

# Chapter 4: Environmental Monitoring Programs – Air



## CHAPTER 4

An estimated total of 3,341Ci ( $1.24 \times 10^{14}$  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 2023. The highest contributors to the total release were the Advanced Test Reactor (ATR) Complex at 86.6%, the Materials and Fuel Complex (MFC) at 11.8%, and the Radioactive Waste Management Complex (RWMC) at 1.29%. Other INL Site facilities contributed 0.28% to the total. The estimated maximum potential dose to a member of the public from all INL Site air emissions (0.029 mrem/yr) is below the regulatory standard of 10 mrem/yr (see Chapter 8 for details).

The INL Site environmental surveillance monitoring 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 2023.

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 these specific radionuclides—cesium-137 ( $^{137}\text{Cs}$ ), americium-241 ( $^{241}\text{Am}$ ), plutonium-239/240 ( $^{239/240}\text{Pu}$ ), plutonium-238 ( $^{238}\text{Pu}$ ), uranium-234 ( $^{234}\text{U}$ ), uranium-238 ( $^{238}\text{U}$ ), zinc-65 ( $^{65}\text{Zn}$ ), chlorine-36 ( $^{36}\text{Cl}$ ), and strontium-90 ( $^{90}\text{Sr}$ ). Results were compared to detection levels, background measurements, historical results, and radionuclide-specific Derived Concentration Standards (DCS) 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.

Amounts of  $^{137}\text{Cs}$ ,  $^{239/240}\text{Pu}$ , and  $^{241}\text{Am}$  were detected in some quarterly composited samples collected during 2023. All concentrations were within historical measurements made during the past ten years (2013-2022), except for some  $^{241}\text{Am}$  and plutonium results collected at RWMC during the fourth quarter. Plutonium isotopes and  $^{241}\text{Am}$  are known to occur in soils at the Subsurface Disposal Area (SDA). The results observed during the fourth quarter are likely related to work activities being performed at SDA. All concentrations were well below the DCSs for these radionuclides.

Airborne particulates were also collected biweekly around the perimeters of the SDA at the RWMC and the Idaho Comprehensive Environmental Response, Compensation, and Liability Act Disposal Facility (ICDF) near the Idaho Nuclear Technology and Engineering Center (INTEC). Detections of americium and plutonium isotopes were comparable to past measurements and are likely due to resuspended soils contaminated from past burial practices at the SDA. The results were below the DCSs 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 the INL Site complies with regulatory standards and limits, and can be used to assess impact to the environment over time.

This chapter presents the results of radiological analyses of airborne effluents and ambient air samples collected both on and off the INL Site. The results include those from both the INL and 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 Site 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 2023 INL Report for Radionuclides" (DOE-ID 2024), 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 contractor to ensure 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<sup>2</sup> (9,000 mi<sup>2</sup>) that extends to Jackson, Wyoming, as observed in Figure 4-2. In 2023, the INL contractor collected approximately 1,900 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. Section 4.3 summarizes the results for ambient air monitoring conducted in 2023.

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 ICDF near the INTEC. These locations are shown in Figure 4-2. Section 4.4 discusses the air sampling that the ICP contractor performs in support of waste management activities. In 2023, the ICP contractor collected approximately 230 air samples (including duplicate samples) for various radiological analyses.

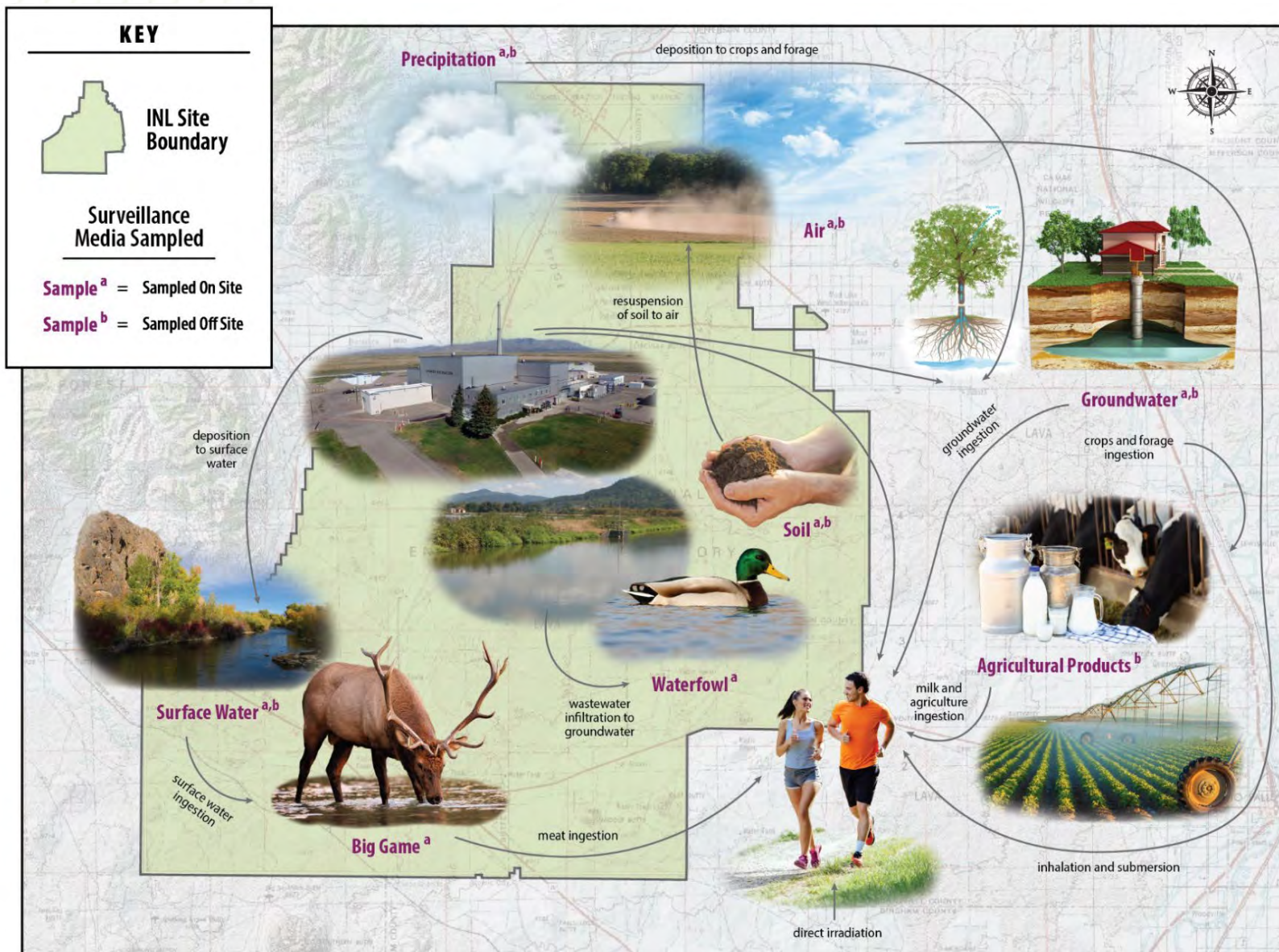


Figure 4-1. INL Site conceptual model.



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

AREA/FACILITY	AIRBORNE EFFLUENT MONITORING PROGRAMS		ENVIRONMENTAL SURVEILLANCE PROGRAMS				
	AIRBORNE EFFLUENTS <sup>a</sup>	LOW-VOLUME CHARCOAL CARTRIDGES ( <sup>131</sup> I)	LOW-VOLUME GROSS ALPHA	LOW-VOLUME GROSS BETA	SPECIFIC RADIONUCLIDES <sup>b</sup>	ATMOSPHERIC MOISTURE	PRECIPITATION
<b>ICP CONTRACTOR<sup>c</sup></b>							
INTEC	•		•	•	•		
RWMC	•		•	•	•		
<b>INL CONTRACTOR<sup>d</sup></b>							
MFC	•						
INL Site/Regional		•	•	•	•	•	•

- a. Facilities that required monitoring during 2023 for compliance with 40 CFR 61, Subpart H, “National Emissions Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities.”
- b. Gamma-emitting radionuclides are measured by the ICP contractor monthly and by the INL contractor quarterly. Amounts of <sup>137</sup>Cs, <sup>241</sup>Am, <sup>239/240</sup>Pu, <sup>238</sup>Pu, <sup>234</sup>U, <sup>238</sup>U, <sup>65</sup>Zn, <sup>36</sup>Cl, and <sup>90</sup>Sr are measured by the INL Site contractors quarterly.
- c. 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.
- d. The INL contractor monitors airborne effluents at the MFC and collects samples onsite, around, and offsite the INL Site to demonstrate compliance with DOE O 458.1, “Radiation Protection of the Public and the Environment.”

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 climatology reports and used by scientists to evaluate atmospheric transport and dispersion. The latest report, “Climatology of the Idaho National Laboratory,” 4<sup>th</sup> 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 found at: [https://niwc.noaa.inl.gov/climate/INL\\_Climate4th\\_Final2.pdf](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 for more information).

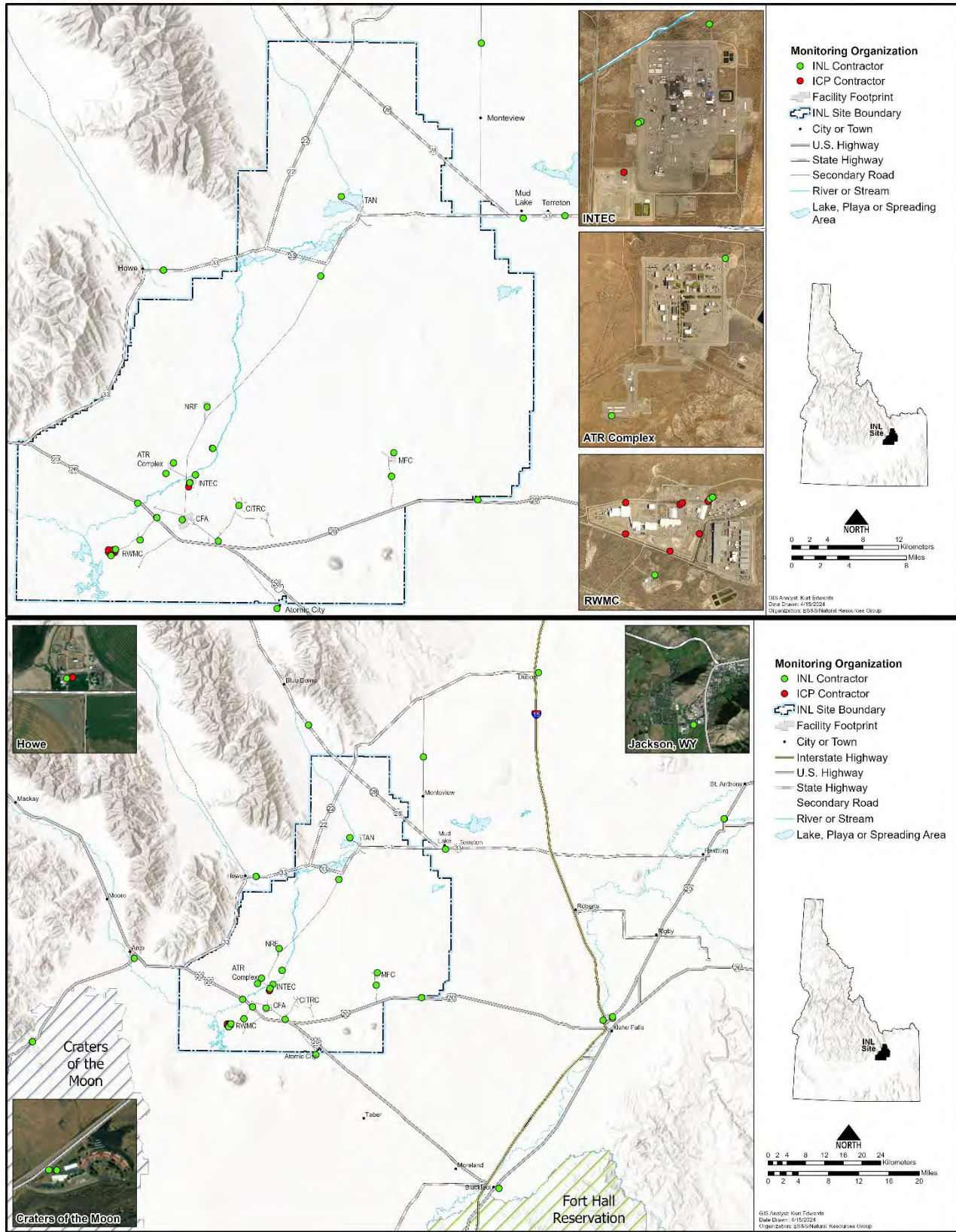


Figure 4-2. INL Site environmental surveillance radiological air sampling locations (onsite [top] and regional [bottom]).



## 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 2023 are reported in the NESHAP Modeling Report (INL 2024a) and the NESHAP Report (DOE-ID 2024).

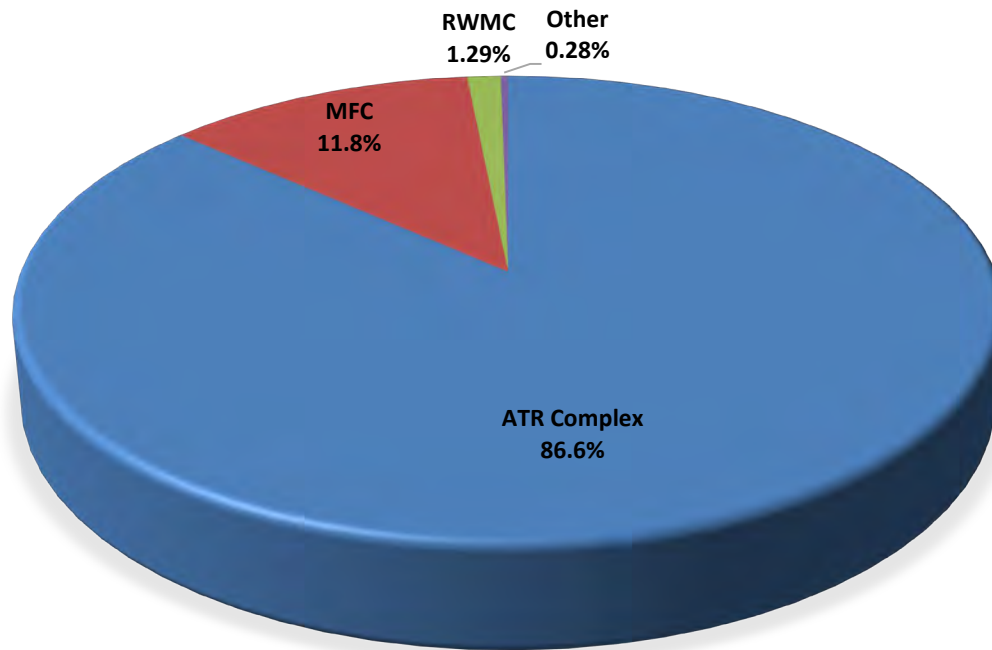
The NESHAP Report includes three categories of airborne emissions:

- Sources that require continuous monitoring under the NESHAP regulation are primarily the stacks at 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 2023, an estimated 3,341 Ci ( $1.24 \times 10^{14}$  Bq) of radioactivity was released to the atmosphere from all INL Site sources. The 2023 release is 936% higher than the estimated total of 357 Ci ( $1.32 \times 10^{13}$  Bq) released in 2022. The increase is primarily the result of the ATR becoming operational again in 2023 after refurbishment of the reactor core was completed, bringing emissions levels back up to historical averages.

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

- **ATR Complex Emissions Sources (86.6% of total INL Site source term).** Emissions from the ATR Complex rose in comparison to 2022 due to the ATR once again becoming operational after the completion of core internal changeout, bringing the emissions levels back up to historical averages. Radiological air emissions from the ATR Complex are primarily associated with the operational 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 (RCL), which has been in operation since 2011, is another emission source at the ATR Complex. Activities at the RCL include inorganic, general purpose analytical chemistry, and wet chemical analysis for trace and high-level radionuclide determination. RCL 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.
- **MFC Emissions Sources (11.8% of total INL Site source term).** Emissions from MFC increased by 78% in 2023 compared to 2022, however with the ATR becoming operation again in 2023, the percent contributed by MFC to total INL emissions was proportionally reduced. 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 due to 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.



**Figure 4-3. Percent contributions in Ci, by facility, to total INL Site airborne radiological releases (2023).**

- RWMC Emissions Sources (1.29% of total INL Site source term).** Emissions from RWMC decreased from 48.1 Ci in 2022 to 42.9 Ci in 2023, and with the emissions from the ATR coming back up to historical averages due to the completion of core internal changeout, the relative percent contribution from RWMC to total INL Site emissions values also decreased in comparison to the 2022 percent contribution (13.5% to 1.29%). 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: (1) waste retrieval activities at the Accelerated Retrieval Projects (ARPs), (2) operation of the Resource Conservation and Recovery Act (RCRA)-permitted Sludge Repackage waste processing project, (3) storage of waste within the Type II storage modules at the Advanced Mixed Waste Treatment Project, (4) storage and characterization of waste at the Drum Vent and Characterization facilities, (5) storage of wastes at the Transuranic Storage Area-Retrieval Enclosure (WMF-636), and (6) treatment of wastes at the Advanced Mixed Waste Treatment Facility (WMF-676). Data from 18 emission sources (both point and diffuse) at RWMC were reported in the 2023 NESHAP Report for Radionuclides (DOE-ID 2024), 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 RCRA facilities (WMF-1617 and WMF-1619) is achieved with the U.S. Environmental Protection Agency (EPA)-approved ambient air monitoring program, which has been in place since 2008. Radiological emissions at RWMC include tritium and carbon-14 ( $^{14}\text{C}$ ) associated with buried beryllium blocks at the SDA. Transuranic radionuclides released from ARP facilities, including  $^{241}\text{Am}$ ,  $^{238}\text{Pu}$ ,  $^{239/240}\text{Pu}$ , and  $^{241}\text{Pu}$ , have declined in recent years as waste exhumation and processing activities progress to completion.
- Radiological Response Training Range (RRTR) Emissions Sources (0.19% of total INL Site source term).** The north RRTR is located 1.6 km (1 mile) NNE of the Specific Manufacturing Capability (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 both aerial- and ground-based detection capabilities 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 “Update of Receptor Locations for INL NESHAP



Assessments” (INL 2023a), 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 fewer in 2023 (6.46 Ci) as compared to 2022 (33.2 Ci) due to variances in operations.

- **INTEC Emissions Sources (0.038% 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. These sources contribute gaseous radionuclides, including tritium, iodine-129, and krypton-85, with contributions of particulate radionuclides  $^{137}\text{Cs}$  and  $^{90}\text{Sr}$  from ICDF. INTEC has one stack continuously monitored for radionuclide emissions (resulting from Waste Management activities) located outside of CPP-666 (Fluorinel Dissolution Process and Fuel Storage Facility). 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 (0.032% 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.
- **Critical Infrastructure Test Range Complex (CITRC) Emissions Sources (0.0066% 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.
- **Test Area North Emissions Sources (0.00043% 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  $^{90}\text{Sr}$  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.
- **SMC Emissions Sources (3.28E-14% 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.

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 2023 was 0.029 mrem/yr (0.29  $\mu\text{Sv/yr}$ ) which is below the regulatory standard of 10 mrem/yr. Six radionuclides—uranium-238 ( $^{238}\text{U}$ ),  $^{234}\text{U}$ , chlorine-36 ( $^{36}\text{Cl}$ ), tritium ( $^3\text{H}$ ),  $^{137}\text{Cs}$ , and  $^{90}\text{Sr}$ —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.



Table 4-2. Radionuclide composition of INL Site airborne effluents (2023).<sup>a</sup>

RADIONUCLIDE <sup>c</sup>	HALF-LIFE <sup>d</sup>	AIRBORNE EFFLUENT (Ci) <sup>b</sup>										
		ATR COMPLEX	CFA <sup>e</sup>	CITRC <sup>e</sup>	INTEC	MFC	NRF <sup>e</sup>	RRTR	RWMC	SMC <sup>e</sup>	TAN <sup>e</sup>	TOTAL
Americium-241	432.2 y	2.22E-05	NS <sup>f</sup>	— <sup>g</sup>	1.30E-05	NS	—	—	5.49E-05	—	—	9.01E-05
Argon-41	1.83 h	1.97E+03	NS	—	—	7.46E+01	—	NS	—	—	—	2.04E+03
Bromine-82	1.47 d	—	NS	—	—	NS	—	6.29E+00	—	—	—	6.29E+00
Carbon-14	5730 y	NS	NS	—	2.43E-03	—	2.10E-01	—	2.22E-02	—	—	2.35E-01
Cesium-134	2.06 y	NS	NS	—	—	8.59E-04	—	—	—	—	—	8.59E-04
Cesium-137	30.2 y	5.29E-03	4.16E-06	—	3.78E-04	7.64E-03	8.04E-05	—	NS	—	—	1.34E-02
Chlorine-36	3.01 x 10 <sup>5</sup> y	—	NS	—	NS	7.17E-03	—	NS	—	—	—	7.17E-03
Cobalt-60	5.271 y	5.90E-03	NS	—	NS	—	—	—	NS	—	—	5.90E-03
Hydrogen-3	12.3 y	5.29E+02	3.62E-01	2.20E-01	1.87E-01	2.17E+02	NS	—	4.29E+01	—	NS	7.90E+02
Iodine-129	1.57 x 10 <sup>7</sup> y	NS	NS	—	1.43E-04	—	NS	—	—	—	—	1.43E-04
Iodine-131	8.02 d	NS	1.41E-02	—	—	NS	NS	—	—	—	—	1.41E-02
Iodine-132	2.30 h	NS	4.74E-02	—	—	—	—	—	—	—	—	4.74E-02
Iodine-133	20.8 h	NS	1.56E-01	—	—	—	—	—	—	—	—	1.56E-01
Iodine-135	6.57 h	NS	1.60E-01	—	—	—	—	—	—	—	—	1.60E-01
Krypton-85	10.756 y	—	NS	—	1.09E+00	NS	NS	NS	—	—	—	1.09E+00
Krypton-87	76.3 min	NS	NS	—	—	9.65E+00	—	NS	—	—	—	9.65E+00
Krypton-88	2.84 h	3.82E+00	1.92E-02	—	—	8.77E+00	—	—	—	—	—	1.26E+01
Plutonium-238	87.7 y	NS	NS	—	7.76E-07	NS	—	—	NS	—	—	7.76E-07
Plutonium-239	24,065 y	8.46E-06	NS	—	4.93E-06	NS	2.70E-06	—	2.57E-05	—	—	4.18E-05
Plutonium-240	6,537 y	NS	NS	—	4.78E-06	NS	—	—	5.89E-06	—	—	1.07E-05
Sodium-22	2.60 y	NS	8.28E-06	—	—	NS	—	—	—	—	—	8.28E-06
Strontium-90	29.12 y	2.82E-02	NS	—	3.00E-04	1.22E-03	5.60E-05	—	NS	—	3.01E-05	2.98E-02
Uranium-234	2.46 x 10 <sup>5</sup> y	NS	NS	—	NS	7.66E-02	—	—	—	2.03E-13	—	7.66E-02
Uranium-235	7.04 x 10 <sup>8</sup> y	NS	NS	—	NS	3.49E-03	—	—	NS	NS	—	3.49E-03
Uranium-238	4.5 x 10 <sup>9</sup> y	NS	NS	—	NS	1.45E-01	—	—	NS	8.83E-13	—	1.45E-01
Xenon-133	5.23 d	3.44E+02	NS	—	—	NS	—	—	—	—	—	3.44E+02
Xenon-135	9.09 h	1.83E+01	2.29E-01	—	—	NS	—	—	—	—	—	1.85E+01
Xenon-138	14.1 min	NS	—	—	—	1.49E+01	—	—	—	—	—	1.49E+01
<b>TOTAL CURIES RELEASED<sup>h</sup></b>		2.86E+03	9.88E-01	2.20E-01	1.28E+00	3.26E+02	2.10E-01	6.29E+00	4.29E+01	1.09E-12	3.01E-05	3.24E+03
<b>TOTAL DOSE (mrem)<sup>i</sup></b>		9.68E-04	6.06E-06	1.10E-06	1.79E-05	2.73E-02	3.11E-05	2.02E-04	5.21E-04	3.41E-14	1.26E-06	2.91E-02



**Table 4-2. continued.**

AIRBORNE EFFLUENT (Ci) <sup>b</sup>												
RADIONUCLIDE <sup>c</sup>	HALF-LIFE <sup>d</sup>	ATR COMPLEX <sup>e</sup>	CFA <sup>e</sup>	CITRC <sup>e</sup>	INTEC <sup>e</sup>	MFC <sup>e</sup>	NRF <sup>e</sup>	RRTR <sup>e</sup>	RWMC <sup>e</sup>	SMC <sup>e</sup>	TAN <sup>e</sup>	TOTAL

- a. Radionuclide release information provided by the INL contractor (INL 2023a).
- b. One curie (Ci) = 3.7 × 10<sup>10</sup> becquerels (Bq).
- c. Includes only those radionuclides that 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, SMC = Specific Manufacturing Capability, TAN = Test Area North.
- f. NS = not significant. The radionuclide was estimated to not be one of the top 99.9% contributors to 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 2023.
- 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 EPA. See Chapter 8 for details.



## 4.3 Ambient Air Surveillance Monitoring

Ambient air surveillance 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). All ambient air surveillance monitoring sample results for 2023 are provided in quarterly surveillance reports (INL 2024b, INL 2024c, INL 2024d, and INL 2024e).

### 4.3.1 Ambient Air Surveillance Monitoring System Design

Figure 4-2 shows the regional and INL Site routine air surveillance monitoring locations. A total of 37 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 2023, 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 INL Research Center (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. 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 surveillance 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 seven locations: Atomic City, Craters of the Moon, EFS, Howe, Idaho Falls (two samplers), the Remote-Handled Low-Level Waste (RHLLW) Disposal Facility, and Van Buren Boulevard. Although there are more particulate air surveillance monitoring stations, additional atmospheric moisture and precipitation surveillance 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 2013 through 2022 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. In addition, the Idaho Falls sampler can be 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 surveillance monitoring summary (2023).**

MEDIUM SAMPLED	TYPE OF ANALYSIS	FREQUENCY	NUMBER OF LOCATIONS		MINIMUM DETECTABLE CONCENTRATION
			ONSITE	OFFSITE	
Air (low-volume) <sup>a,b,c</sup>	Gross alpha	Weekly	21	16	7E-16 µCi/mL
	Gross beta	Weekly	21	16	1E-15 µCi/mL
	Specific gamma <sup>d</sup>	Quarterly	21	16	1.2E-16 µCi/mL
	Plutonium-238	Quarterly	21	16	8.9E-18 µCi/mL
	Plutonium-239/240	Quarterly	21	16	8.8E-18 µCi/mL
	Americium-241	Quarterly	21	16	9.9E-18 µCi/mL
	Chlorine-36 <sup>e</sup>	Quarterly	2	0	5.0E-17 µCi/mL
	Strontium-90	Quarterly	21	16	1.1E-16 µCi/mL
	Uranium-233/234 <sup>e</sup>	Quarterly	21	16	1.9E-17 µCi/mL
	Uranium-238 <sup>e</sup>	Quarterly	21	16	1.3E-17 µCi/mL
Air (high-volume) <sup>f</sup>	Iodine-131	Weekly	21	16	3.7E-13 µCi/mL
	Gross beta scan	Biweekly	–	1	1E-15 µCi/mL
	Gamma scan	Continuous	–	1	Not applicable
	Specific gamma <sup>d</sup>	Annually <sup>g</sup>	–	1	1E-14 µCi/mL
Air (atmospheric moisture) <sup>h</sup>	Isotopic Uranium and Plutonium	Every 4 Years	–	1	2E-18 µCi/mL
	Tritium	3–6/Quarter	3	5	5E-12 µCi/mL (air)
Air (precipitation) <sup>i</sup>	Tritium	Monthly	0	1	95 pCi/L
	Tritium	Weekly	1	2	

- Low-volume air samplers are operated on the INL Site by the INL contractor at the following locations: ATR Complex, CFA, Experimental Breeder Reactor No. 1 (EBR-I), EFS, Gate 4, Highway 26 Rest Area, INTEC (two air samplers), Main Gate, MFC (two air samplers), NRF, Power Burst Facility (PBF), RHLLW, RWMC (two air samplers), SMC, and Van Buren Boulevard. Additionally, there are rotating duplicate samplers for quality assurance. In 2023, the samplers were located at INTEC, RWMC, and Van Buren Boulevard. This table does not include high-volume ‘event’ surveillance monitoring by the INL contractor.
- The INL contractor operates low-volume samplers at INL Site boundary locations. These include Arco, Atomic City, Blue Dome, Federal Aviation Administration Tower, Howe, Montevue, and Terreton.
- The INL contractor operates low-volume samplers offsite at Blackfoot, Craters of the Moon, Dubois, Idaho Falls, IRC (two air samplers), Jackson (WY), and Sugar City. In addition, there is a rotating duplicate sampler for quality assurance. In 2023, the sampler was placed in Dubois.
- The minimum detectable concentration shown is for <sup>137</sup>Cs.
- The radionuclide is a contributor to the estimated MEI dose and was not routinely analyzed for in the past. As a result, analysis for the radionuclide began in 2023.
- 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>.
- If gross beta activity is greater than 1 pCi/m<sup>3</sup>, then a gamma scan is performed at NAREL. Otherwise, an annual composite is analyzed.
- Atmospheric moisture samples are collected onsite at EFS, RHLLW, and Van Buren Boulevard by the INL contractor. Samples are collected offsite at Atomic City, Craters of the Moon, Howe, and Idaho Falls (two samplers) by the INL contractor.
- 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.

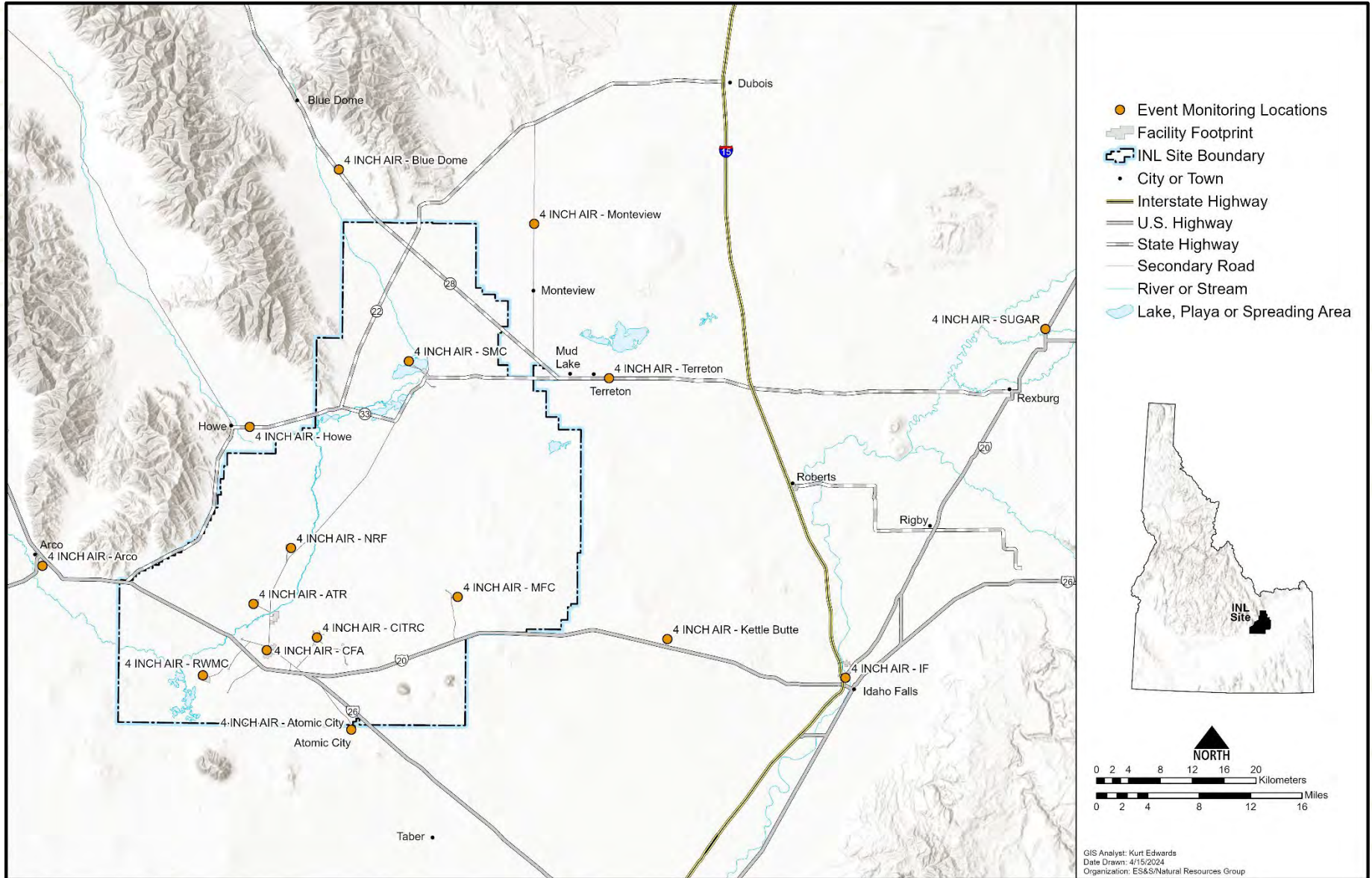


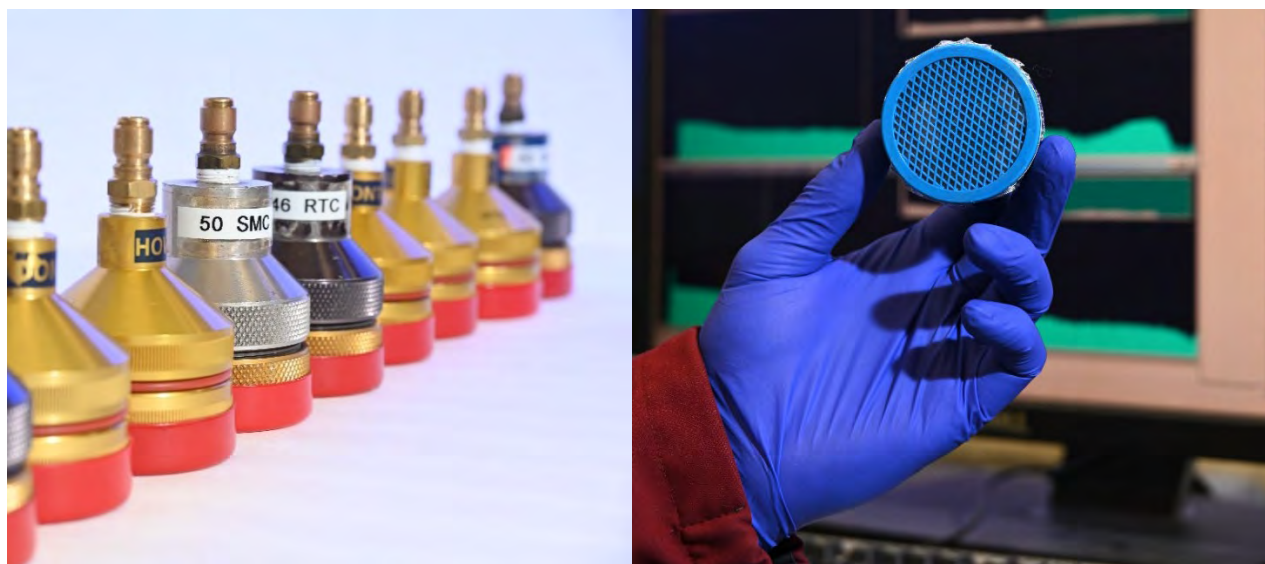
Figure 4-4. Locations of INL contractor high-volume event monitors at NOAA weather stations.



### 4.3.2 Air Particulate, Radioiodine, and Tritium Sampling Methods

#### *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<sup>3</sup>/min]) through a 5-cm (2-in.), 1.2- $\mu$ m particulate filter and a charcoal cartridge, as seen in Figure 4-5, 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.



**Figure 4-5. Air filter heads (left photo). Charcoal cartridge (right photo).**

The filters are composited quarterly for each location by the analytical laboratory prior to analysis for gamma-emitting radionuclides, such as <sup>137</sup>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 (<sup>7</sup>Be) and potassium-40 (<sup>40</sup>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 <sup>241</sup>Am, <sup>36</sup>Cl, <sup>238</sup>Pu, <sup>239/240</sup>Pu, <sup>238</sup>Pu, <sup>233/234</sup>U, <sup>238</sup>U, <sup>65</sup>Zn, and <sup>90</sup>Sr. In 2023, analysis of quarterly composite samples for <sup>36</sup>Cl, <sup>233/234</sup>U, and <sup>238</sup>U began as a result of the radionuclides being listed as contributors to the estimated annual dose to the MEI (Chapter 8, Section 8.2.1). MFC was listed as the location with a <sup>36</sup>Cl source term that contributed >0.005%, therefore analysis for <sup>36</sup>Cl was only performed on samples collected from MFC. Additional radionuclides 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.



## Radioiodine

Charcoal cartridges are collected and analyzed weekly for iodine-131 ( $^{131}\text{I}$ ) 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  $^{131}\text{I}$  in the environment could be from a recent release of fission products.

## Tritium

The INL contractor monitors tritium in atmospheric water vapor in ambient air onsite at EFS, RHLLW, 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 Surveillance Monitoring Results

#### Gaseous Radioiodines

The INL contractor collected and analyzed approximately 1,900 charcoal cartridges (including blanks and duplicates) in 2023. There were no statistically positive measurements of  $^{131}\text{I}$ .

#### Gross Activity

Gross alpha and gross beta results cannot provide concentrations of specific radionuclides. Because these radioactivity measurements include naturally occurring radionuclides (such as  $^{40}\text{K}$ ,  $^7\text{Be}$ , 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. This data provides useful information for trending of the total activity over time.

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

**Gross Alpha** – Gross alpha concentrations are measured on a weekly basis in individual air samples ranged from a low of  $(-1.5 \pm 2.7) \times 10^{-16}$   $\mu\text{Ci}/\text{mL}$ , collected by the INL contractor at IRC North on October 17, 2023, to a high of  $(4.9 \pm 0.2) \times 10^{-14}$   $\mu\text{Ci}/\text{mL}$ , collected by the INL contractor at RWMC on October 10, 2023, as shown in Table 4-4. The elevated alpha result for the air filter collected at RWMC on October 10, 2023, is likely the result of work activities occurring at RWMC. The radiochemical analysis results support this idea since  $^{241}\text{Am}$  and plutonium isotopes were detected in fourth quarter 2023 composite samples collected from RWMC (INL 2024e). Further discussion of radiochemical results are presented in Specific Radionuclides.

The median annual gross alpha concentrations were typical of previous measurements. The maximum result is less than the DCS (DOE 2022) of  $1.1 \times 10^{-13}$   $\mu\text{Ci}/\text{mL}$  for  $^{239/240}\text{Pu}$ , 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  $(0.8 \pm 1.7) \times 10^{-16}$   $\mu\text{Ci}/\text{mL}$  at RWMC South, collected by the INL contractor on January 10, 2023, to a high of  $(3.7 \pm 0.1) \times 10^{-13}$   $\mu\text{Ci}/\text{mL}$  collected by the INL contractor at the Blue Dome on January 31, 2023, as observed in Table 4-4. The lowest detected value (i.e., greater than three sigma [ $3\sigma$ ]) was  $(3.6 \pm 0.5) \times 10^{-15}$   $\mu\text{Ci}/\text{mL}$  collected by the INL contractor at Atomic City on March 14, 2023. 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



**Table 4-4. Median annual gross alpha and gross beta concentrations in ambient air samples collected by the INL contractor in 2023.**

GROUP	LOCATION	NO. OF SAMPLES <sup>a</sup>	GROSS ALPHA		GROSS BETA	
			RANGE OF CONCENTRATIONS <sup>b</sup> ( $\times 10^{-15}$ $\mu\text{Ci/mL}$ )	ANNUAL MEDIAN CONCENTRATION <sup>b</sup> ( $\times 10^{-15}$ $\mu\text{Ci/mL}$ )	RANGE OF CONCENTRATIONS <sup>b</sup> ( $\times 10^{-14}$ $\mu\text{Ci/mL}$ )	ANNUAL MEDIAN CONCENTRATION <sup>b</sup> ( $\times 10^{-14}$ $\mu\text{Ci/mL}$ )
<b>BOUNDARY</b>	Arco	50	0.13 – 3.29	1.4	0.95 – 5.94	2.3
	Atomic City	50	-0.12 – 3.43	1.3	0.36 – 5.98	2.4
	Blue Dome	50	0.61 – 27.40	1.5	1.11 – 37.30	2.3
	FAA <sup>c</sup> Tower	49	0.32 – 2.91	1.5	1.07 – 4.17	2.3
	Howe	51	0.24 – 3.28	1.5	0.83 – 5.96	2.3
	Monteview	51	0.48 – 3.40	1.6	0.76 – 5.66	2.4
	Terreton	51	0.33 – 3.27	1.4	1.46 – 5.85	2.5
	<b>Boundary Median:</b>			<b>1.5</b>	<b>2.3</b>	
<b>OFFSITE</b>	Blackfoot	51	0.11 – 2.66	1.6	1.13 – 4.64	2.3
	Craters of the Moon	49	-0.04 – 2.92	1.1	0.10 – 6.02	2.2
	Dubois	51	0.37 – 4.55	1.4	1.00 – 4.51	2.4
	Idaho Falls	51	0.72 – 3.05	1.7	1.07 – 4.77	2.6
	IRC <sup>d</sup>	51	0.47 – 3.38	1.7	1.19 – 4.80	2.4
	IRC (north)	47	-0.15 – 3.91	1.6	1.04 – 5.60	2.5
	Jackson, WY	51	0.37 – 2.70	1.4	0.49 – 4.00	2.2
	Sugar City	49	0.24 – 3.27	1.5	1.08 – 4.17	2.6
<b>Offsite Median:</b>			<b>1.5</b>	<b>2.4</b>		
<b>ONSITE</b>	ATR Complex	50	0.62 – 3.29	1.8	1.34 – 5.75	2.6
	CFA	50	0.37 – 2.88	1.5	1.37 – 5.94	2.5
	EBR-I	50	0.11 – 2.94	1.6	1.45 – 6.44	2.6
	EFS	45	-0.09 – 3.49	1.6	0.06 – 6.21	2.5
	Gate 4	51	0.22 – 4.44	1.6	1.30 – 6.49	2.6
	Highway 26 Rest Area	51	0.17 – 3.17	1.4	1.02 – 7.14	2.6
	INTEC (NE corner)	18	0.32 – 3.09	1.3	1.07 – 6.11	2.4
	INTEC (west side)	50	0.06 – 3.37	1.5	0.93 – 6.02	2.5
	Main Gate	51	0.25 – 3.72	1.5	0.68 – 6.14	2.3





Table 4-4. continued.

GROUP	LOCATION	NO. OF SAMPLES <sup>a</sup>	GROSS ALPHA		GROSS BETA	
			RANGE OF CONCENTRATIONS <sup>b</sup> ( $\times 10^{-15}$ $\mu\text{Ci/mL}$ )	ANNUAL MEDIAN CONCENTRATION <sup>b</sup> ( $\times 10^{-15}$ $\mu\text{Ci/mL}$ )	RANGE OF CONCENTRATIONS <sup>b</sup> ( $\times 10^{-14}$ $\mu\text{Ci/mL}$ )	ANNUAL MEDIAN CONCENTRATION <sup>b</sup> ( $\times 10^{-14}$ $\mu\text{Ci/mL}$ )
	MFC (north)	50	0.27 – 2.96	1.5	1.12 – 5.34	2.3
	MFC (south)	50	0.24 – 3.92	1.3	1.22 – 5.11	2.5
	NRF	51	0.59 – 2.82	1.4	1.44 – 5.69	2.7
	PBF	51	0.21 – 3.51	1.3	0.97 – 5.92	2.4
	RHLLW <sup>c</sup>	49	0.60 – 3.27	1.6	1.46 – 6.38	2.7
	RWMC	51	0.49 – 49.40	1.7	1.51 – 5.84	2.6
	RWMC (South)	49	-0.06 – 2.96	1.4	0.01 – 6.44	2.7
	SMC	49	0.27 – 3.19	1.7	1.35 – 6.29	2.7
	Van Buren Boulevard	51	0.06 – 3.79	1.6	1.14 – 5.39	2.7
<b>Onsite Median:</b>				<b>1.5</b>		<b>2.5</b>

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

b. 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 the measurement was less than the laboratory background measurement.

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

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



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  $9.6 \times 10^{-12}$   $\mu\text{Ci}/\text{mL}$  for the most restrictive beta-emitting radionuclide in the air,  $^{90}\text{Sr}$ .

### ***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 the monthly boundary and offsite datasets collected by the INL contractor during 2023 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 ( $2.7 \pm 1.0 \times 10^{-14}$  and  $2.6 \pm 2.1 \times 10^{-14}$   $\mu\text{Ci}/\text{mL}$ , respectively) showed equivalence at one sigma ( $1\sigma$ ) uncertainty and are attributable to natural data variation.

### ***Specific Radionuclides***

The INL contractor observed five detections of  $^{137}\text{Cs}$  in quarterly composited samples, as indicated in Table 4-5. The detectable concentrations ranged from  $13.4 \times 10^{-17}$   $\mu\text{Ci}/\text{mL}$  at Van Buren during the first quarter to  $29.4 \times 10^{-17}$   $\mu\text{Ci}/\text{mL}$  at EFS during the first quarter. Strontium-90 was detected in five quarterly composited samples. The detectable concentrations ranged from  $2.7 \times 10^{-17}$   $\mu\text{Ci}/\text{mL}$  at Van Buren (duplicate) during the third quarter to  $24.7 \times 10^{-17}$   $\mu\text{Ci}/\text{mL}$  at SMC in the first quarter. Americium-241 was detected in six quarterly composited samples. The detectable concentrations ranged from  $1.4 \times 10^{-17}$   $\mu\text{Ci}/\text{mL}$  at the ATR Complex during the fourth quarter to  $49.7 \times 10^{-17}$   $\mu\text{Ci}/\text{mL}$  at RWMC during the fourth quarter. Plutonium-239/240 was detected in six quarterly composited samples. The detectable concentrations ranged from  $1.7 \times 10^{-17}$   $\mu\text{Ci}/\text{mL}$  at RWMC south during the fourth quarter to  $189.0 \times 10^{-17}$   $\mu\text{Ci}/\text{mL}$  at RWMC during the fourth quarter. Plutonium-238 was detected in one sample collected at RWMC during the fourth quarter. The observed detection for  $^{238}\text{Pu}$  was  $3.1 \times 10^{-17}$   $\mu\text{Ci}/\text{mL}$ . All results were within historical measurements made during the past ten years (2013–2022) except for  $^{241}\text{Am}$  and plutonium results collected at RWMC during the fourth quarter. Plutonium isotopes and  $^{241}\text{Am}$  are known to occur in soils at the SDA. The results observed during the fourth quarter are likely related to work activities occurring at SDA. All results were well below the DCSs for these radionuclides in air (i.e.,  $3.8 \times 10^{-11}$   $\mu\text{Ci}/\text{mL}$  for  $^{137}\text{Cs}$ ,  $9.6 \times 10^{-12}$   $\mu\text{Ci}/\text{mL}$  for  $^{90}\text{Sr}$ ,  $1.1 \times 10^{-13}$   $\mu\text{Ci}/\text{mL}$  for  $^{239/240}\text{Pu}$ , and  $1.3 \times 10^{-13}$   $\mu\text{Ci}/\text{mL}$  for  $^{241}\text{Am}$ ). In addition to the radionuclides discussed earlier, the INL contractor began surveillance monitoring for uranium during 2023. While not enumerated in Table 4-5, detections of uranium radionuclides occur routinely at concentrations that suggest a natural origin (INL 2024c, INL 2024d, INL 2024e). Chlorine-36 was not detected in quarterly composite samples collected from samplers located at MFC in 2023. Natural  $^7\text{Be}$  was detected in numerous INL contractor composite samples at concentrations consistent with past concentrations. Atmospheric  $^7\text{Be}$  results from reactions of galactic cosmic rays and solar energetic particles with nitrogen and oxygen nuclei in Earth's atmosphere.

#### ***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.



**Table 4-5. Human-made radionuclides detected in ambient air samples collected by the INL contractor in 2023.**

RADIONUCLIDE	RESULT <sup>a</sup> (μCi/mL)	LOCATION	GROUP	QUARTER DETECTED
Americium-241	$(1.4 \pm 0.4) \times 10^{-17}$	ATR Complex	Onsite	4 <sup>th</sup>
Americium-241	$(4.5 \pm 0.5) \times 10^{-17}$	RWMC	Onsite	3 <sup>rd</sup>
Americium-241	$(49.7 \pm 4.6) \times 10^{-17}$	RWMC	Onsite	4 <sup>th</sup>
Americium-241	$(3.5 \pm 0.4) \times 10^{-17}$	RWMC (duplicate)	Onsite	3 <sup>rd</sup>
Americium-241	$(23.1 \pm 2.8) \times 10^{-17}$	RWMC (duplicate)	Onsite	4 <sup>th</sup>
Americium-241	$(3.8 \pm 1.0) \times 10^{-17}$	RWMC South	Onsite	4 <sup>th</sup>
Cesium-137	$(29.4 \pm 7.2) \times 10^{-17}$	EFS	Onsite	1 <sup>st</sup>
Cesium-137	$(24.3 \pm 5.4) \times 10^{-17}$	Highway 26 Rest Area	Onsite	1 <sup>st</sup>
Cesium-137	$(21.0 \pm 5.3) \times 10^{-17}$	RWMC South	Onsite	1 <sup>st</sup>
Cesium-137	$(16.7 \pm 5.0) \times 10^{-17}$	SMC	Onsite	1 <sup>st</sup>
Cesium-137	$(13.4 \pm 4.4) \times 10^{-17}$	Van Buren	Onsite	1 <sup>st</sup>
Plutonium-238	$(3.1 \pm 0.7) \times 10^{-17}$	RWMC	Onsite	4 <sup>th</sup>
Plutonium-239/240	$(13.9 \pm 1.9) \times 10^{-17}$	INTEC (duplicate)	Onsite	2 <sup>nd</sup>
Plutonium-239/240	$(10.7 \pm 0.9) \times 10^{-17}$	RWMC	Onsite	3 <sup>rd</sup>
Plutonium-239/240	$(189.0 \pm 12.1) \times 10^{-17}$	RWMC	Onsite	4 <sup>th</sup>
Plutonium-239/240	$(2.8 \pm 0.4) \times 10^{-17}$	RWMC (duplicate)	Onsite	3 <sup>rd</sup>
Plutonium-239/240	$(5.8 \pm 0.8) \times 10^{-17}$	RWMC (duplicate)	Onsite	4 <sup>th</sup>
Plutonium-239/240	$(1.7 \pm 0.4) \times 10^{-17}$	RWMC south	Onsite	4 <sup>th</sup>
Strontium-90	$(5.1 \pm 1.6) \times 10^{-17}$	Arco	Boundary	2 <sup>nd</sup>
Strontium-90	$(9.7 \pm 3.1) \times 10^{-17}$	Blue Dome	Boundary	1 <sup>st</sup>
Strontium-90	$(20.9 \pm 4.4) \times 10^{-17}$	INTEC (west side)	Onsite	2 <sup>nd</sup>
Strontium-90	$(24.7 \pm 4.8) \times 10^{-17}$	SMC	Onsite	1 <sup>st</sup>
Strontium-90	$(2.7 \pm 0.9) \times 10^{-17}$	Van Buren (duplicate)	Onsite	3 <sup>rd</sup>

a. Results  $\pm 1\sigma$ . Results shown are  $\geq 3\sigma$  and below the DCS values for these radionuclides in air.

#### 4.3.4 Atmospheric Moisture Surveillance Monitoring Results

Tritium is monitored in conjunction with the ambient air surveillance monitoring program at specific locations across the INL Site. With a half-life of approximately 12 years, tritium is an important radionuclide because it is a radioactive form of hydrogen, which combines with oxygen to form tritiated water. The most common forms of tritium in air are tritium gas and tritiated water (ANL 2007). The environmental behavior of tritiated water is like that of water, and it can be present in surface water, precipitation, and atmospheric moisture.

Tritium enters the food chain through surface water that animals drink, as well as from plants that contain water (DOE-ID 2021). Tritium can be taken into the body by drinking water, eating food, or breathing air. It can also be taken in through the skin.

During 2023, the INL contractor collected 76 atmospheric moisture samples, as shown in Figure 4-6, at six locations. Tritium was detected in one INL sample  $(11.8 \pm 2.3) \times 10^{-13} \mu\text{Ci}/\text{mL}_{\text{air}}$  at RHLLW on November 14, 2023. The observed tritium concentration is far below the DCS for tritium in air (as water vapor) of  $1.3 \times 10^{-7} \mu\text{Ci}/\text{mL}_{\text{air}}$ .



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 4.3.4). 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 surveillance monitoring stations because of atmospheric dispersion.

### 4.3.5 Precipitation Surveillance 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 79 precipitation samples were collected during 2023 from the four sites. Tritium was detected in eleven samples, and detectable results ranged from 79.7 pCi/L in March to 168 pCi/L in February in Howe. Most detections were near the approximate detection level of 95 pCi/L. Table 4-6 shows the percentage of detections, the concentration range, and the mean and median concentration for each location. The highest concentration is well below the DCS level of  $2.6 \times 10^6$  pCi/L for tritium in water and within the historical range (-173 to 413 pCi/L) measured from 2013–2022.



Figure 4-6. Atmospheric moisture collection columns.

Sampling precipitation for radioactive contaminants is a good way to determine the amount of contamination that is stripped from the air by rain or snow and deposited at ground level (INL 2023b).

Table 4-6. Tritium concentrations in precipitation samples collected by the INL contractor in 2023.<sup>a,b</sup>

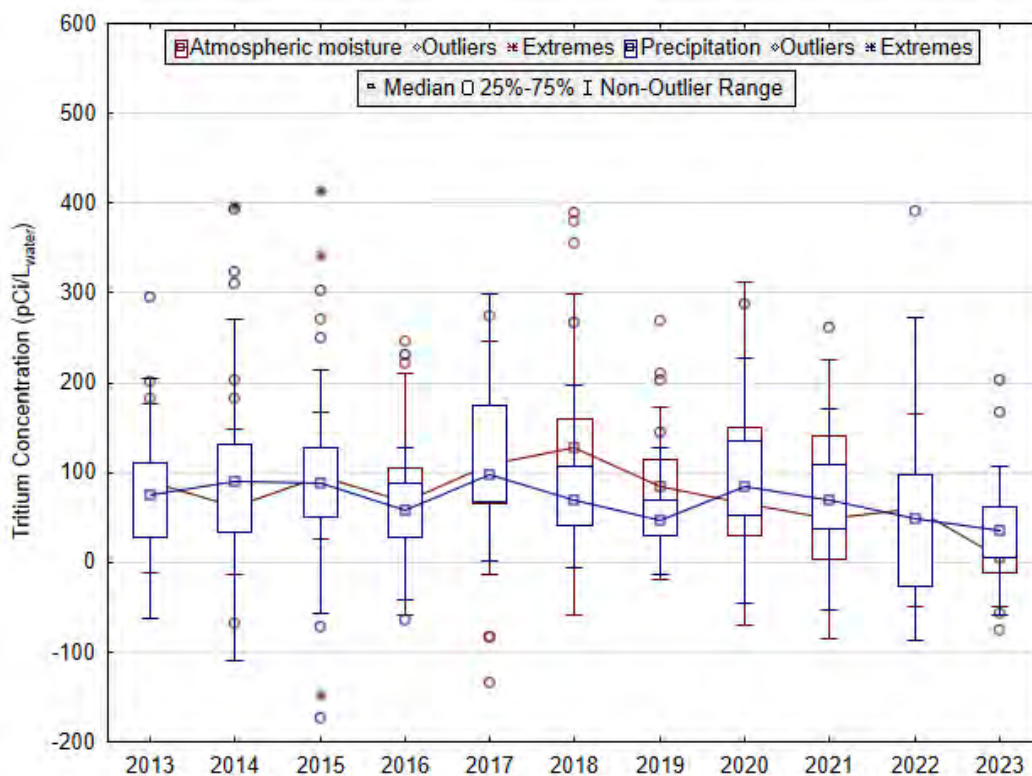
	ATOMIC CITY	EFS	HOWE	IDAHO FALLS
Number of samples	20	25	23	11
Number of detections	3	2	3	3
Detection percentage	15%	8%	13%	27%
Concentration range (pCi/L)	-57.1 ± 24.3 – 115 ± 30	-36.1 ± 24.2 – 145 ± 35.2	-28.2 ± 25.2 – 168 ± 32.4	-31.2 ± 24.7 – 126 ± 30.7
Mean concentration (pCi/L)	23.4	20.1	30.3	35.4
Median concentration (pCi/L)	25.5	14.9	12.6	20.5
Mean detection level (pCi/L)	94.5	94.2	95.2	95.7

- 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 compared with tritium concentrations reported by EPA for precipitation during the 10-year period from 2002–2011 (measurements discontinued after 2011) based on the query of available data ([https://enviro.epa.gov/enviro/erams\\_query\\_v2.simple\\_query](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 non-parametric 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 4-7. 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 4-7. Box plots of tritium concentrations measured in atmospheric moisture and in precipitation from 2013–2023.**

## 4.4 Waste Management Environmental Air Surveillance Monitoring

### 4.4.1 Gross Activity

The ICP contractor conducts environmental surveillance monitoring 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 2023, as observed in Figure 4-8. Samples were also collected at a control location at Howe 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 4-7 shows the median annual and range of gross alpha concentrations at each location. Gross alpha concentrations ranged from a low of  $(0.15 \pm 0.09) \times 10^{-16} \mu\text{Ci/mL}$  collected at location SDA 9.3 on September 14, 2023, to a high of  $(9.18 \pm 0.68) \times 10^{-16} \mu\text{Ci/mL}$ , collected at location SDA 11.3 on February 2, 2023.

**Table 4-7. Median annual gross alpha concentration in air samples collected at waste management sites in 2023.<sup>a</sup>**

GROUP	LOCATION	NO. OF SAMPLES COLLECTED	RANGE OF CONCENTRATIONS ( $\times 10^{-16} \mu\text{Ci/mL}$ )	ANNUAL MEDIAN ( $\times 10^{-16} \mu\text{Ci/mL}$ )
SDA	SDA 1.3	23	0.19 – 6.80	4.46
	SDA 2.3	23	3.35 – 6.18	5.58
	SDA 4.2B/C and 4.3B/C <sup>a</sup>	46	0.82 – 7.09	4.93
	SDA 6.3	23	0.48 – 7.72	4.76
	SDA 9.3	23	0.15 – 6.28	4.90
	SDA 11.3	23	0.65 – 9.18	6.38
ICDF	INT 100.3	23	3.54 – 8.53	5.57
Boundary	HOWE 400.4	23	3.35 – 5.25	4.95

a. Results for SDA 4.2B/C, a replicate of SDA 4.3B/C, are included in the table for 2023 because of mechanical issues with SDA 4.3B/C occurring in 2023.

Table 4-8 shows the annual median and range of gross beta concentrations at each location. Gross beta concentrations ranged from a low of  $(3.20 \pm 0.01) \times 10^{-16} \mu\text{Ci/mL}$  at location HOWE 400.4 on October 2, 2023, to a high of  $(1.0 \pm 0.47) \times 10^{-14} \mu\text{Ci/mL}$  at location SDA 4.3 on December 14, 2023.

**Table 4-8. Median annual gross beta concentration in air samples collected at waste management sites in 2023.<sup>a</sup>**

GROUP	LOCATION	NO. OF SAMPLES COLLECTED	RANGE OF CONCENTRATIONS ( $\times 10^{-15} \mu\text{Ci/mL}$ )	ANNUAL MEDIAN ( $\times 10^{-15} \mu\text{Ci/mL}$ )
SDA	SDA 1.3	23	0.52 – 8.06	5.92
	SDA 2.3	23	0.49 – 8.55	5.46
	SDA 4.2B/C and 4.3B/C <sup>a</sup>	46	1.90 – 10.08	6.15
	SDA 6.3	23	0.56 – 9.40	5.90
	SDA 9.3	23	0.40 – 7.07	6.12
	SDA 11.3	23	0.52 – 9.06	5.92
ICDF	INT 100.3	23	0.60 – 8.30	6.60
Boundary	HOWE 400.4	23	0.32 – 9.41	6.17

a. Results for SDA 4.2B/C, a replicate of SDA 4.3B/C, are included in the table for 2023 because of mechanical issues with SDA 4.3B/C occurring in 2023.

The 2023 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. 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 shown in Figure 4-8 and 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 2023, no human-made, beta-emitting, gamma-emitting, or alpha-emitting radionuclides were detected in air samples at ICDF at INTEC. No gamma emitting or beta-emitting radionuclides were detected in air samples at the RWMC SDA.

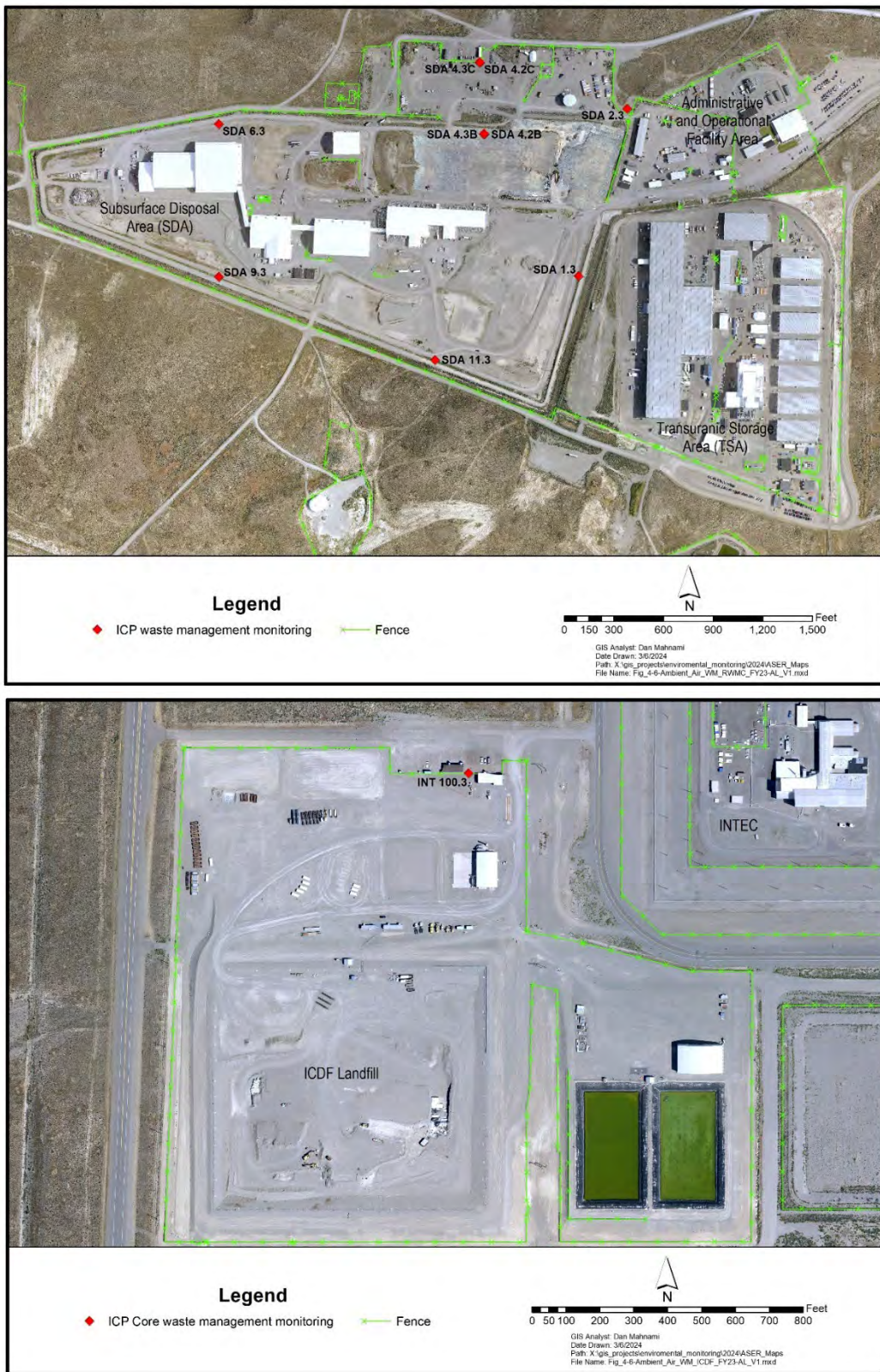
Table 4-9 shows human-made specific radionuclides detected at the SDA in 2023. There were no human-made radionuclides detected at INTEC in 2023. These detections are consistent with levels measured in the air at the SDA in previous years. All detections were three to four orders of magnitude below the DCS (stipulated in DOE 2022) 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 4-9, detections of uranium radionuclides occur routinely at concentrations that suggest a natural origin.

Radionuclides were not analyzed in the first, second, or third quarters of 2023 because of a miscommunication in the contract with GEL when lab analysis changed from ALS. Radionuclide analysis was written as requested instead of being composited quarterly by default. Fourth quarter results are referenced in Table 4-9. Corrective actions have been set in place to ensure the lab knows which samples to composite and the appropriate schedule. Power supply issues to the monitoring locations are being addressed. Bi-weekly gross alpha and gross beta results of samples collected during the quarters for which radionuclide-specific composites were missing were comparable with historical results, which suggest that concentrations of specific radionuclides were well below DCSs for that period. Additionally, monthly NESHAP environmental air measurement samples located in the predominant downwind direction were analyzed to determine that no statistically positive detections were observed.

**Table 4-9. Fourth quarter radionuclide concentrations in air samples collected at waste management sites in 2023.**

RADIONUCLIDE	LOCATION	RESULT ( $\mu\text{Ci/mL}$ )	UNCERTAINTY (1 SIGMA)
Americium-241	SDA 1.3	1.31E-15	1.37E-15
	SDA 11.3	3.10E-16	5.37E-16
	SDA 2.3	7.04E-17	1.69E-17
Plutonium-238	SDA 4.3C	1.02E-16	8.98E-17
Plutonium-239/240	SDA 2.3	8.29E-17	1.04E-17
	SDA 4.2C	5.18E-17	8.29E-18
Strontium-90	SDA 6.3	2.35E-16	1.32E-16



**Figure 4-8. Locations of ICP contractor low-volume air samplers at waste management areas (SDA [top] and ICDF [bottom]).**





## 4.5 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 consumption of HFCs. This is not a phaseout of HFC production, it is a phasedown. The end goal is an 85% reduction in production by 2036 as compared to the 2013 production baseline (OE-3 2021-06) (Table 4-10). This will decrease the availability of HFCs and increase the cost but HFCs will still be available. The EPA recently finalized regulations restricting the use of some HFCs in certain applications; the compliance dates vary depending on the application. As with the phasedown regulations, the EPA is not prohibiting or restricting the use of existing equipment.

**Table 4-10. HFC Phasedown Schedule (OE-3 2021-06).**

YEARS	PERCENT OF BASELINE	PERCENT REDUCTION
2011–2013 (Baseline)	100%	0%
2020–2023	90%	10%
2024–2028	60%	40%
2029–2033	30%	70%
2034–2035	20%	80%
2036 onwards	15%	85%

### 4.5.1 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, 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.

A list of equipment containing HFCs was obtained in March 2022. The list includes 46 HVAC systems that contain 50 pounds or more of refrigerant, 26 computer room air conditioning units, six fire protection systems, and 158 chillers, condensing units, etc., for laboratory equipment. There are currently no changes to operations because this is a phasedown, not a phaseout and the EPA is not prohibiting the use of existing equipment.



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 within the DOE Complex.

#### 4.5.2 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 (IWTU). The total charge for both chillers is approximately 830 lb. These units will continue to be used for the IWTU 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.

## 4.6 References

- 40 CFR 61, Subpart H, 2023, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities," Code of Federal Regulations, Office of the Federal Register, National Archives and Records Administration, Washington, D.C., <https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-61/subpart-H>.
- ANL 2007, "Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas," March 2007, Environmental Science Division, Argonne National Laboratory, Argonne, IL, [https://remm.hhs.gov/ANL\\_ContaminantFactSheets\\_All\\_070418.pdf](https://remm.hhs.gov/ANL_ContaminantFactSheets_All_070418.pdf).
- Cauquoin, A., P. Jean-Baptiste, C. Risia, É. Fourré, B. Stenni, and A. Landais, 2015, "The global distribution of natural tritium in precipitation simulated with an Atmospheric General Circulation Model and comparison with observations," *Earth Planet. Sci. Lett.*, 427:160–170, <https://doi.org/10.1016/j.epsl.2015.06.043>.
- Clawson, K. L., J. D. Rich, R. M. Eckman, N. F. Hukari, D. Finn, and B. R. Reese, 2018, "Climatology of the Idaho National Laboratory," 4th Edition, National Oceanic and Atmospheric Organization (NOAA) Technical Memorandum Oceanic and Atmospheric Research (OAR) Air Resources Laboratory (ARL) 278, NOAA, Washington, D.C., <https://doi.org/10.25923/ze6p-4e52>.
- DOE, 2015, "Environmental Radiological Effluent Monitoring and Environmental Surveillance," DOE-HDBK-1216-2015 Chg Notice 1 (Reaffirmed 2022), September 2022, U.S. Department of Energy, Washington, D.C., [https://www.standards.doe.gov/standards-documents/1200/1216-hdbk-2015-cn1-2022-reaff-2022/@\\_@images/file](https://www.standards.doe.gov/standards-documents/1200/1216-hdbk-2015-cn1-2022-reaff-2022/@_@images/file).
- DOE, 2022, "Derived Concentration Technical Standard," DOE-STD-1196-2022, December 2022, U.S. Department of Energy, Washington, D.C., [https://www.standards.doe.gov/standards-documents/1100/1196-astd-2022/@\\_@images/file](https://www.standards.doe.gov/standards-documents/1100/1196-astd-2022/@_@images/file).
- DOE O 435.1, 2001, "Radioactive Waste Management," Change 2, U.S. Department of Energy, Washington, D.C., [https://directives.dev.doxcelerate.com/directives-documents/400-series/0435.1-BOrder-chg2-AdminChg/@\\_@images/file](https://directives.dev.doxcelerate.com/directives-documents/400-series/0435.1-BOrder-chg2-AdminChg/@_@images/file).
- DOE O 458.1, 2020, "Radiation Protection of the Public and the Environment," Administrative Change 4, U.S. Department of Energy, Washington, D.C., [https://www.directives.doe.gov/directives-documents/400-series/0458.1-BOrder-chg4-ltdchg/@\\_@images/file](https://www.directives.doe.gov/directives-documents/400-series/0458.1-BOrder-chg4-ltdchg/@_@images/file).
- DOE-ID, 2021, "Idaho National Laboratory Site Environmental Monitoring Plan," DOE/ID-11088, Rev. 5, April 2021, U.S. Department of Energy Idaho Operations Office, Idaho Falls, ID, <https://inl.gov/content/uploads/2023/08/DOEID-11088-Rev-5-1.pdf>.



- DOE-ID, 2024, “National Emissions Standards for Hazardous Air Pollutants—Calendar Year 2023 INL Report for Radionuclides,” DOE/ID-11441, U.S. Department of Energy, Idaho Operations Office, Idaho Falls, ID.
- INL 2019, “Assessment of INL Ambient Air Radiological Monitoring for Idaho Falls Facilities,” INL/EXT-19-53491, Idaho National Laboratory, Idaho Falls, ID.
- INL 2023a, “Update of Receptor Locations for INL National Emissions Standard for Hazardous Air Pollutants (NESHAP) Assessments,” INL/RPT-23-72759, Idaho National Laboratory, Idaho Falls, ID.
- INL 2023b, “Data Quality Objectives Summary Report Supporting Radiological Air Surveillance Monitoring for the INL Site,” INL/MIS-15-34927, Rev. 1, Idaho National Laboratory, Idaho Falls, ID.
- INL 2024a, “Idaho National Laboratory CY 2023 National Emission Standards for Hazardous Air Pollutants Analysis, Methodology and Results for Radionuclides,” INL/RPT-24-78717, Idaho National Laboratory, Idaho Falls, ID.
- INL, 2024b, “Idaho National Laboratory Surveillance Program Report: First Quarter 2023,” INL/RPT-23-74742, Idaho National Laboratory, Idaho Falls, ID.
- INL, 2024c, “Idaho National Laboratory Surveillance Program Report: Second Quarter 2023,” INL/RPT-23-75715, Idaho National Laboratory, Idaho Falls, ID.
- INL, 2024d, “Idaho National Laboratory Surveillance Program Report: Third Quarter 2023,” INL/RPT-24-77413, Idaho National Laboratory, Idaho Falls, ID.
- INL, 2024e, “Idaho National Laboratory Surveillance Program Report: Fourth Quarter 2023,” INL/RPT-24-77055, Idaho National Laboratory, Idaho Falls, ID.
- OE-3 2021-06, 2021, “Hydrofluorocarbon Phasedown,” December 2021, Office of Environmental, Health, Safety and Security, Washington, D.C., <https://www.energy.gov/ehss/oe-3-2021-06-hydrofluorocarbon-phasedown>.
- Rood, A. S., A. J. Sondrup, and P. D. Ritter, 2016, “Quantitative evaluation of an air monitoring network using atmospheric transport modeling and frequency of detection methods,” *Health Phys.*, 110(4):311–327, <http://dx.doi.org/10.1097/HP.0000000000000466>.



*Sage thrasher (special status bird)*