	5.89E+01
Iodine-129	1.57E+07 y	NS	NS	–	7.93E-05	4.94E-05	NS	–	–	–	–	1.29E-04
Iodine-131	192.5 h	NS	NS	–	–	8.93E-02	NS	–	–	–	–	8.93E-02
Krypton-85m	4.48 h	NS	NS	–	–	1.01E+01	–	–	–	–	–	1.01E+01
Krypton-87	76.3 m	NS	NS	–	–	1.06E+01	–	NS	–	–	–	1.06E+01
Krypton-88	2.84 h	NS	8.95E-03	–	–	9.63E+00	–	–	–	–	–	9.64E+00
Plutonium-238	87.7 y	NS	NS	–	6.32E-06	NS	–	–	NS	–	–	6.32E-06
Plutonium-239	24110 y	8.46E-06	NS	–	2.14E-04	NS	2.70E-06	–	3.75E-05	–	–	2.63E-04
Plutonium-240	6564 y	NS	NS	–	2.14E-04	NS	–	–	8.61E-06	–	–	2.23E-04
Strontium-90	28.79 y	2.75E-02	NS	–	2.99E-03	1.97E-03	5.50E-05	–	NS	–	3.01E-05	3.25E-02
Tellurium-129	69.6 m	–	NS	–	–	2.71E+01	–	–	–	–	–	2.71E+01
Tellurium-129m	33.6 d	–	NS	–	–	3.93E-02	–	–	–	–	–	3.93E-02
Uranium-234	2.45E+05 y	NS	NS	–	NS	4.32E-02	–	–	–	2.03E-08	–	4.32E-02
Uranium-235	7.04E+08 y	NS	NS	NS	NS	2.44E-03	–	–	NS	NS	–	2.44E-03
Uranium-238	4.46 E+09 y	NS	NS	8.71E-10	NS	5.98E-02	–	–	NS	1.13E-07	–	5.98E-02

Table 4-2. continued.

AIRBORNE EFFLUENT (Ci)[b]													
RADIONUCLIDE[c]	HALF-LIFE[d]	ATR COMPLEX[e]	CFA[e]	CITRC[e]	INTEC[e]	MFC[e]	NRF[e]	RRTR[e]	RWMC[e]	SMC[e]	TAN[e]	TOTAL
Xenon-135	9.14 h	NS	1.49E-01	–	–	NS	–	–	–	–	–	1.49E-01
Xenon-138	14.08 m	NS	NS	–	–	1.64E+01	–	–	–	–	–	1.64E+01
TOTAL CI RELEASED[h]		9.92E+00	6.97E-01	8.71E-10	4.42E-03	1.56E+02	3.20E-01	3.30E+01	4.81E+01	1.33E-07	3.01E-05	2.48E+02
DOSE (MREM)[i]		6.08E-04	3.13E-06	2.56E-11	2.77E-04	1.61E-02	4.58E-05	2.14E-04	6.12E-04	4.08E-09	1.23E-06	1.78E-02

a. Radionuclide release information provided by the INL contractor (INL 2023a).

b. One curie (Ci) = 3.7 × 10^{10} becquerels (Bq).

c. Includes only those radionuclides which collectively contribute 99.9% of the total dose to the MEI estimated for each INL Site facility. Other radionuclides not shown in this table account for less than 0.1% of the dose estimated for each facility.

d. Half-life units: m = minutes, h=hours, d = days, y = years.

e. ATR = Advanced Test Reactor, CFA = Central Facilities Area, CITRC = Critical Infrastructure Test Range Complex, INTEC = Idaho Nuclear Technology and Engineering Center, MFC = Materials and Fuels Complex, NRF = Naval Reactors Facility, RRTR = Radiological Response Training Range, RWMC = Radioactive Waste Management Complex (including Advanced Mixed Waste Treatment Project and Accelerated Retrieval Projects), TAN = Test Area North, SMC = Specific Manufacturing Capability.

f. NS = not significant. The radionuclide contribution was estimated to be < 0.1% of the total MEI dose from that facility.

g. A long dash signifies the radionuclide was not reported to be released to the air from the facility in 2022.

h. Total curies may be less than the total curies in Table 8-1 in Chapter 8 because Table 4-2 accounts only for radionuclides that collectively contribute 99.9% of the total dose to the MEI estimated for each INL Site facility. Total curies may be less than the originally reported amounts due to changes in total activity associated with conversion from short-lived radionuclides into progeny with half-lives long enough to be modeled, and for dose to be calculated.

i. The annual dose (mrem) for each facility was calculated at the location of the MEI using estimated radionuclide releases and methodology recommended by the Environmental Protection Agency. See Chapter 8 for details.

Integrated Waste Treatment Unit mission. ICP preventative maintenance practices will minimize the potential for leaks. ICP possesses an inventory of recovery cylinders dedicated to these units, ensuring that refrigerant recovered during maintenance is available to recharge the equipment. Should there be a major failure resulting in a loss of HFC-134a that renders the units inoperable, they would be replaced or retrofitted. New equipment at ICP will be specified to use refrigerants that are not subject to the HFC phasedown.

4.3 Ambient Air Monitoring

Ambient air monitoring is conducted onsite and offsite to identify regional and historical trends, to detect accidental and unplanned releases, and to determine if air concentrations are below DCSs established by DOE for inhaled air (DOE 2021). Each radionuclide-specific DCS corresponds to a dose of 100 mrem for continuous exposure during the year. The Clean Air Act NESHAP regulatory standard is 10 mrem/yr (0.1 mSv/yr) (40 CFR 61, Subpart H).

4.3.1 Ambient Air Monitoring System Design

Figure 4-2 shows the regional and INL Site routine air monitoring locations. A total of 38 low-volume air samplers (including four quality assurance samplers), one high-volume air sampler, eight atmospheric moisture samplers, and four precipitation samplers operated in the network in 2022, as shown in Table 4-3.

Historically, air samplers were positioned near INL Site facilities or sources of contamination, in predominant downwind directions from sources of radionuclide air emissions, at potential offsite receptor population centers, and at background locations. In 2015, the network was evaluated quantitatively, using atmospheric transport modeling and frequency of detection methods (Rood, Sondrup, and Ritter 2016). A Lagrangian Puff air dispersion model (CALPUFF) with three years of meteorological data was used to model atmospheric transport of radionuclides released from six major facilities and to predict air concentrations at each sampler location for a given release time and duration. Frequency of detection is defined as the fraction of events resulting in a detection at either a single sampler or network. The frequency of detection methodology allowed for an evaluation of short-term releases that included effects of short-term variability in meteorological conditions. Results showed the detection frequency was over 97.5% for the entire network considering all sources and radionuclides. Network intensity results (i.e., the fraction of samplers in the network that have a positive detection for a given event) ranged from 3.75% to 62.7%. An evaluation of individual samplers indicated some samplers were poorly located and added little to the overall effectiveness of the network. Using this information, some monitors were relocated to improve the performance of the network. In 2019, the frequency of detection method was used to evaluate the Idaho Falls facilities (INL 2019), which resulted in the installation of an additional monitor at the IRC.

Tritium is present in air moisture due to natural production in the atmosphere, the remnants of global fallout from historical nuclear weapons testing, and releases from INL Site facilities (Table 4-2). Historical emissions data show that most tritium is released from the ATR Complex, INTEC, and RWMC. Tritium enters the environment as tritiated water and behaves like water in the environment. The air monitoring network evaluation described in the previous paragraph was used to locate atmospheric moisture samplers. The Experimental Field Station (EFS) and Van Buren Boulevard samplers are located onsite and appear to be in or near the areas of the highest projected air concentration. Atomic City and Howe are Idaho communities located close to the INL Site boundary. Idaho Falls and Craters of the Moon are good offsite locations for measuring background concentrations because they do not appear to be impacted by modeled dispersion of tritium. Thus, one or two atmospheric moisture samplers are currently placed at each of the six locations: Atomic City, Craters of the Moon, EFS (two samplers), Howe, Idaho Falls (two samplers), and Van Buren Boulevard. Although there are more particulate air monitoring stations, additional atmospheric moisture and precipitation monitoring stations are not warranted because the estimated potential dose for INL Site releases is less than 0.1 mrem/yr, which is the recommended DOE limit for routine surveillance (DOE 2015). See Chapter 8 for additional information on dose.

Historical tritium concentrations in precipitation and atmospheric moisture samples collected by the INL contractor during the 10-year period from 2011 through 2021 were compared statistically; results indicate there are no differences between the datasets. For this reason, INL contractor precipitation samplers were placed at the same locations as the atmospheric moisture samplers at Atomic City, EFS, Howe, and Idaho Falls, Idaho. In addition, Idaho Falls can be easily and readily accessed by the INL contractor personnel after a precipitation event. The EPA has a precipitation sampler in Idaho Falls and subsamples are collected for the INL contractor.

To support emergency response, the INL contractor maintains 16 high-volume event air samplers at NOAA weather towers, as shown in Figure 4-4. These event monitors are only turned on as needed for sampling if an event occurs, such as a range fire or unplanned release of radioactivity.

Table 4-3. INL Site and regional ambient air monitoring summary (2022).

MEDIUM SAMPLED	TYPE OF ANALYSIS	FREQUENCY	NUMBER OF LOCATIONS		MDC
			ONSITE	OFFSITE	
Air (low volume)[a,b]	Gross alpha	Weekly	20	18	1E-15 µCi/mL
	Gross beta	Weekly	20	18	2E-15 µCi/mL
	Specific gamma[c]	Quarterly	20	18	2E-16 µCi/mL
	Plutonium-238	Quarterly	18-19	18	3.5E-18 µCi/mL
	Plutonium-239/240	Quarterly	18-19	18	3.5E-18 µCi/mL
	Americium-241	Quarterly	18-19	18	4.6E-18 µCi/mL
	Strontium-90	Quarterly	18-19	18	3.4E-17 µCi/mL
	Iodine-131	Weekly	20	18	1.5E-15 µCi/mL
Air (high volume)[d]	Gross beta scan	Biweekly	–	1	1E-15 µCi/mL
	Gamma scan	Continuous	–	1	Not applicable
	Specific gamma[c]	Annually[e]	–	1	1E-14 µCi/mL
	Isotopic Uranium & Plutonium	Every 4 yrs	–	1	2E-18 µCi/mL
Air (atmospheric moisture)[f]	Tritium	3–6/Quarter	3	5	2E-13 µCi/mL (air)
Air (precipitation)[g]	Tritium	Monthly	0	1	88 pCi/L
		Weekly	1	2	

a. Low volume air samplers are operated on the INL Site by the INL contractor at the following locations: ATR Complex (two air samplers), CFA, Experimental Breeder Reactor No. 1 (EBR-I), Experimental Field Station (EFS), Highway 26 Rest Area, INTEC (two air samplers), Gate 4, Main Gate, MFC (two air samplers), NRF, Power Burst Facility (PBF [sampling began at the end of September 2022]), RWMC (two air samplers), SMC, and Van Buren Boulevard. Additionally, there are rotating duplicate samplers for quality assurance. In 2022, the samplers were located at INTEC (westside), RWMC, and Van Buren Boulevard. This table does not include high volume 'event' monitoring by the INL contractor.

b. The INL contractor operates low volume samplers offsite at Arco, Atomic City, Blackfoot, Blue Dome, Craters of the Moon, Dubois, Federal Aviation Administration Tower, Howe, Idaho Falls, INL Research Center (IRC) (two air samplers), Jackson (WY), Monteview, Mud Lake, Sugar City, and Terreton (sampling began at the end of September 2022). In addition, there is a rotating duplicate sampler for quality assurance. In 2022, the sampler was placed in Dubois.

c. The minimum detectable concentration shown is for cesium-137.

d. The EPA RadNet stationary monitor at Idaho Falls runs 24 hours a day, seven days a week, and sends near-real-time measurements of gamma radiation to EPA's National Analytical Radiation Environmental Laboratory (NAREL). Filters are collected by INL personnel for the EPA RadNet program and sent to NAREL. Data are reported by the EPA's RadNet at http://www.epa.gov/radnet/radnet-databases-and-reports.

e. If gross beta activity is greater than 1 pCi/m^3, then a gamma scan is performed at NAREL. Otherwise, an annual composite is analyzed.

f. Atmospheric moisture samples are collected onsite at EFS and Van Buren Boulevard by the INL contractor. Samples are collected offsite at Atomic City, Craters of the Moon, Howe, and at Idaho Falls (two samplers) by the INL contractor.

g. Precipitation samples are currently collected onsite at EFS and offsite at Atomic City, Howe, and Idaho Falls (also used as the EPA RadNet precipitation location) by the INL contractor.

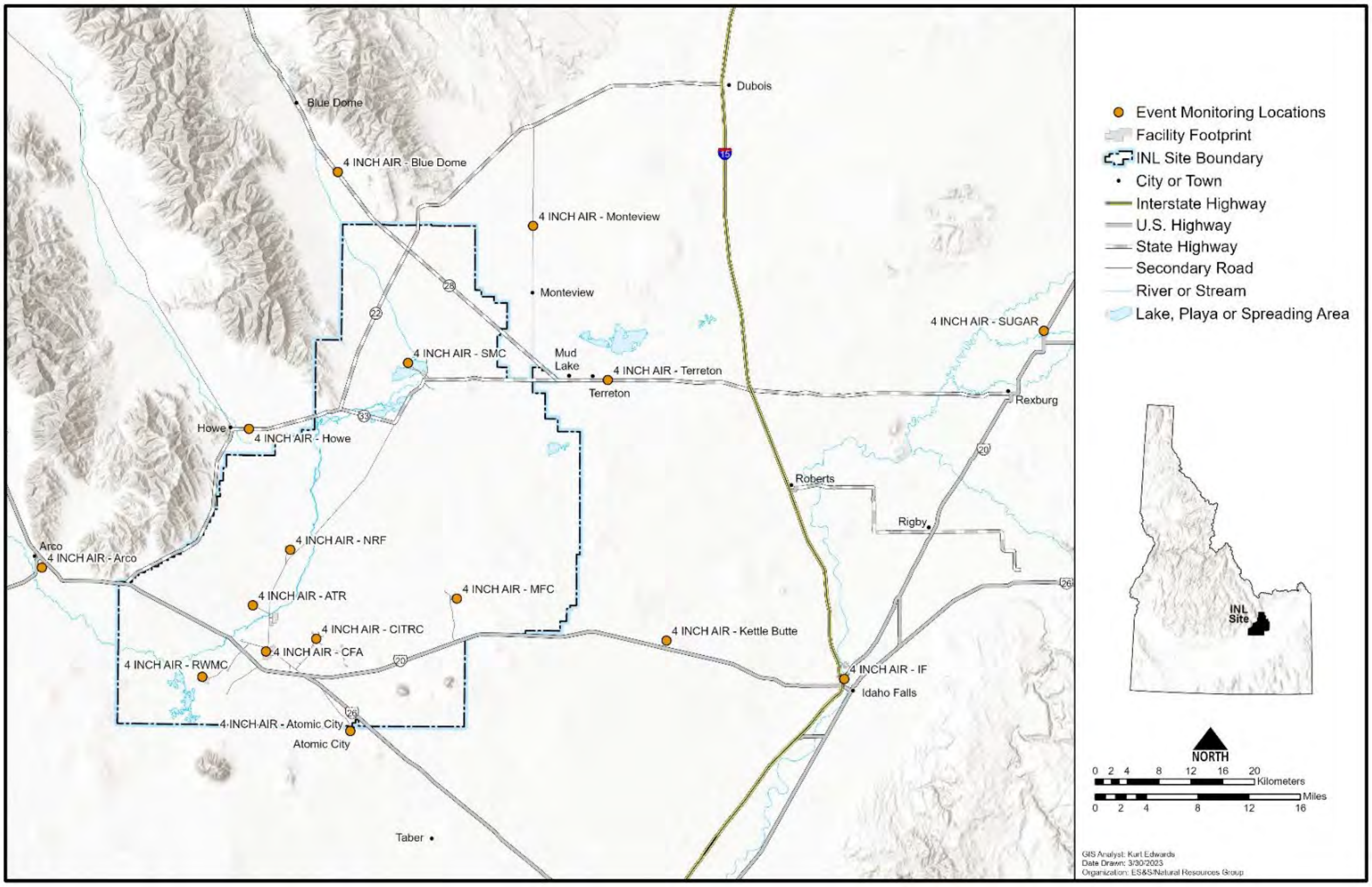


Figure 4-4. Locations of INL contractor high-volume event monitors at NOAA weather stations.

4.3.2 Air Particulate, Radioiodine, and Tritium Sampling Methods

4.3.2.1 Air Particulates

Filters are collected weekly by the INL contractor from a network of low-volume air samplers, as shown in Table 4-3. A pump pulls air (about 57 L/min [2 ft^3/min]) through a 5-cm (2-in.), 1.2-µm particulate filter and a charcoal cartridge at each low-volume air sampler. After a five-day holding time to allow for the decay of naturally occurring radon progeny, the filters are analyzed in a laboratory for gross alpha and gross beta activity. Gross alpha and gross beta results are considered screenings because specific radionuclides are not identified. Rather, the results reflect a mix of alpha- and beta-emitting radionuclides. Gross alpha and gross beta radioactivity in air samples is typically dominated by the presence of naturally occurring radionuclides. Gross beta radioactivity is, with rare exceptions, detected in each air filter collected. Gross alpha activity is only irregularly detected, but it becomes more commonly detected during wildfires and temperature inversions. If the results are higher than those typically observed, sources other than background radionuclides may be suspected, and other analytical techniques are used to identify specific radionuclides of concern. Gross alpha and gross beta activity are also examined over time and between locations to detect trends, which might indicate the need for more specific analyses.

The filters are composited quarterly for each location by the INL contractor for laboratory analysis of gamma-emitting radionuclides, such as ^{137}Cs, which is a man-made radionuclide present in soil both onsite and offsite due to historical INL Site activities and global fallout. The contaminated soil particles can become airborne and subsequently filtered by air samplers. Naturally occurring gamma-emitting radionuclides that are typically detected in air filters include beryllium-7 (^{7}Be) and potassium-40 (^{40}K).

The INL contractor also uses a contracted laboratory to radiochemically analyze quarterly composited samples for selected alpha- and beta-emitting radionuclides. These radionuclides include ^{241}Am, ^{238}Pu, $^{239/240}$Pu, ^{238}Pu, ^{234}U, ^{238}U, ^{65}Zn, and ^{90}Sr. They were selected for analysis because they have been detected historically in air samples and may be present due to site releases or to the resuspension of surface soil particles contaminated by INL Site activities or global fallout. INL contractor samples are analyzed on a rotating basis; each quarter five or six composites are selected for alpha spectrometry and five or six composites are selected for beta spectrometry.

4.3.2.2 Radioiodine

Charcoal cartridges are collected and analyzed weekly for iodine-131 (^{131}I) by the INL contractor at the locations shown in Table 4-3. Iodine-131 is of particular interest because it is produced in relatively large quantities by nuclear fission, is readily accumulated in human and animal thyroids, and has a half-life of eight days. This means that any elevated level of ^{131}I in the environment could be from a recent release of fission products.

4.3.2.3 Tritium

The INL contractor monitors tritium in atmospheric water vapor in ambient air onsite at EFS and Van Buren Boulevard and offsite at Atomic City, Howe, Craters of the Moon, and Idaho Falls. Air passes through a column of molecular sieve, which is a material that adsorbs water vapor. The molecular sieve is sent to a laboratory for analysis once the material has adsorbed sufficient moisture to obtain a sample. The laboratory extracts water from the material by distillation and determines tritium concentrations through liquid scintillation counting.

Precipitation samples are collected by the INL contractor at Atomic City, EFS, Howe, and Idaho Falls and are analyzed for tritium using liquid scintillation counting.

4.3.3 Ambient Air Monitoring Results

4.3.3.1 Gaseous Radioiodines

The INL contractor collected and analyzed approximately 2,200 charcoal cartridges (including blanks and duplicates) in 2022. There were no statistically positive measurements of ^{131}I.

4.3.3.2 Gross Activity

Gross alpha and gross beta results cannot provide concentrations of specific radionuclides. Because these radioactivity measurements include naturally occurring radionuclides (such as ^{40}K, ^{7}Be, uranium, thorium, and the daughter isotopes of uranium, and thorium) in uncertain proportions, a meaningful limit cannot be adopted or constructed. However, elevated gross alpha and gross beta results can be used to indicate a potential problem, such as an unplanned release, on a timely basis. Weekly results are reviewed for changes in patterns between locations and groups (i.e., onsite, boundary, and offsite locations) and for unusually elevated results. Anomalies are further investigated by reviewing sample or laboratory issues, meteorological events (e.g., inversions), and INL Site activities that are possibly related. If indicated, analyses for specific radionuclides may be performed. The dataset provide useful information for trending of the total activity over time.

Concentrations of gross alpha and gross beta radioactivity detected by ambient air monitoring conducted by the INL contractor are summarized in Tables 4-4 and 4-5. Results are further discussed below.

Table 4-4. Median annual gross alpha concentrations in ambient air samples collected by the INL contractor in 2022.

GROUP	LOCATION[a]	NO. OF SAMPLES[b]	RANGE OF CONCENTRATIONS[c] (× 10^{-15} μCi/mL)	ANNUAL MEDIAN CONCENTRATION (× 10^{-15} μCi/mL)
Boundary	Arco	51	0.26 – 5.35	1.5
	Atomic City	50	0.29 – 6.44	1.6
	Blue Dome	50	0.43 – 5.19	1.6
	FAA Tower	51	0.29 – 3.69	1.4
	Howe	49	0.51 – 4.87	1.7
	Monteview	51	0.44 – 6.29	1.7
	Mud Lake	50	0.26 – 4.66	1.6
	Terreton	12	0.65 – 2.59	1.8
			Boundary Median:	*1.6*
Offsite	Blackfoot	88	-0.09 – 5.88	1.5
	Craters of the Moon	90	-0.36 – 5.15	1.2
	Dubois	50	0.24 – 4.20	1.6
	Idaho Falls	88	-0.21 – 4.63	1.5
	IRC[d]	51	-0.44 – 3.90	1.2
	IRC (north)	47	-0.20 – 3.90	1.3
	Jackson, WY	51	0.48 – 5.32	1.6
	Sugar City	89	-0.58 – 4.30	1.4
			Offsite Median:	*1.4*
Onsite	ATR Complex (NE corner)	47	-0.27 – 3.42	1.4
	CFA	50	0.03 – 4.20	1.3
	EBR-I	49	-0.57 – 5.16	1.1
	EFS	85	-0.42 – 5.93	1.5
	Gate 4	51	-0.42 – 5.38	1.6
	Highway 26 Rest Area	51	-0.52 – 5.21	1.5
	INTEC	48	-0.25 – 5.54	1.3
	INTEC (west side)	50	0.10 – 4.91	1.4
	Main Gate	50	0.37 – 9.73	1.6
	MFC (north)	49	-0.09 – 6.20	1.4
	MFC (south)	51	-0.53 – 4.95	1.4
	NRF	49	-0.55 – 4.98	1.3
	PBF	12	0.28 – 1.55	1.1
	RHLLW	51	-0.73 – 6.60	1.2
	RWMC	51	-0.52 – 4.04	1.3
	RWMC (South)	50	-1.50 – 4.27	1.5
	SMC	47	-0.39 – 5.62	1.1
	Van Buren Boulevard	89	-0.17 – 5.04	1.2
			Onsite Median:	*1.4*

Table 4-4. continued.

GROUP	LOCATION[a]	NO. OF SAMPLES[b]	RANGE OF CONCENTRATIONS[c] ($\times 10^{-15}$ µCi/mL)	ANNUAL MEDIAN CONCENTRATION ($\times 10^{-15}$ µCi/mL)

a. FAA = Federal Aviation Administration, RHLLW = Remote Handled Low-Level Waste Disposal Facility. See Figure 4-2 for locations on INL Site.

b. Includes valid (i.e., sufficient volume) samples only. Does not include duplicate measurements, which are made for quality assurance purposes.

c. All measurements made by the INL contractor, except for duplicate measurements made for quality assurance purposes, are included in this table and in computation of median annual values. A negative result indicates that the measurement was less than the laboratory background measurement.

d. IRC is an in-town (Idaho Falls) facility within the Research and Education Campus.

Gross Alpha – Gross alpha concentrations are measured on a weekly basis in individual air samples ranged from a low of (-1.5 ± 1.5) $\times 10^{-15}$ µCi/mL, collected by the INL contractor at RWMC (south) on June 15, 2022, to a high of (9.7 ± 1.0) $\times 10^{-15}$ µCi/mL, collected by the INL contractor at Main Gate on November 15, 2022, as shown in Table 4-4.

The median annual gross alpha concentrations were typical of previous measurements. The maximum result is less than the DCS (DOE 2021) of 1.1×10^{-13} µCi/mL for $^{239/240}Pu$, which is the most conservative specific radionuclide DCS that could be—although unrealistically—applied to gross alpha activity.

Gross Beta – Weekly gross beta concentrations measured in air samples ranged from a low of (1.0 ± 1.0) $\times 10^{-15}$ µCi/mL at Blackfoot, collected by the INL contractor on June 1, 2022, to a high of (11.4 ± 0.2) $\times 10^{-14}$ µCi/mL collected by the INL contractor at Main Gate on November 22, 2022, as observed in Table 4-5. The lowest detected value (i.e., greater than three sigma [3σ]) was (2.9 ± 0.38) $\times 10^{-15}$ µCi/mL collected by the INL contractor at MFC (north) on September 14, 2022. All results were less than the maximum concentration of 1.0×10^{-13} µCi/mL which was reported in previous Annual Site Environmental Reports (2012–2021). In general, median airborne radioactivity levels for the onsite, boundary, and offsite locations tracked each other closely throughout the year. The typical temporal fluctuations for natural gross beta concentrations in the air were observed, with higher values usually occurring at the beginning and end of the calendar year during winter inversion conditions (see sidebar). This pattern occurs over the entire sampling network, is representative of natural conditions, and is not caused by a localized source, such as a facility or activity at the INL Site. An inversion can lead to natural radionuclides being trapped close to the ground. The maximum weekly gross beta concentration is significantly below the DCS of 9.6×10^{-12} µCi/mL for the most restrictive beta-emitting radionuclide in the air, ^{90}Sr.

Table 4-5. Median annual gross beta concentrations in ambient air samples collected the INL contractor in 2022.

GROUP	LOCATION[a]	NO. OF SAMPLES[b]	RANGE OF CONCENTRATIONS[c] (× 10^{-14} µCi/mL)	ANNUAL MEDIAN CONCENTRATION[c] (× 10^{-14} µCi/mL)
Boundary	Arco	51	1.29 – 5.37	2.4
	Atomic City	50	1.24 – 6.59	2.6
	Blue Dome	50	1.15 – 5.44	2.5
	FAA Tower	51	1.28 – 4.98	2.3
	Howe	49	1.24 – 6.21	2.7
	Monteview	51	1.28 – 6.96	2.7
	Mud Lake	50	0.41 – 6.35	2.7
	Terreton	12	1.14 – 5.05	2.4
			Boundary Median:	*2.5*
Offsite	Blackfoot	88	0.10 – 6.31	2.3
	Craters of the Moon	90	0.56 – 5.47	2.0
	Dubois	50	1.28 – 5.12	2.4
	Idaho Falls	88	0.95 – 6.05	2.4
	IRC[d]	51	0.88 – 4.67	2.4
	IRC (north)	47	0.99 – 5.57	2.3
	Jackson, WY	51	1.26 – 6.13	2.6
	Sugar City	89	0.96 – 5.02	2.4
			Offsite Median:	*2.3*
Onsite	ATR Complex (NE corner)	47	0.98 – 5.55	2.2
	CFA	50	0.93 – 5.35	2.5
	EBR-I	49	1.02 – 4.88	2.2
	EFS	85	0.52 – 8.76	2.6
	Gate 4	51	0.93 – 5.63	2.4
	Highway 26 Rest Area	51	1.16 – 4.79	2.5
	INTEC	48	0.90 – 5.61	2.5
	INTEC (west side)	50	0.74 – 5.17	2.5
	Main Gate	50	1.14 – 11.40	2.6
	MFC (north)	49	0.29 – 5.41	2.2
	MFC (south)	51	0.19 – 5.01	2.1
	NRF	49	1.04 – 4.61	2.4
	PBF	12	0.97 – 2.62	1.6
	RHLLW	51	0.99 – 4.68	2.4
	RWMC	51	0.90 – 5.57	2.4
	RWMC (south)	50	1.07 – 5.37	2.6
	SMC	47	1.05 – 4.94	2.3
	Van Buren Boulevard	89	0.92 – 5.15	2.4
			Onsite Median:	*2.4*

Table 4-5. continued.

GROUP	LOCATION[a]	NO. OF SAMPLES[b]	RANGE OF CONCENTRATIONS[c] (× 10^{-14} µCi/mL)	ANNUAL MEDIAN CONCENTRATION[c] (× 10^{-14} µCi/mL)

a. FAA = Federal Aviation Administration, RHLLW = Remote Handled Low-Level Waste Disposal Facility. See Figure 4-2 for locations on INL Site.

b. Includes valid (i.e., sufficient volume) samples only. Does not include duplicate measurements which are made for quality assurance purposes.

c. All measurements made by the INL contractor, with the exception of duplicate measurements made for quality assurance purposes, are included in this table and in computation of median annual values. A negative result indicates that the measurement was less than the laboratory background measurement.

d. IRC is an in-town (Idaho Falls) facility within the INL Research and Education Campus.

4.3.3.3 Gross Activity Statistical Comparisons

Statistical comparisons were made using the gross alpha and gross beta radioactivity data collected by the INL contractor from the onsite, boundary, and offsite locations For these analyses, uncensored analytical results (i.e., values less than their analysis-specific minimum detectable concentrations) were included. There were a few statistical differences between monthly boundary and offsite data sets collected by the INL contractor during 2022 that can be attributed to expected statistical variation in the data and not to INL Site releases. Quarterly reports detailing these analyses are provided at https://idahoeser.inl.gov/publications.html.

The INL contractor compared gross beta concentrations from samples collected at onsite and boundary locations. Statistical evaluation revealed no significant differences between onsite and boundary concentrations. Onsite and boundary mean concentrations (2.5 ± 1.0 × 10^{-14} and 2.7 ± 1.0 × 10^{-14} µCi/mL, respectively) showed equivalence at one sigma (1σ) uncertainty and are attributable to natural data variation.

What is an inversion?

Usually within the lower atmosphere, the air temperature decreases with height above the ground. This is largely because the atmosphere is heated from below as solar radiation warms the earth's surface, which, in turn, warms the layer of the atmosphere directly above it. A meteorological inversion is a deviation from this normal vertical temperature gradient such that the temperature increases with height above the ground. A meteorological inversion is typically produced whenever radiation from the earth's surface exceeds the amount of radiation received from the sun. This commonly occurs at night or during the winter when the sun's angle is very low in the sky.

Specific Radionuclides – The INL contractor observed six detections of ^{90}Sr throughout 2022. The detectable concentrations ranged from 3.0 x 10^{-17} µCi/mL at Monteview during the fourth quarter to 9.4 x 10^{-17} µCi/mL at Dubois in the first quarter, as observed in Table 4-6. Plutonium-239/240 was detected in quarterly composited samples that were collected at Blue Dome, RWMC, and RWMC (duplicate) during the fourth quarter (Table 4-6). Americium-241 was detected in quarterly composited samples collected at RWMC and the RWMC (duplicate) in the fourth quarter. Plutonium-238 was not detected in any sample collected by the INL contractor. All results were within historical measurements made during the past ten years (2012-2021). The results were well below the DCSs for these radionuclides in air (i.e., 9.6 × 10^{-12} µCi/mL for ^{90}Sr, 1.1 × 10^{-13} µCi/mL for $^{239/240}$Pu, and 1.3 × 10^{-13} µCi/mL for ^{241}Am). In addition to the radionuclides discussed earlier, the INL contractor began monitoring for uranium during 2022. While not enumerated in Table 4-6, detections of uranium radionuclides occur routinely at concentrations that suggest a natural origin (INL 2023c, INL 2023d). Natural ^{7}Be was detected in numerous INL contractor composite samples at concentrations consistent with past concentrations. Atmospheric ^{7}Be results from reactions of galactic cosmic rays and solar energetic particles with nitrogen and oxygen nuclei in Earth's atmosphere.

Table 4-6. Human-made radionuclides detected in ambient air samples collected by the INL contractor in 2022.

RADIONUCLIDE	RESULT[a] (µCi/mL)	LOCATION	GROUP	QUARTER DETECTED
Americium-241	$(4.5 \pm 0.8) \times 10^{-17}$	RWMC	Onsite	4th
Americium-241	$(3.1 \pm 0.7) \times 10^{-17}$	RWMC (duplicate)	Onsite	4th
Strontium-90	$(5.0 \pm 0.9) \times 10^{-17}$	Howe	Boundary	1st
Strontium-90	$(6.6 \pm 0.6) \times 10^{-17}$	Blue Dome	Boundary	1st
Strontium-90	$(8.1 \pm 0.6) \times 10^{-17}$	FAA Tower	Boundary	1st
Strontium-90	$(9.4 \pm 0.8) \times 10^{-17}$	Dubois	Offsite	1st
Strontium-90	$(6.4 \pm 0.7) \times 10^{-17}$	Dubois (duplicate)	Offsite	1st
Strontium-90	$(3.0 \pm 0.6) \times 10^{-17}$	Monteview	Boundary	4th
Plutonium-239/240	$(3.1 \pm 0.7) \times 10^{-17}$	Blue Dome	Boundary	4th
Plutonium-239/240	$(2.6 \pm 0.6) \times 10^{-17}$	RWMC	Onsite	4th
Plutonium-239/240	$(1.8 \pm 0.5) \times 10^{-17}$	RWMC (duplicate)	Onsite	4th

a. Results ± 1σ. Results shown are ≥ 3σ.

4.3.4 Atmospheric Moisture Monitoring Results

During 2022, the INL contractor collected 66 atmospheric moisture samples at six locations. Table 4-7 presents the percentage of samples containing detectable tritium, the range of concentrations, and the mean concentration for each location. Tritium was detected in eight INL samples, with a high of $(14.5 \pm 2.9) \times 10^{-13}$ $\mu Ci/mL_{air}$ at Idaho Falls on August 24, 2022. The highest concentration of tritium detected in an atmospheric moisture sample collected since 2011 was 31×10^{-13} $\mu Ci/mL_{air}$ at EFS in 2015. The highest observed tritium concentration in a 2022 sample collected by the INL contractor is far below the DCS for tritium in air (as water vapor) of 1.3×10^{-7} $\mu Ci/mL_{air}$.

The source of tritium measured in atmospheric moisture samples collected on and around the INL Site is probably of cosmogenic origin and, to some extent, global fallout (see Section 4.3.5). Tritium releases from non-fugitive sources are highly localized and although they may be detected immediately adjacent to the facility, they are unlikely to be detected at current air monitoring stations because of atmospheric dispersion.

4.3.5 Precipitation Monitoring Results

Tritium exists in the global atmosphere primarily from nuclear weapons testing and from natural production in the upper atmosphere by the interaction of galactic cosmic rays with atmospheric gases and can be detected in precipitation. Since the Nuclear Test Ban Treaty in 1963, the level of tritium measured in precipitation has been steadily decreasing due to radioactive decay and dilution in the world oceans. The International Atomic Energy Agency has participated in surveying tritium compositions in precipitation around the globe since 1961 (https://www.iaea.org/services/networks/gnip). Long-term data suggest that tritium levels in precipitation are close to their pre-nuclear test values (Cauquoin et al. 2015). The tritium measured in precipitation at the INL Site is most likely cosmogenic in origin and not from weapons testing.

The INL contractor collects precipitation samples weekly, when available, at Atomic City, EFS, and Howe. Precipitation is collected monthly at Idaho Falls for EPA RadNet monitoring (https://www.epa.gov/radnet) and a subsample is taken by the INL contractor for analysis.

A total of 74 precipitation samples were collected during 2022 from the four sites. Tritium was detected in seven samples, and detectable results ranged from 104 pCi/L at EFS in March to 203 pCi/L at Howe in April. Most detections were near the approximate detection level of 93 pCi/L. Table 4-8 shows the percentage of detections, the concentration range, the mean and median concentration for each location. The highest concentration is well below the DCS level of 2.6 × 10^6 pCi/L for tritium in water and within the historical range (-173 to 413 pCi/L) measured from 2012–2021.

Table 4-7. Tritium concentrations[a] in atmospheric moisture samples collected by the INL contractor onsite and offsite in 2022.

	ATOMIC CITY	CRATERS OF THE MOON	EFS	HOWE	IDAHO FALLS	VAN BUREN BOULEVARD
Number of samples	10	6	17	8	17	8
Number of detections[b]	1	0	4	1	2	0
Detection percentage	10%	0%	24%	13%	12%	0%
Concentration range (×10^{-13} µCi/mL_{air})[c]	0.5 ± 0.8 – 7.2 ± 2.2	-22 ± 35 – 176 ± 480	-104 ± 49 – 14 ± 41	-4.0 ± 2.7 – 4.1 ± 1.1	-5.1 ± 22.0 – 14.5 ± 2.9	-50 ± 58 – 51 ± 32
Mean concentration (×10^{-13} µCi/mL_{air})[c]	2.5	27.2	-3.2	1.2	2.4	0.58
Median concentration (×10^{-13} µCi/mL_{air})	1.8	3.1	4.0	2.3	1.9	1.6
Mean detection level (×10^{-13} µCi/mL_{air})	4.2	300	36	4.7	22	93

a. Results ± 1σ.

b. All measurements, including negative results, are included in this table and in computation of mean annual values. A negative result indicates that the measurement was less than the laboratory background measurement.

c. An analyte is considered detected when the result is greater than or equal to three times the uncertainty (sigma).

Table 4-8. Tritium concentrations in precipitation samples collected by the INL contractor in 2022.[a,b]

	ATOMIC CITY	EFS	HOWE	IDAHO FALLS
Number of samples	20	21	21	12
Number of detections	2	2	3	0
Detection percentage	10%	10%	14%	0%
Concentration range (pCi/L)	-57.4 ± 107 – 136 ± 27.2	-58.3 ± 32.6 – 167 ± 31.9	-25.1 ± 23.4 – 203 ± 35.1	-16.0 ± 33.2 – 104 ± 35.7
Mean concentration (pCi/L)	32.3	26.3	50.6	45.3
Median concentration (pCi/L)	32.5	28.7	36.5	49.9
Mean detection level (pCi/L)	92.9	93.9	93.0	95.9

a. Results ± 1σ.

b. All measurements are included in this table and in computation of mean annual values. A negative result indicates that the measurement was less than the laboratory background measurement.

The results were also comparable with tritium concentrations reported by EPA for precipitation during the 10-year period from 2002–2011 (measurements were discontinued after 2011) based on a query of available data (https://enviro.epa.gov/enviro/erams_query_v2.simple_query). Concentrations reported by EPA for Idaho Falls during that period ranged from 0–1720 pCi/L and averaged 35.1 pCi/L.

Annual tritium concentrations in atmospheric moisture and precipitation have no discernable statistical distribution, so nonparametric statistical methods were used to assess both datasets (see *Statistical Methods Used in the Idaho National*

Laboratory Annual Site Environmental Report, a supplement to this annual report). To summarize the results, box plots were constructed illustrating annual tritium concentrations measured in atmospheric moisture (as water) and precipitation samples collected by the INL contractor for the past 10 years, as can be seen in Figure 4-5. The results appear to be similar for each year. A statistical comparison of both datasets (using the non-parametric Wilcoxon Matched Pairs Test) shows there are no differences between median annual tritium concentrations measured in atmospheric moisture and in precipitation samples. Because low levels of tritium exist in the environment at all times as a result of cosmic ray reactions with atmospheric gases in the upper atmosphere and the decreasing influence of fallout from nuclear weapons testing in the atmosphere and because tritium concentrations do not appear to differ between precipitation and atmospheric moisture samples, the source of tritium measured in precipitation and atmospheric moisture is most likely of natural origin and past nuclear tests and not from INL Site releases.

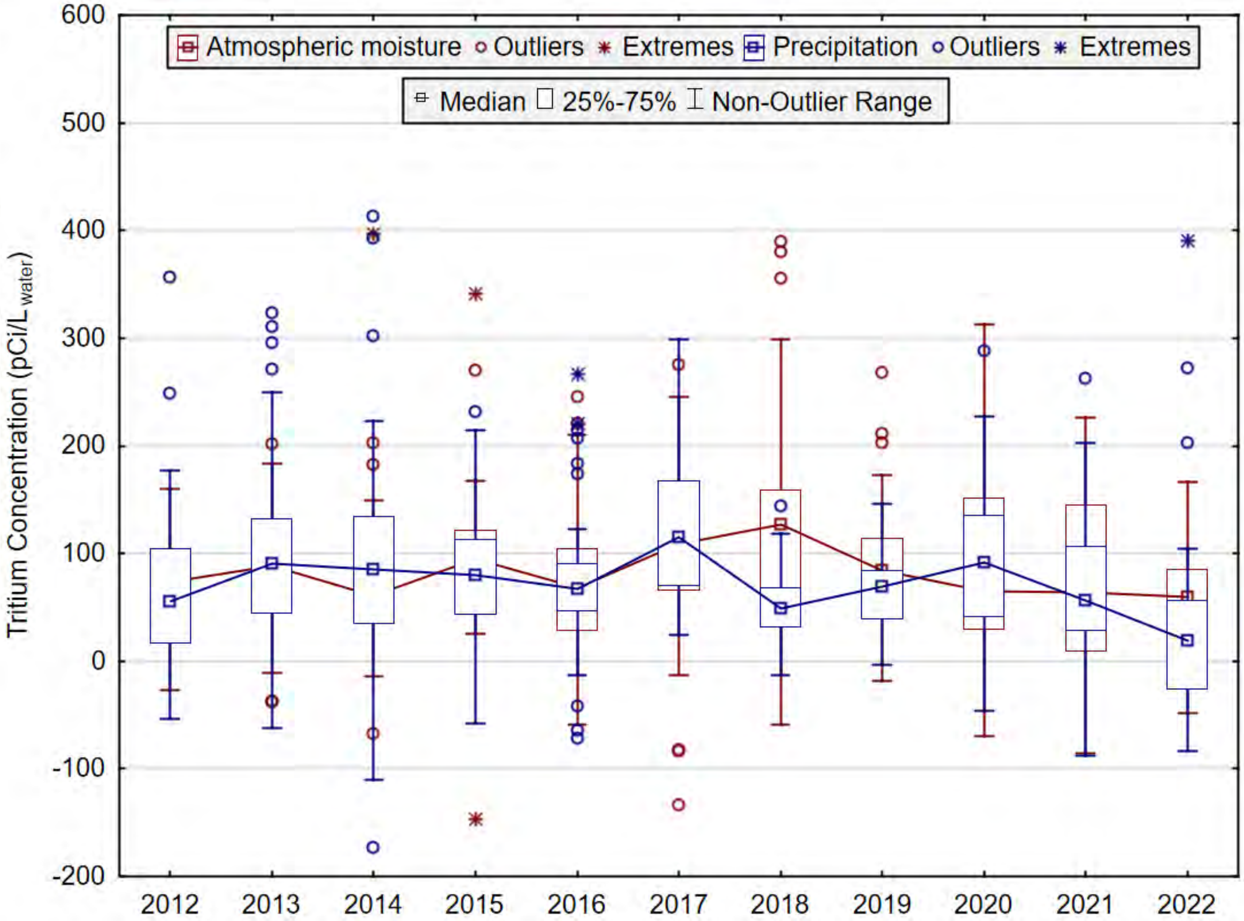


Figure 4-5. Box plots of tritium concentrations measured in atmospheric moisture and in precipitation from 2012–2022.

4.4 Waste Management Environmental Surveillance Air Monitoring

4.4.1 Gross Activity

The ICP contractor conducts environmental surveillance in and around waste management facilities to comply with DOE O 435.1, "Radioactive Waste Management." Currently, ICP waste management operations are performed at the SDA at RWMC and the ICDF at INTEC. These operations have the potential to emit radioactive airborne particulates. The ICP contractor collected samples of airborne particulate material from the perimeters of these waste management areas in 2022, as observed in Figure 4-6. Samples were also collected at a control location at Howe, Idaho, as shown in Figure 4-2, to compare with the results of the SDA and ICDF.

Samples were obtained using suspended particulate monitors similar to those used by the INL contractor. The air filters have a 4-in. diameter and are changed out on the closest working day to the first and 15th of each month. Gross alpha and gross beta activity were determined on all suspended particulate samples. Table 4-9 shows the median annual and range of gross alpha concentrations at each location. Gross alpha concentrations ranged from a low of (0.57 ± 0.09) × 10^{-15} μCi/mL collected at location SDA 6.3 on September 15, 2022, to a high of (4.62 ± 0.68) × 10^{-15} μCi/mL, collected at location SDA 9.3 on February 15, 2022.

Table 4-10 shows the annual median and range of gross beta concentrations at each location. Gross beta concentrations ranged from a low of (0.10 ± 0.01) × 10^{-14} μCi/mL at location SDA 6.3 on September 15, 2022, to a high of (5.50 ± 0.47) x 10^{-14} μCi/mL at location HOWE 400.4 on February 15, 2022.

Figure 4-7 compares gross alpha and gross beta sample results from 2011 through 2022 to the most restrictive DCS values ($^{239/240}Pu$ for gross alpha and ^{90}Sr for gross beta) established by DOE for inhaled air (DOE 2021). The 2022 results for the SDA and ICDF are well below their respective DCS values. Results from the SDA and ICDF were compared with the results collected from the background monitoring location in Howe, Idaho. The ranges of concentrations measured at the SDA and ICDF were aligned with the range measured at the Howe (background) monitoring location.

4.4.2 Specific Radionuclides

Air filters collected by the ICP contractor are composited in a laboratory and analyzed for human-made, gamma-emitting radionuclides and specific alpha-emitting and beta-emitting radionuclides. Gamma spectroscopy analyses are performed monthly, and radiochemical analyses are performed quarterly.

In 2022, no human-made, gamma-emitting radionuclides were detected in air samples at the ICDF at INTEC. However, multiple human-made specific alpha-emitting radionuclides were detected at the SDA at RWMC.

Table 4-11 shows human-made specific radionuclides detected at INTEC and the SDA in 2022. These detections are consistent with levels measured in the air at the SDA in previous years. All detections were three to four orders of magnitude below the DCS stipulated in the DOE Order (2021), as shown in Figure 4-8, and statistically false positives at the 95% confidence error are possible.

In addition to the human-made, gamma-emitting radionuclides discussed above, the ICP contractor also monitors for uranium. While not enumerated in Table 4-11, detections of uranium radionuclides occur routinely at concentrations that suggest a natural origin.

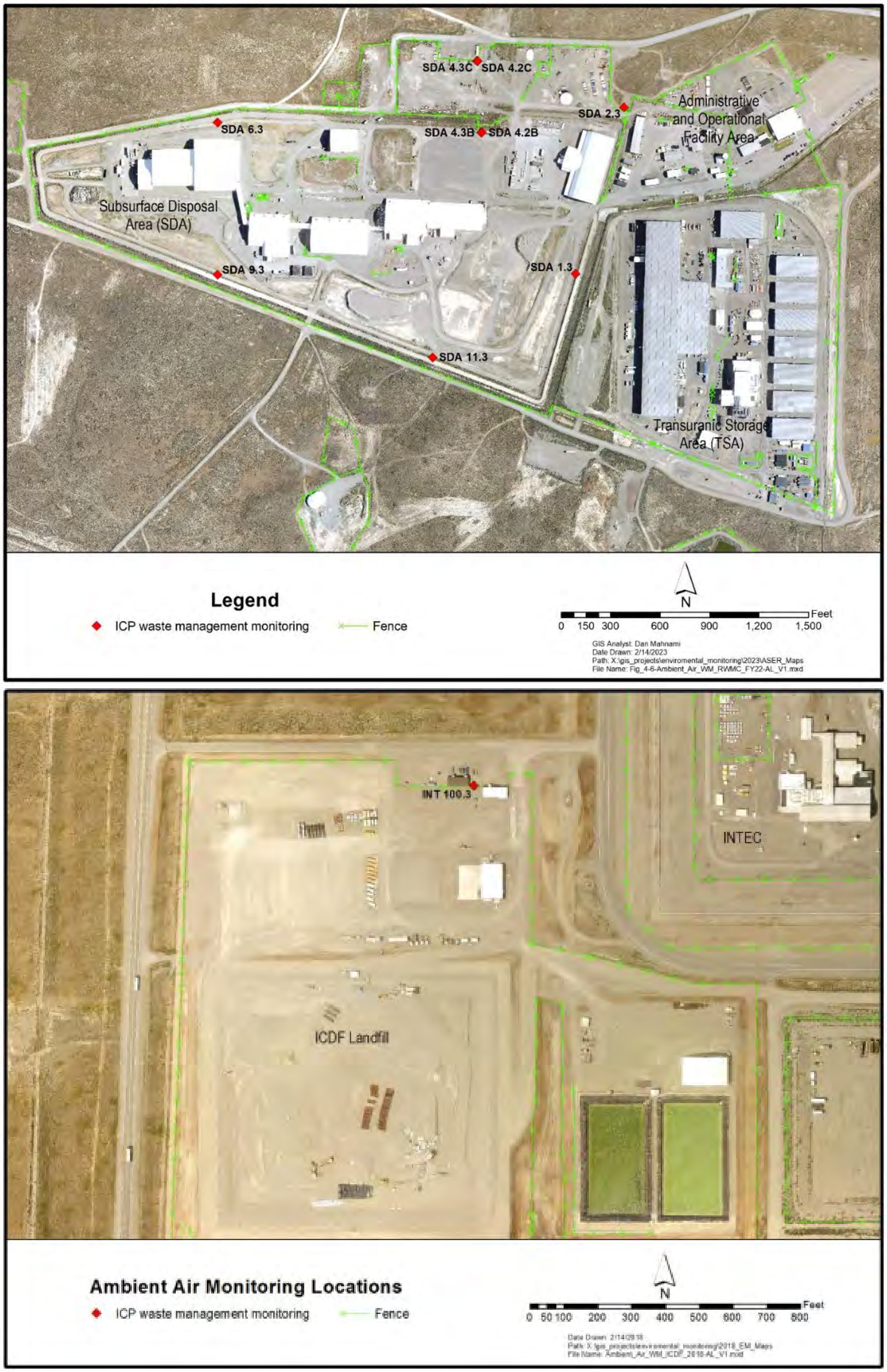


Figure 4-6. Locations of ICP contractor low-volume air samplers at waste management areas (SDA [top] and ICDF [bottom]).

Table 4-9. Median annual gross alpha concentration in air samples collected at waste management sites in 2022.[a]

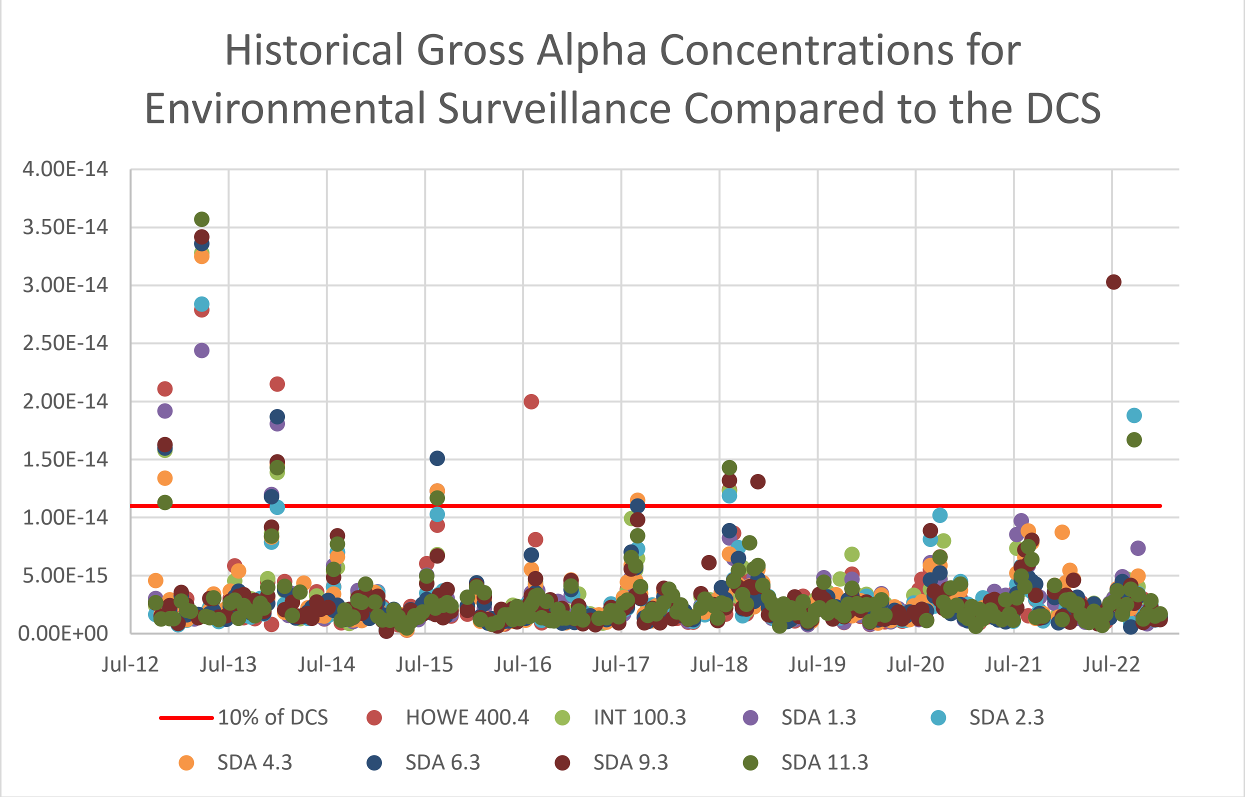
GROUP	LOCATION	NO. OF SAMPLES COLLECTED	RANGE OF CONCENTRATIONS (× 10^{-15} µCi/mL)	ANNUAL MEDIAN (× 10^{-15} µCi/mL)
SDA	SDA 1.3	16	0.86 - 3.06	1.66
	SDA 2.3	18	0.90 - 3.44	1.66
	SDA 4.2B/C and 4.3B/C [a]	26	0.79 - 3.69	1.83
	SDA 6.3	20	0.57 - 3.20	1.77
	SDA 9.3	17	0.86 - 4.62	1.84
	SDA 11.3	19	0.73 - 3.37	1.72
ICDF	INT 100.3	19	1.16 - 4.07	1.74
Boundary	HOWE 400.4	18	1.02 - 3.22	1.97

a. Results for SDA 4.2B/C, a replicate of SDA 4.3B/C, are included in the table for 2022 because of mechanical issues with SDA 4.3B/C occurring in 2022.

Table 4-10. Median annual gross beta concentration in air samples collected at waste management sites in 2022.[a]

GROUP	LOCATION	NO. OF SAMPLES COLLECTED	RANGE OF CONCENTRATIONS (× 10^{-14} µCi/mL)	ANNUAL MEDIAN (× 10^{-14} µCi/mL)
SDA	SDA 1.3	16	0.28 - 3.89	0.81
	SDA 2.3	19	0.18 - 4.93	0.98
	SDA 4.2B/C and 4.3B/C [a]	29	0.13 - 4.93	1.00
	SDA 6.3	21	0.10 - 4.68	0.80
	SDA 9.3	17	0.14 - 4.91	1.16
	SDA 11.3	19	0.12 - 5.24	0.95
ICDF	INT 100.3	20	0.27 - 4.28	1.00
Boundary	HOWE 400.4	18	0.19 - 5.50	0.92

a. Results for SDA 4.2B/C, a replicate of SDA 4.3B/C, are included in the table for 2022 because of mechanical issues with SDA 4.3B/C occurring in 2022.



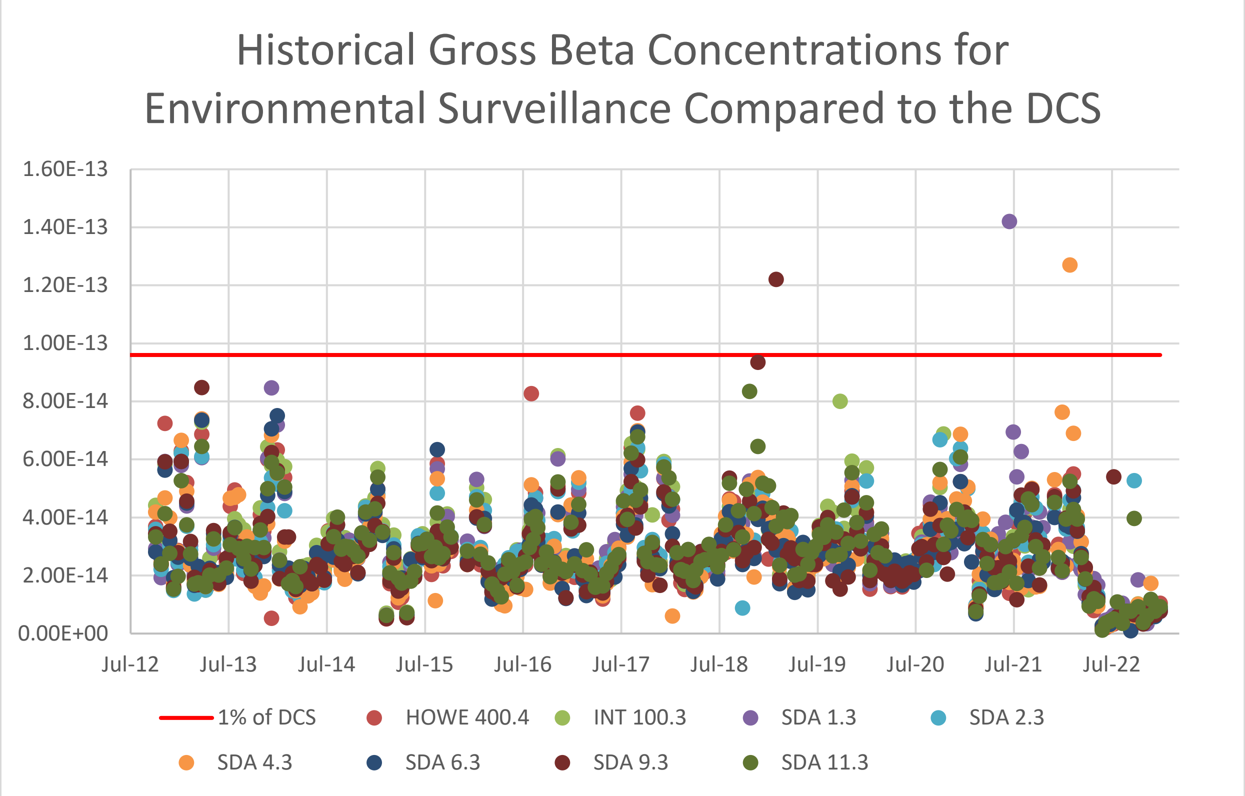


Figure 4-7. Gross alpha (top) and gross beta (bottom) results from waste management site air samples (µCi/mL) compared to their respective DCSs.

Table 4-11. Human-made radionuclides detected in air samples collected at waste management sites in 2022.[a]

RADIONUCLIDE	LOCATION	RESULT (µCi/mL)	UNCERTAINTY (1 SIGMA)	PERIOD DETECTED
Americium-241	SDA 1.3	3.70E-18	9.94E-19	12/20/2021–3/31/2022
	SDA 2.3	4.11E-18	1.28E-18	12/20/2021–3/31/2022
	SDA 4.2B/C and 4.3B/C [b]	1.44E-17	2.34E-18	12/20/2021–3/31/2022
	SDA 4.2B/C and 4.3B/C [b]	8.06E-18	1.60E-18	3/31/2022–5/16/2022 [c]
	SDA 4.2B/C and 4.3B/C [b]	8.18E-18	1.76E-18	3/31/2022–5/16/2022 [c]
Plutonium-238	SDA 4.2B/C and 4.3B/C [b]	2.90E-18	7.85E-19	3/31/2022–5/16/2022 [c]
Plutonium-239/240	SDA 1.3	2.12E-18	5.15E-19	12/20/2021–3/31/2022
	SDA 2.3	1.56E-18	9.94E-19	12/20/2021–3/31/2022
	SDA 4.2B/C and 4.3B/C [b]	2.99E-18	6.16E-19	12/20/2021–3/31/2022
	SDA 4.2B/C and 4.3B/C [b]	2.70E-18	8.02E-19	12/20/2021–3/31/2022
	SDA 4.2B/C and 4.3B/C [b]	1.65E-18	5.15E-19	3/31/2022–5/16/2022 [c]
	SDA 4.2B/C and 4.3B/C [b]	4.82E-18	9.97E-19	3/31/2022–5/16/2022 [c]
	SDA 11.3	2.44E-18	9.97E-19	3/31/2022–5/16/2022 [c]

a. Results shown are ≥ 3σ.

b. Results for SDA 4.2B/C, a replicate of SDA 4.3B/C, are included in the table for 2022 because of mechanical issues with SDA 4.3B/C occurring in 2022.

c. Samples collected in calendar year quarters 2–4 were not composited correctly by the laboratory as agreed upon in the task order statement of work. Laboratory staff were not aware of the need to composite the samples due to unfamiliarity (the previous lab shut down mid-year).

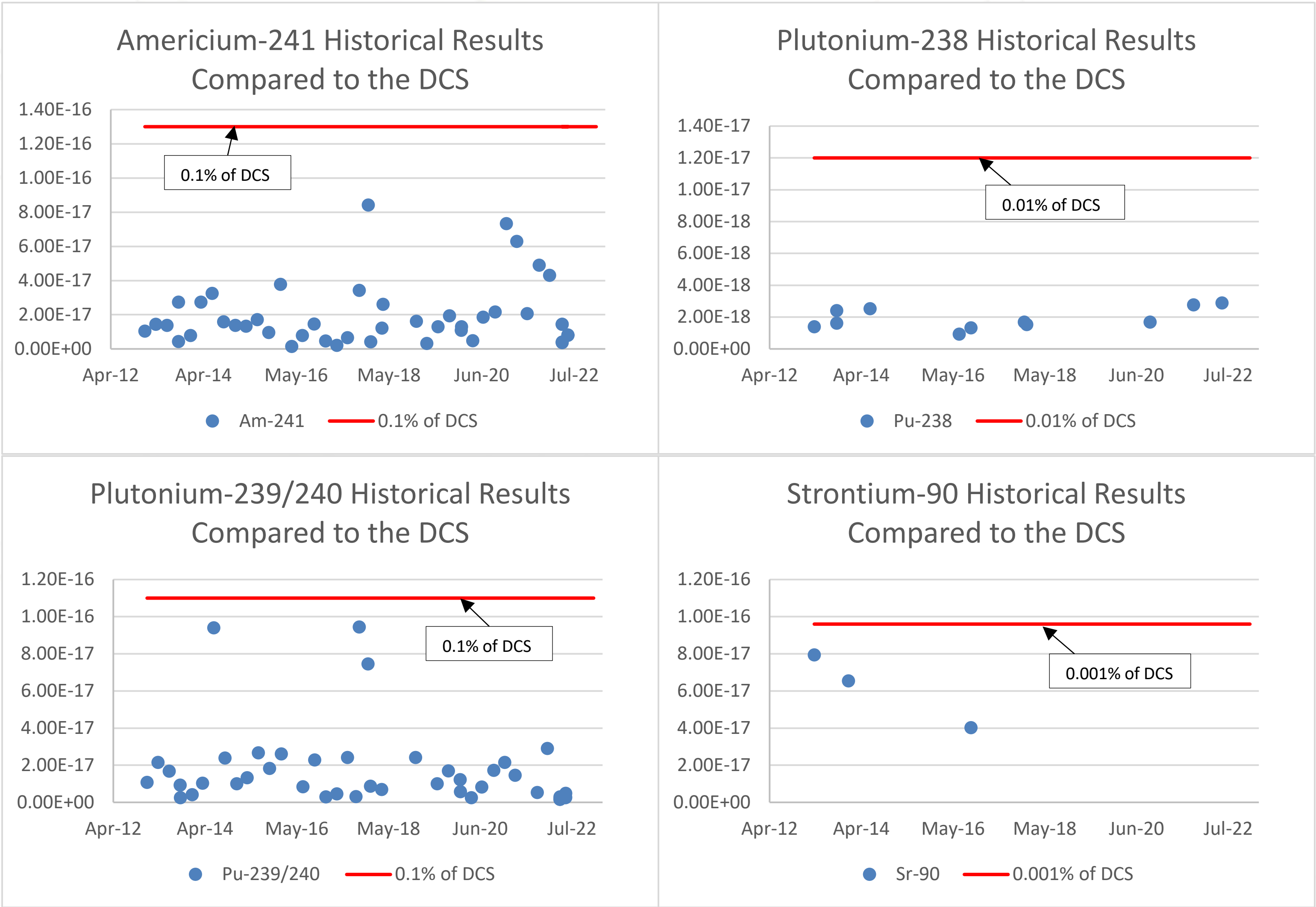


Figure 4-8. Specific human-made radionuclide detections (μCi/mL) from waste management air samples compared to various fractions of their respective DCSs.

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