Chapter 4: Environmental Monitoring Programs - Air

CHAPTER 4

An estimated total of 1,076 Ci (3.98×10^{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 2021. The highest contributors to the total release were the Advanced Test Reactor Complex at 76.9%, Materials and Fuel Complex at 17.4%, and Radioactive Waste Management Complex at 4.5%. Other INL Site facilities each contributed less than 1% to the total. The estimated maximum potential dose to a member of the public from all INL Site releases (0.067 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 on the INL Site, at INL Site boundary locations, and at distant communities, and were analyzed for radioactivity in 2021.

Particulates were filtered from 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, 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 to protect human health and the environment. Gross alpha and gross beta activities were used primarily for trend analyses and indicated that fluctuations were observable that correlate with seasonal variations in natural radioactivity.

Specific gamma-emitting (primarily cesium-137) radionuclides were not detected by either the Environmental Surveillance, Education, and Research Program contractor or the INL contractor during 2021. Strontium-90 was detected in eight quarterly composited samples during 2021. Plutonium-239/240 was detected in a quarterly composited sample collected along the INL Site boundary during the fourth quarter. All concentrations were within historical measurements made during the past ten years (2011-2020) and well below the DCSs for these radionuclides. Plutonium-238 and americium-241 were not detected in any quarterly composite samples during 2021.

Airborne particulates were also collected biweekly around the perimeters of the Subsurface Disposal Area at the Radioactive Waste Management Complex and the Idaho Comprehensive Environmental Response, Compensation, and Liability Act Disposal Facility at the Idaho Nuclear Technology and Engineering Center. Gross alpha and gross beta activities measured on the filters were comparable with historical results, and no new trends were identified in 2021. Detections of americium and plutonium isotopes were 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 and not INL Site releases. All measured results were below health-based regulatory limits.

4. ENVIRONMENTAL MONITORING PROGRAMS: AIR

Although all Idaho National Laboratory (INL) Site facilities are carefully managed and controlled the potential to release radioactive and nonradioactive hazardous constituents in amounts above regulatory limits during an operational upset or emergency incident situation still exists. In such an event, pathway vectors, such as air, soil, plants, animals, and groundwater, may transport these constituents to nearby populations, as observed in Figure 4-1. 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 is in compliance 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 contractor; the Idaho Cleanup Project (ICP) Core contractor; and the Environmental Surveillance, Education, and Research (ESER) Program contractor. Table 4-1 summarizes the radiological air monitoring activities on and off the INL Site. Details may be found in the INL Site Environmental Monitoring Plan (DOE-ID 2017).

4.1 Organization of Air Monitoring Programs

The INL contractor documents airborne radiological effluents at 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 2021 INL Report for Radionuclides* (DOE-ID 2022), 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, ICP Core, and ESER contractors to ensure that the INL Site remains in compliance with U.S. Department of Energy (DOE) O 458.1, "Radiation Protection of the Public and the Environment."

The INL contractor collects air samples primarily on the INL Site, as observed in Figure 4-2. In 2021, the INL contractor collected approximately 1,460 air samples (including duplicate samples and blanks) for various radiological analyses. Air moisture samples were collected at four sites for tritium analysis.

The ICP Core contractor collects air samples primarily on the INL Site at Remote Handled Low-Level Waste (RHLLW) disposal facilities subject to DOE O 435.1, "Radioactive Waste Management," and downwind of facilities subject to an EPA-approved alternative for the National Emission Standards for Hazardous Air Pollutants (NESHAP) air monitoring method in accordance with 40 CFR 61.93(g). In 2021, the ICP Core contractor collected approximately 280 air samples (including duplicate samples) for various radionuclide analyses.

The ESER 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 2021, the ESER contractor collected approximately 775 air samples (including duplicate samples and blanks) for various radionuclide analyses. The ESER contractor also collects air moisture and precipitation samples at four locations for tritium analysis.

In December 2020, DOE initiated transition of the ESER Program from DOE management to the INL contract managed by Battelle Energy Alliance, LLC (BEA). A team composed of DOE, BEA, and the ESER Program contractor, Veolia Nuclear Solutions – Federal Services (VNSFS), successfully transitioned the Program on September 30, 2021, and it is now called the Environmental Monitoring & Natural Resource Services. The ESER Program environmental surveillance scope has been integrated into the INL environmental surveillance program. Sampling activities conducted prior to September 30, 2021, were performed by VNSFS and the results are presented in this chapter under the ESER contractor. Sampling activities conducted after September 30, 2021, were performed under BEA and are presented in this chapter under the INL contractor.

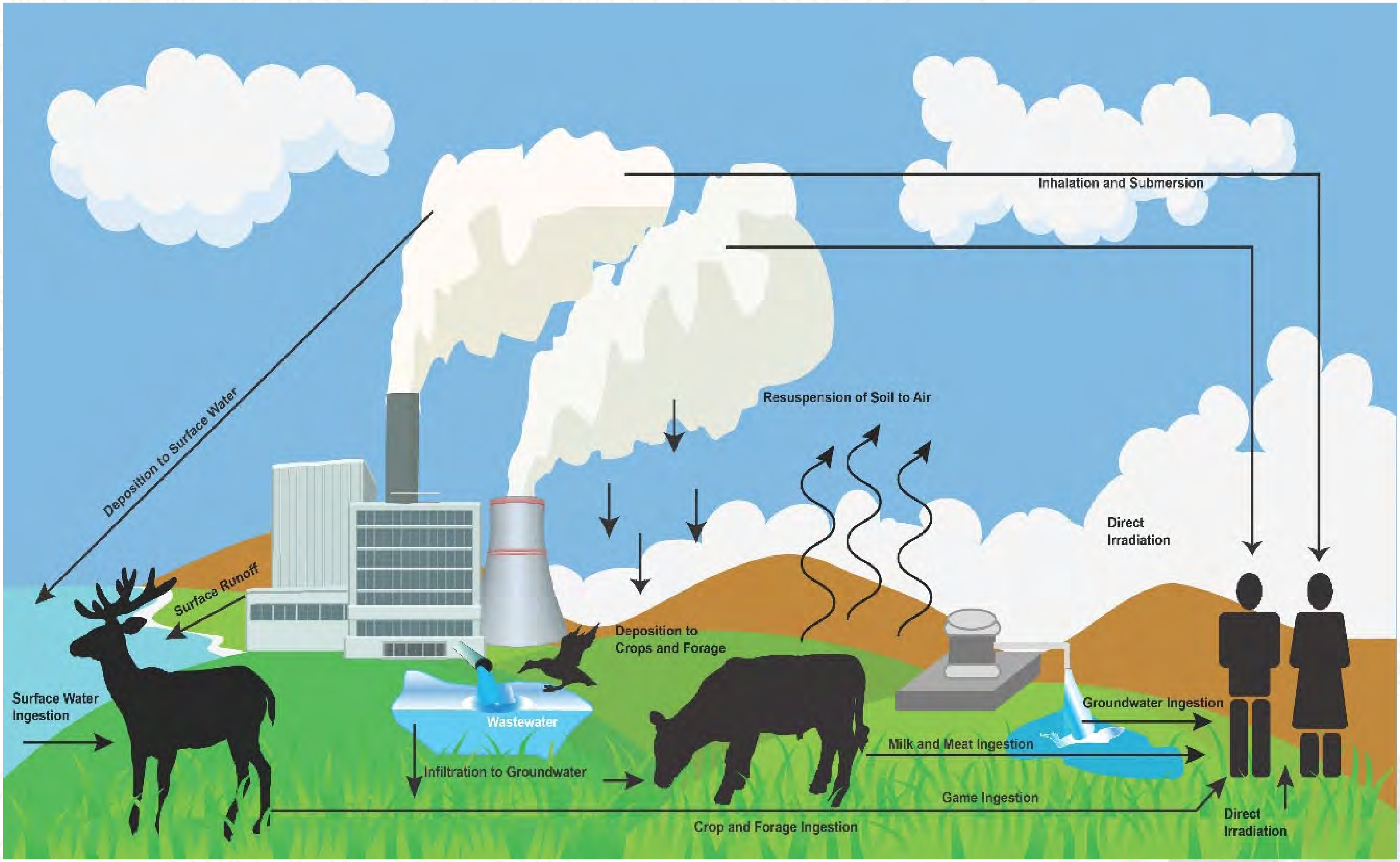


Figure 4-1. Potential exposure pathways to humans from the INL Site.

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

AREA/FACILITY[a]	AIRBORNE EFFLUENT MONITORING PROGRAMS	ENVIRONMENTAL SURVEILLANCE PROGRAMS					
	AIRBORNE EFFLUENTS[b]	LOW-VOLUME CHARCOAL CARTRIDGES (^{131}I)	LOW-VOLUME GROSS ALPHA	LOW-VOLUME GROSS BETA	SPECIFIC RADIONUCLIDES[c]	ATMOSPHERIC MOISTURE	PRECIPITATION
ICP CORE CONTRACTOR[d]							
INTEC	●		●	●	●		
RWMC	●		●	●	●		
INL CONTRACTOR[e]							
MFC	●						
INL Site/Regional		●	●	●	●	●	
ESER CONTRACTOR[f]							
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 2021 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 Core contractor monthly and by the ESER contractor and the INL contractor quarterly. Strontium-90, plutonium-238, plutonium-239/240, and americium-241 are measured by the INL, ICP Core, and ESER contractors quarterly.

d. The ICP Core contractor monitors waste management facilities to demonstrate compliance with DOE O 435.1, "Radioactive Waste Management." Also, 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 ambient air outside INL Site facilities to demonstrate compliance with DOE O 458.1, "Radiation Protection of the Public and the Environment."

f. The ESER contractor collects samples on, around, and distant from the INL Site to demonstrate compliance with DOE O 458.1.

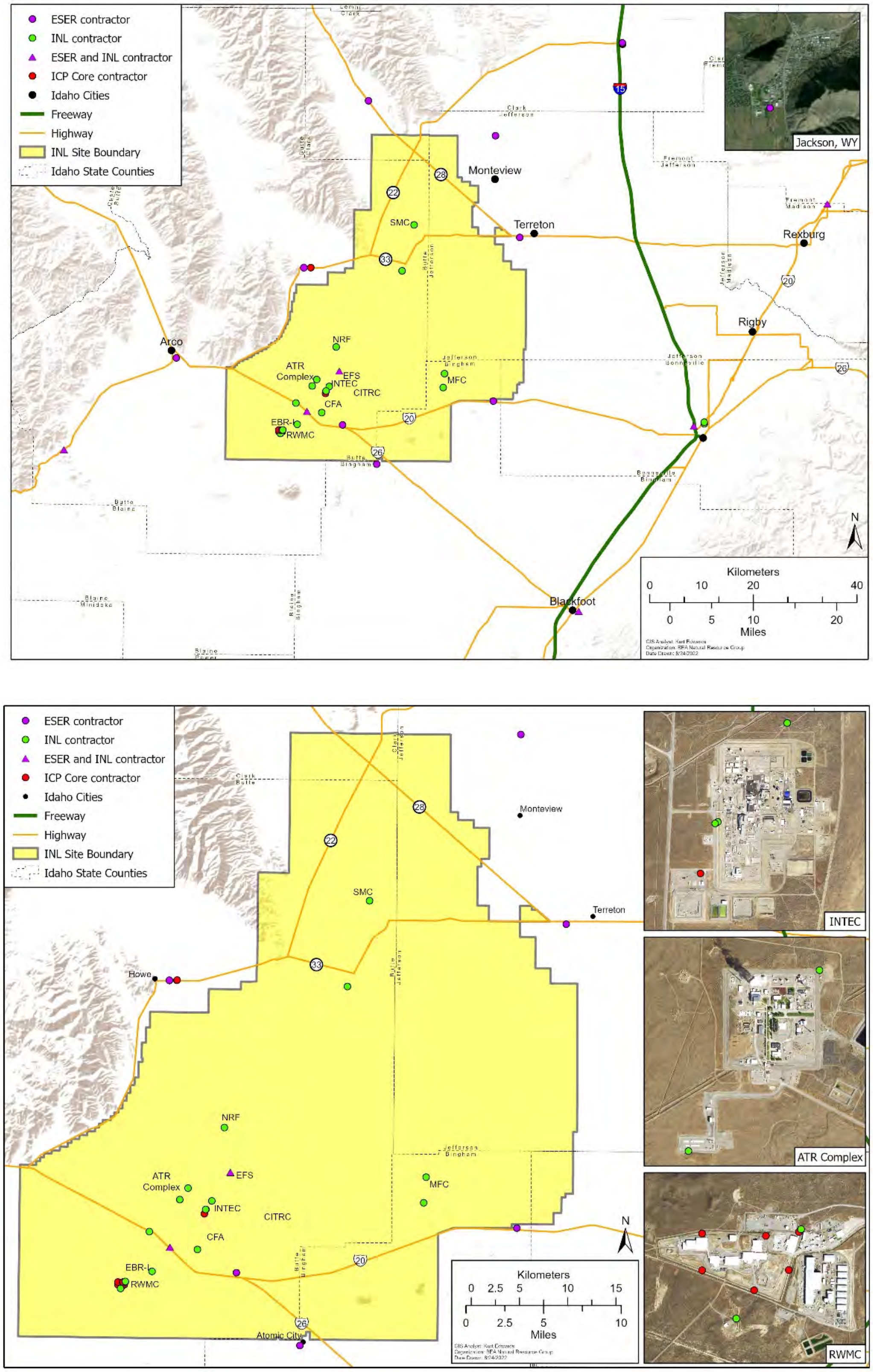


Figure 4-2. INL Site environmental surveillance radiological air sampling locations (regional [top] and on the INL Site [bottom]).

The ICP Core contractor monitors air around waste management facilities to comply with DOE O 435.1, "Radioactive Waste Management." These facilities are the Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex (RWMC) and the Idaho Comprehensive Environmental Response, Compensation, and Liability Act Disposal Facility (ICDF) near the Idaho Nuclear Technology and Engineering Center (INTEC). These locations are shown in Figure 4-2. Section 4.4 discusses air sampling by the ICP Core contractor in support of waste management activities. In 2021, the ICP Core 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 for use 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 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 Field Research Division to scientists modeling the dispersion of INL Site releases and resulting potential dose impact (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 2021 are reported in the NESHAP Modeling Report (INL 2022) and the NESHAP Report (DOE-ID 2022).

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 (AMWTP), 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 2021, an estimated 1,076 Ci (3.98×10^{13} Bq) of radioactivity was released to the atmosphere from all INL Site sources. The 2021 release is 34% lower than the estimated total of 1,628 Ci (6.02×10^{13} Bq) released in 2020. The reduction is primarily the result of shutdown of the Advanced Test Reactor (ATR) during most of 2021 for refurbishment of the reactor core.

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

- ***ATR Complex Emissions Sources (76.9% of total INL Site source term).*** Radiological air emissions from the ATR Complex are primarily associated with 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, 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.

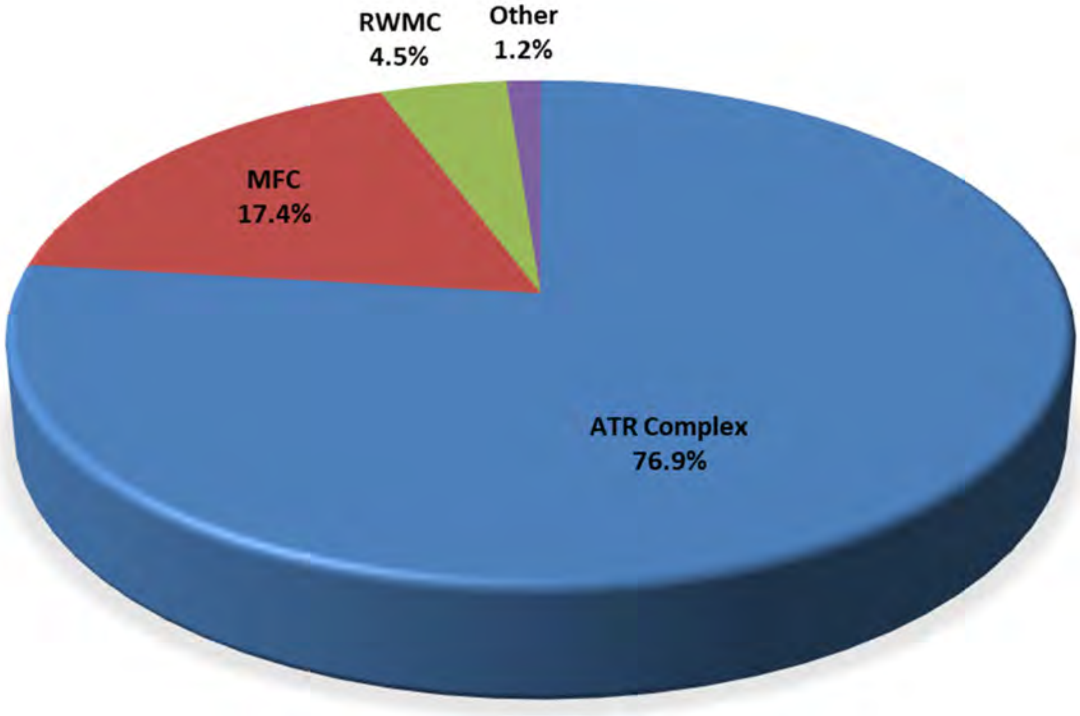


Figure 4-3. Percent contributions in Ci, by facility, to total INL Site airborne radiological releases (2021).

- ***MFC Emissions Sources (17.4% 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 in excess of 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 (TREAT), 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.
- ***RWMC Emissions Sources (4.5% 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 (RCRA) permitted Sludge Repackage waste processing project; storage of waste within the Type II storage modules at AMWTP; storage and characterization of waste at the Drum Vent and Characterization facilities; and storage and treatment of wastes at the Transuranic Storage Area-Retrieval Enclosure (WMF-636) and the Advanced Mixed Waste Treatment Facility (WMF-676). Data from 13 emission sources (both point and diffuse) at RWMC were reported in the 2021 NESHAP Report for Radionuclides (DOE-ID 2022), including three continuously monitored point sources. WMF-676 has two continuously monitored stacks, while WMF-636 has one continuously monitored stack. Monitoring of the radionuclide emissions 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 associated with buried beryllium blocks at the SDA. Releases of transuranic radionuclides 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.

Table 4-2. Radionuclide composition of INL Site airborne effluents (2021).[a]

		AIRBORNE EFFLUENT (Ci)[b]								
RADIONUCLIDE[c]	HALF-LIFE[d]	ATR COMPLEX[e]	CFA[e]	CITRC[e]	INTEC[e]	MFC[e]	NRF[e]	RWMC[e]	TAN[e]	TOTAL
Americium-241	432.2 y	2.25E-05	NS[f]	—[g]	3.14E-04	NS	—	1.05E-04	—	4.41E-04
Argon-41	1.83 h	3.47E+02	NS	—	—	8.09E+01	—	—	NS	4.28E+02
Bromine-82	1.47 d	—	NS	—	—	—	—	—	1.03E+01	1.03E+01
Carbon-14	5730 y	NS	NS	—	3.15E-02	—	5.50E-01	2.22E-02	—	6.04E-01
Chlorine-36	3.01E+05 y	—	—	—	5.02E-06	7.19E-03	—	—	NS	7.19E-03
Cobalt-60	5.271 y	7.08E-03	NS	—	1.64E-05	NS	—	NS	—	7.08E-03
Cesium-137	30.2 y	5.52E-03	NS	—	2.17E-04	2.60E-01	6.30E-05	NS	—	2.66E-01
Gallium-68	67.7 m	—	—	2.20E-08	—	—	—	—	—	2.20E-08
Hydrogen-3 (tritium)	12.3 y	4.55E+02	5.19E-01	—	1.61E-01	NS	NS	4.81E+01	NS	5.04E+02
Iodine-129	1.57E+07 y	NS	NS	—	7.30E-05	NS	NS	—	—	7.30E-05
Iodine-131	8.02 d	NS	NS	—	—	9.40E-02	NS	—	—	9.40E-02
Potassium-42	12.4 h	—	—	—	—	—	—	—	2.80E-01	2.80E-01
Krypton-88	2.84 h	NS	3.75E-03	—	—	9.51E+00	—	—	—	9.51E+00
Plutonium-238	87.7 y	NS	NS	—	2.12E-06	NS	—	2.37E-06	—	4.49E-06
Plutonium-239	24,065 y	8.46E-06	NS	—	1.16E-04	NS	3.80E-06	4.14E-05	—	1.70E-04
Plutonium-240	6,537 y	NS	NS	—	1.15E-04	NS	—	1.13E-05	—	1.26E-04
Plutonium-241	14.3 y	NS	NS	—	1.00E-04	NS	—	—	—	1.00E-04
Strontium-90	29.12 y	2.65E-02	NS	—	5.28E-05	NS	6.90E-05	NS	NS	2.66E-02
Uranium-234	2.46E+05 y	NS	NS	—	NS	6.52E-02	—	—	NS	6.52E-02
Uranium-235	7.04E+08 y	NS	NS	—	NS	2.19E-02	—	NS	NS	2.19E-02
Uranium-238	4.5E+09 y	NS	NS	—	NS	1.10E-01	—	NS	NS	1.10E-01
Xenon-135	9.09 h	NS	6.30E-02	—	—	NS	—	—	—	6.30E-02
Zinc-65	243.7 d	NS	NS	—	NS	3.32E-01	—	—	NS	3.32E-01

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]	RWMC[e]	TAN[e]	TOTAL
TOTAL CI RELEASED[h]		**8.02E+02**	**5.86E-01**	**2.20E-08**	**1.93E-01**	**9.13E+01**	**5.50E-01**	**4.81E+01**	**1.06E+01**	**9.54E+02**
DOSE (MREM)[i]		**9.69E-04**	**2.13E-06**	**3.96E-15**	**1.07E-04**	**6.48E-02**	**7.33E-05**	**4.27E-04**	**3.51E-04**	**6.67E-02**

a. Radionuclide release information provided by the INL contractor (INL 2022).

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, RWMC = Radioactive Waste Management Complex (including Advanced Mixed Waste Treatment Project and Accelerated Retrieval Projects), TAN = Test Area North (includes emissions from Specific Manufacturing Capability and Radiological Response Training Range-Northern Test Range).

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 2021.

h. Total curies may be less than the total curies in Table 8-1 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.

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.

- ***Test Area North Emissions Sources (0.99% of total INL Site source term).*** Emissions sources at Test Area North (TAN) are the Specific Manufacturing Capability (SMC) project, the New Pump and Treat Facility, and the nearby Northern Test Range of the Radiological Response Training Range. Radiological air emissions from the SMC project are associated with processing of depleted uranium. Potential emissions are uranium isotopes. 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. Emissions from the Radiological Response Training Range are the result of training activities such as contamination control, site characterization, and field sampling techniques for response to radiological incidents using mostly short-lived radioactive materials.
- ***INTEC Emissions Sources (0.12% 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 (0.049% 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 (0.000000002% 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 2021 due to the curtailment of some activities as a result 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. The estimated dose to the MEI in Calendar Year 2021 was 0.067 mrem/yr (0.67 µSv/yr) which is below the regulatory standard of 10 mrem/yr. Five radionuclides—cesium-137 (^{137}Cs), uranium-238 (^{238}U), uranium-234 (^{234}U), zinc-65 (^{65}Zn), and chlorine-36 (^{36}Cl)—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 that ozone-depleting substances have historically been used in, 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, therefore, the consumption of HFCs.

In addition, the INL contractor is participating in the voluntary HFC task team lead 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 is currently working on writing an Operating Experience Summary for the DOE complex that will provide information on operational impacts to critical systems from these regulations that will decrease the amount of HFCs manufactured in the future. 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, 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. Two hundred thirty-six pieces of equipment and systems were identified.

In addition, the INL contractor is participating in the voluntary HFC task team lead 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.

4.2.1.2 ICP Core Contractor

An inventory of refrigeration equipment at ICP Core facilities, using those HFCs scheduled for phasedown, was conducted in December 2021. This activity identified two chillers (four circuits total) using R-134a at the Integrated Waste Treatment Unit (IWTU). The total charge for both chillers is approximately 830 lbs. These units will continue to be used for the IWTU mission. ICP Core preventative maintenance practices will minimize the potential for leaks. ICP Core 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 R-134a rendering the units inoperable, they would be replaced or retrofitted. New equipment at ICP Core will be specified to use refrigerants that are not subject to the HFC phasedown.

4.3 Ambient Air Monitoring

Ambient air monitoring is conducted on and off the INL Site to identify regional and historical trends, to detect accidental and unplanned releases, and to determine if air concentrations are below derived concentration standards (DCSs) established by DOE for inhaled air (DOE 2011). 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, one high-volume air sampler, eight atmospheric moisture samplers, and four precipitation samplers operated in the network in 2021, 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 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 (e.g., 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 performance of the network. In 2019, the frequency of detection method was used to evaluate the Idaho Falls facilities (INL 2019), with the result being 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 (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 also 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 highest projected air concentration. Atomic City and Howe are 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. This is 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 ESER contractor during the 10-year period from 2009 through 2018 were compared statistically; results indicate there are no differences between the data sets. For this reason, ESER precipitation samplers were placed at the same locations as the ESER atmospheric moisture samplers at Atomic City, EFS, Howe, and Idaho Falls. In addition, Idaho Falls can be easily and readily accessed by ESER personnel after a precipitation event. The EPA has a precipitation sampler in Idaho Falls and subsamples are collected for the ESER Program.

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 when an event occurs, such as a range fire or unplanned release of radioactivity.

Table 4-3. INL Site and regional ambient air monitoring summary (2021).

MEDIUM SAMPLED	TYPE OF ANALYSIS	FREQUENCY	NUMBER OF LOCATIONS: ONSITE			NUMBER OF LOCATIONS: OFFSITE			MINIMUM DETECTABLE CONCENTRATION (MDC)
			INL[a]	ESER[b]	*TOTAL*	INL[a]	ESER[b]	*TOTAL*	
Air (low volume)	Gross alpha	Weekly	16	3	**19**	6	13	**19**	1E-15 µCi/mL
	Gross beta	Weekly	16	3	**19**	6	13	**19**	2E-15 µCi/mL
	Specific gamma[c]	Quarterly	16	3	**19**	6	13	**19**	2E-16 µCi/mL
	Plutonium-238	Quarterly	16	1-2	**17-18**	6	4	**10**	3.5E-18 µCi/mL
	Plutonium-239/240	Quarterly	16	1-2	**17-18**	6	4	**10**	3.5E-18 µCi/mL
	Americium-241	Quarterly	16	1-2	**17-18**	6	4	**10**	4.6E-18 µCi/mL
	Strontium-90	Quarterly	16	1-2	**17-18**	6	4	**10**	3.4E-17 µCi/mL

Table 4-3. continued.

MEDIUM SAMPLED	TYPE OF ANALYSIS	FREQUENCY	NUMBER OF LOCATIONS						MINIMUM DETECTABLE CONCENTRATION (MDC)
			ONSITE			OFFSITE			
			INL[a]	ESER[b]	*TOTAL*	INL[a]	ESER[b]	*TOTAL*	
	Iodine-131	Weekly	16	3	**19**	6	13	**19**	1.5E-15 µCi/mL
	Total particulates	Weekly	–	3	**3**	–	13	**13**	10 µg/m^3
Air (high volume)[d]	Gross beta scan	Biweekly	–	–	**–**	–	1	**1**	1E-15 µCi/mL
	Gamma scan	Continuous	–	–	**–**	–	1	**1**	Not applicable
	Specific gamma[c]	Annually[e]	–	–	**–**	–	1	**1**	1E-14 µCi/mL
	Isotopic Uranium & Plutonium	Every 4 yrs	–	–	**–**	–	1	**1**	2E-18 µCi/mL
Air (atmospheric moisture)[f]	Tritium	3–6/Quarter	2	1	**3**	2	3	**5**	2E-13 µCi/mL (air)
Air (precipitation)[g]	Tritium	Monthly	–	0	**0**	–	1	**1**	88 pCi/L
		Weekly	–	1	**1**	–	2	**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, MFC (two air samplers), NRF, RWMC (two air samplers), Specific Manufacturing Capability (SMC), and Van Buren Boulevard. In addition, there are two rotating duplicate samplers for QA. In 2021, the samplers were located at INTEC (Westside) and RWMC. The INL contractor also samples offsite (i.e., outside INL Site boundaries) at Blackfoot, Craters of the Moon, Idaho Falls, INL Research Center (IRC) (two air samplers), and Sugar City. This table does not include high volume 'event' monitoring by the INL contractor.

b. The ESER contractor operates low volume samplers on the INL Site at Main Gate, EFS, and Van Buren Blvd. Offsite locations include Arco, Atomic City, Blackfoot, Blue Dome, Craters of the Moon, Dubois, Federal Aviation Administration Tower, Howe, Idaho Falls, Jackson (WY), Monteview, Mud Lake, and Sugar City. In addition, there are two rotating duplicate samplers for quality assurance. In 2021, these were placed at Arco and Mud Lake.

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 ESER 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 by the ESER and INL contractors, and at Van Buren Boulevard by the INL contractor. Samples are collected offsite at Atomic City by ESER, at Craters of the Moon by INL, at Howe by ESER, and at Idaho Falls by the ESER and INL contractors.

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

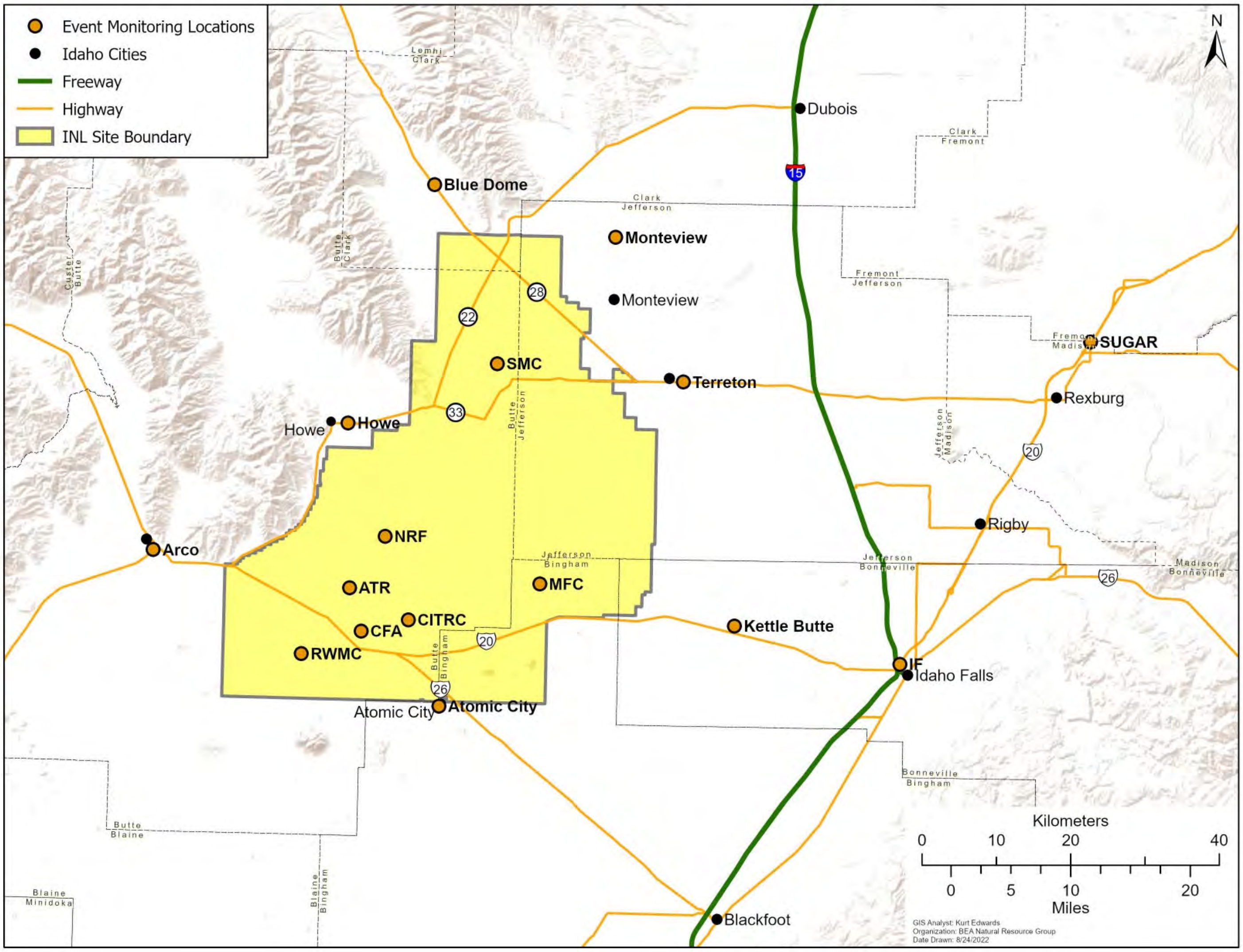


Figure 4-4. Locations of INL contractor high-volume event monitors at NOAA weather stations.

4.3.2 Air Particulate, Radioiodine, and Tritium Sampling Methods

4.3.2.1 Air Particulates

Filters are collected weekly by the INL and ESER contractors 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 ESER and INL contractors for laboratory analysis of gamma-emitting radionuclides, such as ^{137}Cs, which is a man-made radionuclide present in soil both on and off the INL Site 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 ESER and INL contractors also use a contract laboratory to radiochemically analyze quarterly composited samples for selected alpha- and beta-emitting radionuclides. These radionuclides include ^{241}Am, ^{238}Pu, $^{239/240}$Pu, 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. ESER 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 and ESER contractors at the same locations described 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 ESER and INL contractors monitor tritium in atmospheric water vapor in ambient air on the INL Site at EFS and Van Buren Boulevard and off the INL Site 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 when 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 ESER and INL contractors at Atomic City, EFS, Howe, and Idaho Falls and are analyzed for tritium using liquid scintillation counting.

4.3.3 Ambient Air Monitoring Results

Gaseous Radioiodines – The INL contractor collected and analyzed approximately 1,460 charcoal cartridges (including blanks and duplicates) in 2021. There were no statistically positive measurements of ^{131}I. During 2021, the ESER contractor analyzed approximately 775 cartridges (including blanks and duplicate samples), usually in batches of 10 cartridges, looking specifically for ^{131}I. Analyses of cartridges found no detectable ^{131}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}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 data also 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 INL and ESER contractors 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 in 2021.

GROUP	LOCATION[a]	NO. OF SAMPLES[b]	RANGE OF CONCENTRATIONS[c] ($\times 10^{-15}$ µCi/mL)	ANNUAL MEDIAN CONCENTRATION ($\times 10^{-15}$ µCi/mL)
ESER CONTRACTOR				
Distant	Blackfoot	39	-1.1 – 3.2	1.2
	Craters of the Moon	38	0.13 – 3.1	1.2
	Dubois	39	0.36 – 3.8	1.1
	Idaho Falls	39	-1.3 – 2.9	1.5
	Jackson	39	-0.87 – 3.4	1.4
	Sugar City	38	0.24 – 3.3	1.1
			Distant Median:	1.2
Boundary	Arco	39	0.19 – 3.2	1.3
	Atomic City	39	0.34 – 4.1	1.2
	Blue Dome	39	0.24 – 4.2	0.97
	FAA Tower	39	-1.0 – 2.8	1.1
	Howe	39	0.21 – 4.3	1.1
	Monteview	39	0.27 – 3.2	1.2
	Mud Lake	39	0.32 – 3.6	1.0
			Boundary Median:	1.2
INL Site	EFS	38	0.0 – 3.7	1.1
	Main Gate	38	0.27 – 3.4	1.2
	Van Buren	38	-0.08 – 2.7	1.1
			INL Site Median:	1.1
INL CONTRACTOR				
Distant	Blackfoot	63	-0.48 – 6.0	1.3
	Craters of the Moon	61	-0.15 – 7.8	1.2
	Dubois	13	0.80 – 2.5	1.9
	Idaho Falls	64	0.12 – 5.8	1.4
	IRC[d]	51	-0.38 – 5.3	1.3
	IRC (North)	51	-0.22 – 6.8	1.5
	Jackson	13	1.1 – 2.8	1.3
	Sugar City	64	-0.06 – 6.4	1.6
			Distant Median:	1.3
Boundary	Arco	13	1.1 – 2.8	1.6
	Atomic City	13	1.1 – 3.5	1.9
	Blue Dome	13	0.95 – 2.5	1.5
	FAA Tower	13	0.91 – 2.6	1.9
	Howe	13	0.85 – 3.0	1.7
	Monteview	13	0.97 – 2.8	1.8
	Mud Lake	13	-0.25 – 3.7	1.9
			Boundary Median:	1.8

Table 4-4. continued.

GROUP	LOCATION[a]	NO. OF SAMPLES[b]	RANGE OF CONCENTRATIONS[c] (× 10^{-15} µCi/mL)	ANNUAL MEDIAN CONCENTRATION (× 10^{-15} µCi/mL)
INL Site	RHLLW	51	-0.28 – 7.2	1.6
	ATR Complex (NE corner)	49	-0.54 – 7.4	1.7
	Highway 26 Rest Area	51	-0.18 – 6.3	1.0
	CFA	49	-0.04 – 6.0	1.9
	EBR-I	49	-0.64 – 5.4	1.2
	EFS	61	-0.04 – 9.6	1.7
	Gate 4	51	-0.62 – 7	1.4
	INTEC (NE corner)	51	-0.1 – 8	1.5
	INTEC (west side)	48	-0.13 – 4.8	1.1
	MFC (North)	48	-0.48 – 6.2	1.4
	MFC (South)	51	-0.11 – 8.3	1.5
	NRF	51	-0.3 – 5.7	1.3
	RWMC	49	-0.37 – 5.0	1.2
	RWMC (South)	51	-0.01 – 4.7	1.4
	SMC	51	0.27 – 6.9	1.5
	Van Buren Boulevard	64	-0.5 – 9.1	1.5
			INL Site Median:	1.4

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 INL and ESER contractors, 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 Research and Education Campus.

- ***Gross Alpha.*** Gross alpha concentrations are measured on a weekly basis in individual air samples ranged from a low of (-1.3 ± 0.09) × 10^{-15} µCi/mL collected by the ESER contractor at Idaho Falls on February 17, 2021, to a high of (9.6 ± 3.2) × 10^{-15} µCi/mL collected by the INL contractor at EFS on August 18, 2021, as shown in Table 4-4.

  The median annual gross alpha concentrations were typical of previous measurements. In fact, the maximum result is less than the DCS (DOE 2011) of 3.4 × 10^{-14} µCi/mL for $^{239/240}$Pu (see Table A-2), which is the most conservative specific radionuclide DCS that could, although unrealistically, be applied to gross alpha activity.

- ***Gross Beta.*** Weekly gross beta concentrations measured in air samples ranged from a low of (-8.9 ± 5.3) × 10^{-16} µCi/mL at Jackson, collected by the ESER contractor on March 17, 2021, to a high of (8.3 ± 8.5) × 10^{-14} µCi/mL collected by the INL contractor at CFA on December 9, 2021, as observed in Table 4-5. The lowest detected value (i.e., greater than 3-sigma) was (2.3 ± 0.45) × 10^{-15} µCi/mL collected by the ESER contractor at Jackson on July 15, 2021. All results were less than the maximum concentration of 1.0 × 10^{-13} µCi/mL which was reported in previous Annual Site Environmental Reports (2011–2019). In general, median airborne radioactivity levels for the INL Site, boundary, and distant locations tracked each other closely throughout the year. The typical temporal fluctuations for natural gross beta concentrations in 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, and is representative of natural conditions, and is not caused by a localized source, such as a facility or

Table 4-5. Median annual gross beta concentrations in ambient air samples collected in 2021.

GROUP	LOCATION[a]	NO. OF SAMPLES[b]	RANGE OF CONCENTRATIONS[c] (× 10^{-14} µCi/mL)	ANNUAL MEDIAN CONCENTRATION[c] (× 10^{-14} µCi/mL)
ESER CONTRACTOR				
Distant	Blackfoot	39	0.14 – 4.3	2.8
	Craters of the Moon	38	0.97 – 5.7	2.7
	Dubois	39	0.75 – 4.1	2.5
	Idaho Falls	39	0.44 – 3.4	2.4
	Jackson	39	-0.09 – 4.3	2.7
	Sugar City	38	0.65 – 4.0	2.4
			Distant Median:	2.6
Boundary	Arco	39	1.2 – 6.0	2.7
	Atomic City	39	0.99 – 5.8	2.8
	Blue Dome	39	0.82 – 3.9	2.6
	FAA Tower	39	0.67 – 3.8	2.5
	Howe	39	0.84 – 3.8	2.8
	Monteview	39	0.88 – 3.6	2.5
	Mud Lake	39	0.86 – 4.0	2.5
			Boundary Median:	2.6
INL Site	EFS	38	0.04 – 4.9	2.7
	Main Gate	38	0.86 – 5.3	2.7
	Van Buren	38	-1.3 – 4.2	2.5
			INL Site Median:	2.7
INL CONTRACTOR				
Distant	Blackfoot	63	1.4 – 6.1	2.6
	Craters of the Moon	61	1.6 – 5.7	2.4
	Dubois	13	1.6 – 4.6	2.8
	Idaho Falls	64	1.7 – 5.8	2.6
	IRC[d]	51	1.04 – 4.45	2.6
	IRC (North)	51	0.98 – 4.48	2.8
	Jackson	13	1.3 – 4.4	2.4
	Sugar City	64	1.0 – 6.3	2.5
			Distant Median:	2.6
Boundary	Arco	13	1.6 – 5.6	3.1
	Atomic City	13	1.5 – 6.5	3.3
	Blue Dome	13	1.6 – 5.3	3.4
	FAA Tower	13	1.6 – 5.2	2.7
	Howe	13	1.8 – 6.2	3.0
	Monteview	13	1.6 – 5.5	3.1
	Mud Lake	13	1.7 – 6.3	3.1
INL Site	RHLLW	51	1.49 – 4.51	2.7
	ATR Complex (NE corner)	49	1.26 – 5.31	2.5

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)
	Highway 26 Rest Area	51	0.97 – 4.8	2.6
	CFA	49	1.37 – 8.3	2.8
	EBR-I	49	1.08 – 4.61	2.6
	EFS	61	1.8 – 7.7	2.7
	Gate 4	51	1.32 – 4.74	2.8
	INTEC (NE corner)	51	1.26 – 6.18	2.8
	INTEC (west side)	48	1.15 – 4.74	2.5
	MFC (North)	46	1.09 – 4.0	2.4
	MFC (South)	51	1.14 – 5.49	2.6
	NRF	51	1.28 – 4.86	2.7
	RWMC	49	1.25 – 4.41	2.6
	RWMC (South)	51	1.24 – 4.52	2.6
	SMC	51	1.22 – 4.77	2.5
	Van Buren Boulevard	64	1.4 – 5.7	2.7
			INL Site Median:	2.6

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 INL and ESER contractors, 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.

c. IRC is an in-town (Idaho Falls) facility within the INL REC.

activity at the INL Site. An inversion can lead to natural radionuclides being trapped close to the ground. In 2021, the most prominent inversion periods occurred in January, November, and December. The maximum weekly gross beta concentration is significantly below the DCS of 2.5 × 10^{-11} µCi/mL (see Table A-2) for the most restrictive beta-emitting radionuclide in air, ^{90}Sr.

- ***Gross Activity Statistical Comparisons.*** Statistical comparisons were made using the gross alpha and gross beta radioactivity data collected by the ESER contractor from the INL Site, boundary, and distant locations (see the supplemental report, *Statistical Methods Used in the Idaho National Laboratory Annual Site Environmental Report*, for a description of the methods used). If the INL Site were a significant source of offsite contamination, contaminant concentrations would be statistically greater at boundary locations than at distant locations. For these analyses, uncensored analytical results (i.e., values less than their analysis-specific minimum detectable concentrations) were included. There were no statistical differences between annual concentrations collected from the INL Site, boundary, and distant locations in 2021. There were a few statistical differences between weekly boundary and distant data sets collected by the ESER contractor during 2021 that can be attributed to expected statistical variation in the data and

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.

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 offsite locations. Statistical evaluation revealed no significant differences between onsite and offsite concentrations. Onsite and offsite mean concentrations ($2.6 \pm 0.3 \times 10^{-14}$ and $2.6 \pm 0.3 \times 10^{-14}$ μCi/mL, respectively) showed equivalence at one sigma uncertainty and are attributable to natural data variation.

Specific Radionuclides – None of the 100 INL contractor quarterly samples composited in 2021 had measurable concentrations of specific radionuclides (i.e., ^{90}Sr, ^{137}Cs, plutonium isotopes, or ^{241}Am).

The ESER contractor observed eight detections of ^{90}Sr throughout 2021. The detectable concentrations ranged from 3.3 x 10^{-17} μCi/mL at Howe during the third quarter to 2.1 x 10^{-16} μCi/mL at Mud Lake in the first quarter, as observed in Table 4-6. Plutonium-239/240 was detected in a quarterly composited sample that was collected at Arco during the fourth quarter (Table 4-6). It was not detected in a duplicate sample collected at the same location. Plutonium-238 and ^{241}Am were not detected in any sample collected by the ESER contractor. All results were within historical measurements made during the past ten years (2011-2020). In addition, the results were well below the DCSs for these radionuclides in air (i.e., 2.5×10^{-11} μCi/mL for ^{90}Sr, and 3.7×10^{-14} μCi/mL for ^{238}Pu). Natural ^{7}Be was detected in numerous ESER and 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 ESER contractor in 2021.

RADIONUCLIDE	RESULT[a] (μCi/mL)	LOCATION	GROUP	QUARTER DETECTED
Plutonium-239/240	$(55 \pm 16) \times 10^{-18}$	Arco	Boundary	4th
Strontium-90	$(48 \pm 7) \times 10^{-18}$	Dubois	Distant	1st
Strontium-90	$(59 \pm 9) \times 10^{-18}$	Howe	Boundary	1st
Strontium-90	$(50 \pm 12) \times 10^{-18}$	Main Gate	INL Site	1st
Strontium-90	$(192 \pm 12) \times 10^{-18}$	Mud Lake	Boundary	1st
Strontium-90	$(214 \pm 12) \times 10^{-18}$	Mud Lake (duplicate)	Boundary	1st
Strontium-90	$(33 \pm 11) \times 10^{-18}$	Howe	Boundary	3rd
Strontium-90	$(40 \pm 10) \times 10^{-18}$	Arco	Boundary	4th
Strontium-90	$(44 \pm 11) \times 10^{-18}$	Atomic City	Boundary	4th

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

4.3.4 Atmospheric Moisture Monitoring Results

During 2021, the ESER contractor collected 51 atmospheric moisture samples at four 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 17 ESER samples, with a high of $(12.8 \pm 2.5) \times 10^{-13}$ μCi/mL$_{air}$ at EFS on July 21, 2021. The highest concentration of tritium detected in an atmospheric moisture sample collected since 2011 was 28×10^{-13} μCi/mL at Idaho Falls in 2014. The highest observed tritium concentration in a 2021 sample collected by the ESER contractor is far below the DCS for tritium in air (as water vapor) of 2.1×10^{-7} μCi/mL$_{air}$ (see Table A-5).

In 2021, the INL contractor collected 31 atmospheric moisture samples on the INL Site at EFS and Van Buren Boulevard and off the INL Site at Idaho Falls and Craters of the Moon, as observed in Table 4-7. Tritium was detected in six samples. The maximum detected concentration measured was 1.36×10^{-12} μCi/mL$_{air}$ at EFS on June 30, 2021. This result is well below the DCS for tritium, as vapor, in air (2.1×10^{-7} μCi/mL), and is the maximum measured since 2011.

Fewer detections were observed in INL samples than in ESER samples most likely because ESER samples have more volume and were counted longer resulting in lower detection levels.

Table 4-7. Tritium concentrations[a] in atmospheric moisture samples collected on and off the INL Site in 2021.

ESER CONTRACTOR				
	ATOMIC CITY	**EFS**	**HOWE**	**IDAHO FALLS**
Number of samples	11	13	12	15
Number of detections	4	8	3	2
Detection percentage	36%	62%	25%	13%
Concentration range ($\times10^{-13}$ µCi/mL$_{air}$)[b]	-2.6 ± 1.6 – 6.8 ± 2.1	0.2 ± 1.3 – 12.8 ± 2.5	-3.3 ± 1.8 – 9.1 ± 1.3	-4.7 ± 1.3 – 9.3 ± 1.8
Mean concentration ($\times10^{-13}$ µCi/mL$_{air}$)[b]	2.1	6.0	3.1	1.7
Median concentration ($\times10^{-13}$ µCi/mL$_{air}$)	1.5	5.9	2.5	0.2
Mean detection level ($\times10^{-13}$ µCi/mL$_{air}$)	4.7	5.0	5.3	5.6
INL CONTRACTOR				
	CRATERS OF THE MOON	**EFS**	**IDAHO FALLS**	**VAN BUREN BOULEVARD**
Number of samples	6	8	8	9
Number of detections[c]	1	3	1	1
Detection percentage	17%	38%	13%	11%
Concentration range (µCi/mL$_{air}$)[b]	-7.0E-14 – 7.3E-13	-3.7E-13 – 1.4E-12	-3.5E-13 – 1.1E-12	-7.6E-14 – 1.2E-12
Mean concentration ($\times10^{-13}$ µCi/mL$_{air}$)[b]	1.9	5.7	2.2	5.5
Median concentration ($\times10^{-13}$ µCi/mL$_{air}$)	1.3	5.0	1.6	5.8
Mean detection level ($\times10^{-13}$ µCi/mL$_{air}$)	7.0	9.0	8.4	8.9

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).

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, such as ATR, 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 composition 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 thus most likely cosmogenic in origin and not from weapons testing.

The ESER 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 ESER contractor for analysis.

A total of 71 precipitation samples were collected during 2021 from the four sites. Tritium was detected in 23 samples, and detectable results ranged from 90 pCi/L at Howe in August to 391 pCi/L at Howe in November. Most detections were near the approximate detection level of 91 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 for tritium in water of 1.9 × 10^6 pCi/L and within the historical range (-244 – 413 pCi/L) measured from 2011–2020.

Table 4-8. Tritium concentrations in precipitation samples collected in 2021.[a,b]

	ATOMIC CITY	EFS	HOWE	IDAHO FALLS
Number of samples	15	21	23	12
Number of detections	3	8	9	3
Detection percentage	20%	38%	39%	25%
Concentration range (pCi/L)	-83.9 ± 23.1 – 203 ± 29.7	-53.1 ± 23.5 – 262 ± 45.7	-77.2 ± 25.5 – 391 ± 31.2	-87.8 ± 24.6 – 165 ± 32.3
Mean concentration (pCi/L)	41	79	74	30
Median concentration (pCi/L)	45	69	57	38
Mean detection level (pCi/L)	90	91	91	92

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 sets of data (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 of annual tritium concentrations measured in atmospheric moisture (as water) and precipitation samples collected by the ESER 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 sets of data (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.

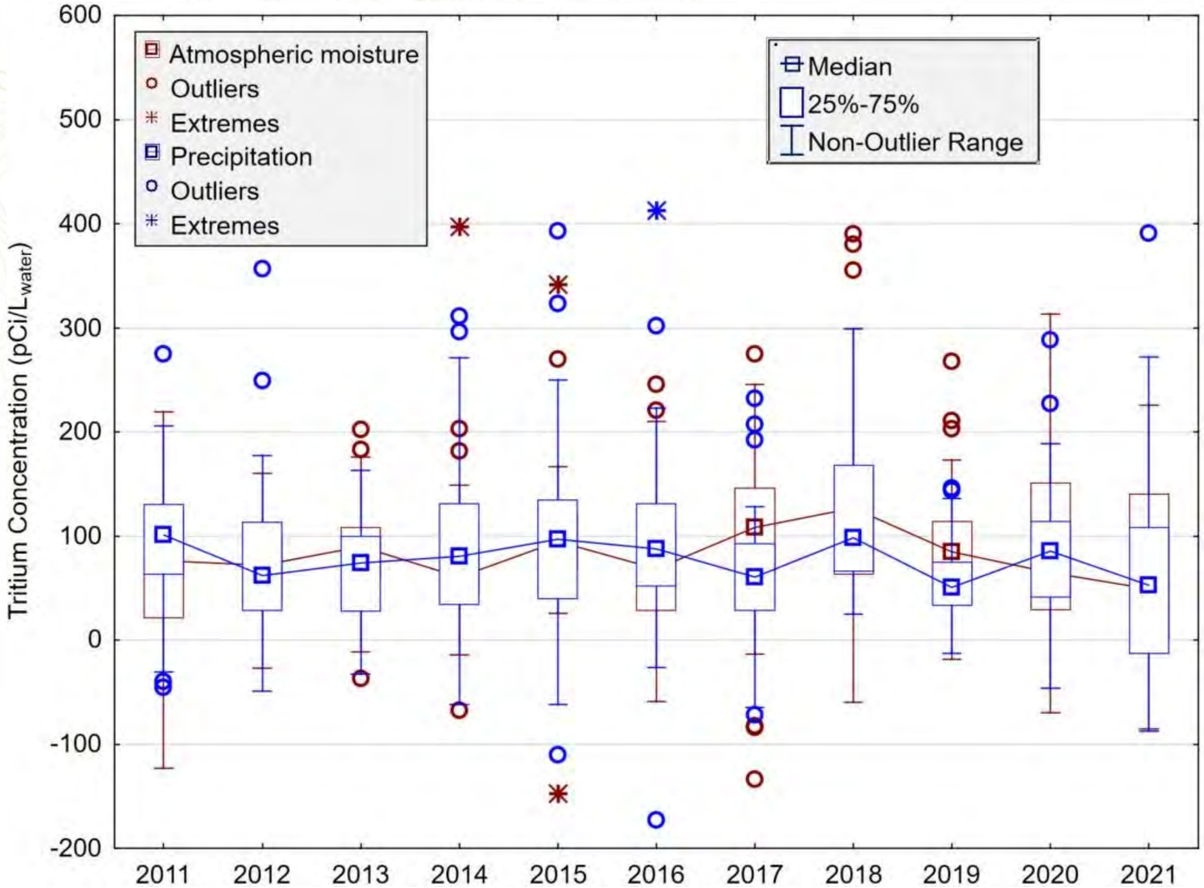


Figure 4-5. Box plots of tritium concentrations measured in atmospheric moisture and in precipitation from 2011–2021.

4.3.6 Suspended Particulates Monitoring Results

In 2021, the ESER contractor measured concentrations of suspended particulates using filters collected from the low-volume air samplers. The filters are 99% efficient for the collection of particles greater than 0.3 µm in diameter. That is, they collect the total particulate load greater than 0.3 µm in diameter.

In general, particulate concentrations were highest during the period from the end of June through mid-September. This was most likely influenced by smoke from regional wildfires observed at all locations, as well as from agricultural activities off the INL Site that resulted in increased dust loads.

The mean annual particulate concentrations ranged from 9.84 µg/m^3 at Blue Dome to 23.27 µg/m^3 at Idaho Falls. In general, particulate concentrations were higher at offsite locations than at the INL Site stations. This is most likely influenced by agricultural activities off the INL Site.

4.4 Waste Management Environmental Surveillance Air Monitoring

4.4.1 Gross Activity

The ICP Core contractor conducts environmental surveillance in and around waste management facilities to comply with DOE O 435.1, “Radioactive Waste Management.” Currently, ICP Core 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 Core contractor collected samples of airborne particulate material from the perimeters of these waste management areas in 2021, as observed in Figure 4-6. Samples were also collected at a control location at Howe, Idaho, as previously seen 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 and ESER contractors. The air filters are 4 in. 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 $(0.65 \pm 0.12) \times 10^{-15}$ µCi/mL collected at location SDA 11.3 on February 16, 2021, to a high of $(4.29 \pm 0.65) \times 10^{-15}$ µCi/mL at location SDA 6.3 on September 27, 2021.

Table 4-10 shows the annual median and range of gross beta concentrations at each location. Gross beta concentrations ranged from a low of $(0.68 \pm 0.06) \times 10^{-14}$ µCi/mL at location SDA 6.3 on February 16, 2021, to a high of $(5.30 \pm 0.45) \times 10^{-14}$ µCi/mL at location SDA 4.3B on December 6, 2021.

Figure 4-7 compares gross alpha and gross beta sample results from 2011 through 2021 to the most restrictive DCS values ($^{239/240}$Pu for gross alpha, ^{90}Sr for gross beta) established by DOE for inhaled air (DOE 2011). The 2021 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 Core 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 2021, only one human-made, gamma-emitting radionuclide was detected in air samples at the ICDF at INTEC. However, multiple human-made specific alpha-emitting and beta-emitting radionuclides were detected at the SDA at RWMC.

Table 4-11 shows human-made specific radionuclides detected at INTEC and the SDA in 2021. These detections are consistent with levels measured in air at the SDA in previous years. All detections were three to four orders of magnitude below the DCS stipulated in DOE (2011), 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 Core 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.

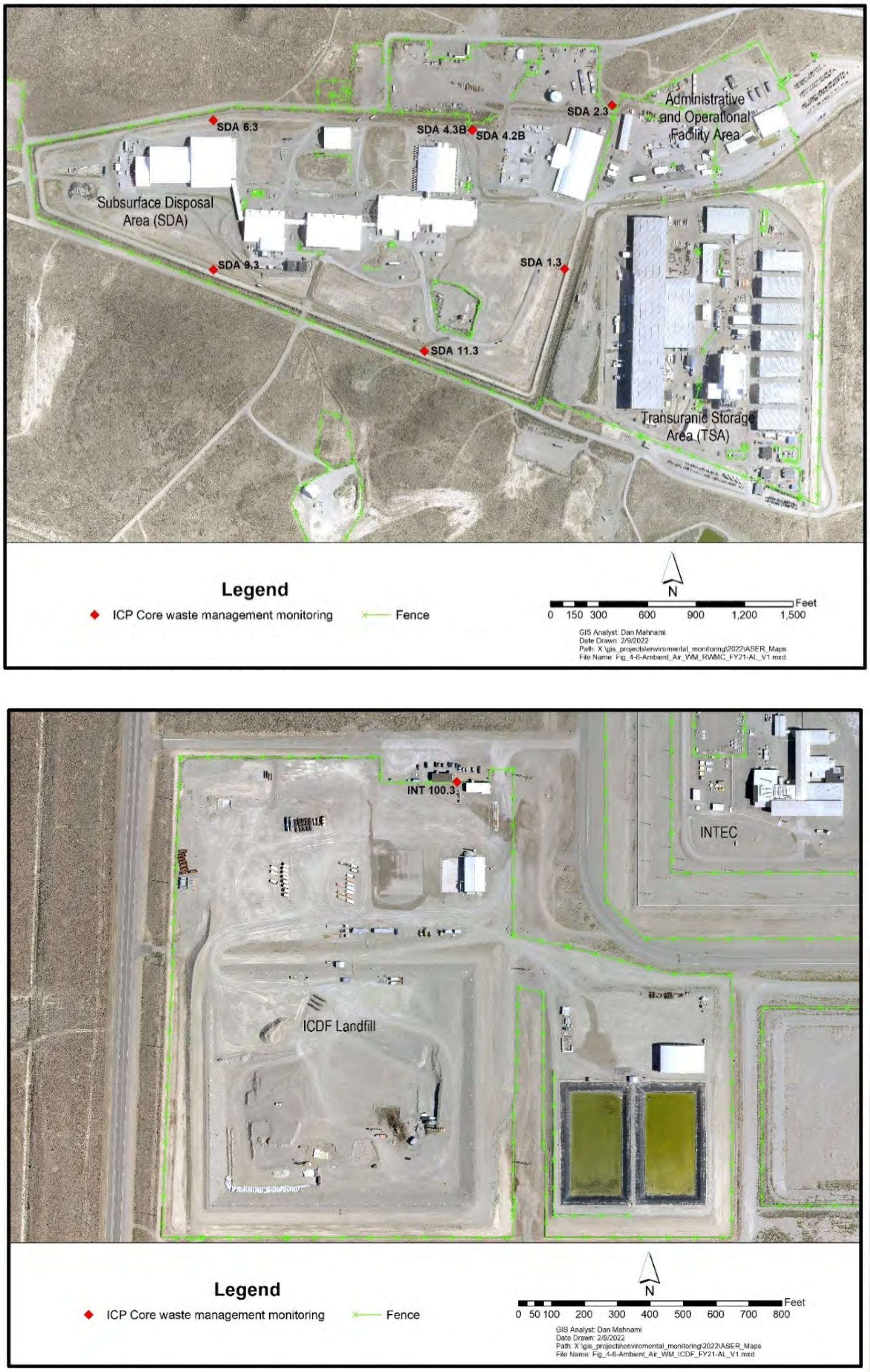


Figure 4-6. Locations of ICP Core contractor low-volume air samplers at waste management areas (SDA [top] and ICDF [bottom]).

Table 4-9. Median annual gross alpha concentration in air samples collected at waste management sites in 2021.[a]

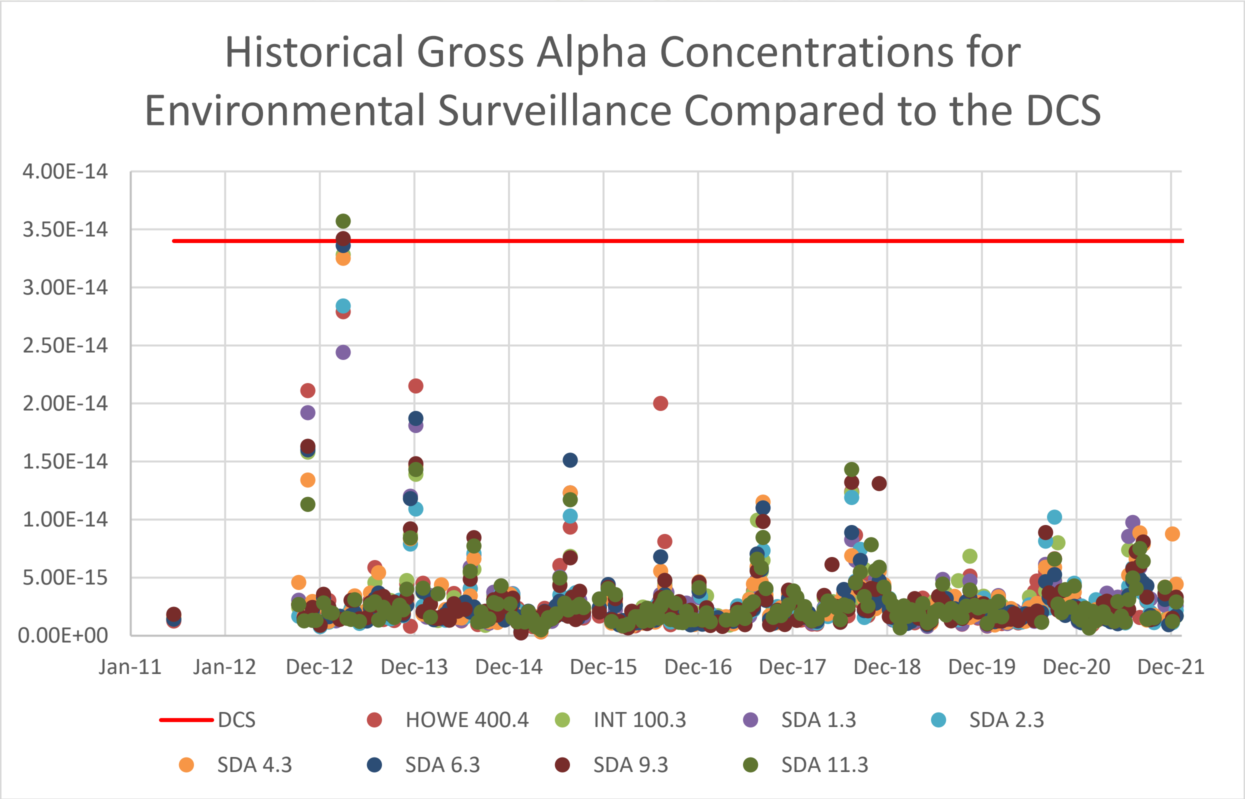
GROUP	LOCATION	NO. OF SAMPLES COLLECTED	RANGE OF CONCENTRATIONS ($\times 10^{-15}$ µCi/mL)	ANNUAL MEDIAN ($\times 10^{-15}$ µCi/mL)
SDA	SDA 1.3	17	0.88 - 3.65	2.70
	SDA 2.3	18	1.08 - 3.66	2.91
	SDA 4.3B [a]	16	0.85 - 4.18	2.94
	SDA 6.3	19	0.77 - 4.29	2.91
	SDA 9.3	19	0.85 - 3.60	2.65
	SDA 11.3	20	0.65 - 4.16	2.73
ICDF	INT 100.3	19	0.75 - 4.06	2.78
Boundary	HOWE 400.4	20	0.70 - 3.09	2.24

a. Results for SDA 4.2B, a replicate of SDA 4.3B, do not appear in the table.

Table 4-10. Median annual gross beta concentration in air samples collected at waste management sites in 2021.[a]

GROUP	LOCATION	NO. OF SAMPLES COLLECTED	RANGE OF CONCENTRATIONS ($\times 10^{-14}$ µCi/mL	ANNUAL MEDIAN ($\times 10^{-14}$ µCi/mL)
SDA	SDA 1.3	17	0.72 - 4.19	2.82
	SDA 2.3	18	0.98 - 4.99	3.47
	SDA 4.3B [a]	16	0.92 - 5.30	3.57
	SDA 6.3	19	0.68 – 4.00	2.68
	SDA 9.3	19	0.85 - 4.72	3.21
	SDA 11.3	20	0.75 - 4.52	3.01
ICDF	INT 100.3	19	0.86 - 4.61	3.17
Boundary	HOWE 400.4	20	0.95 - 4.78	3.34

a. Results for SDA 4.2B, a replicate of SDA 4.3B, do not appear in the table.



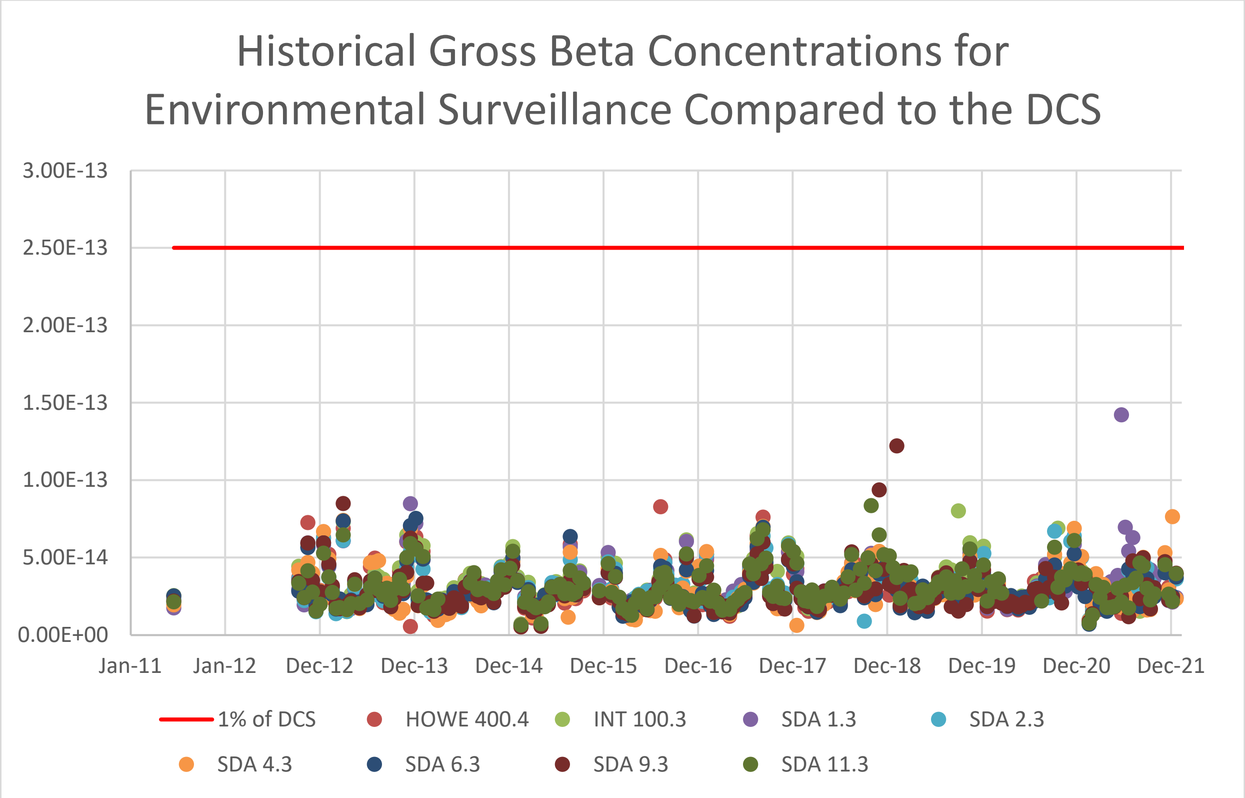


Figure 4-7. Gross alpha (top) and gross beta (bottom) results from waste management site air samples compared to their respective derived concentration standards.

Table 4-11. Human-made radionuclides detected in air samples collected at waste management sites in 2021.[a]

RADIONUCLIDE	LOCATION	RESULT (µCi/mL)	UNCERTAINTY (1 SIGMA)	PERIOD DETECTED
Americium-241	HOWE 400.4	4.91E-17	5.57E-18	09/13/2021 - 09/27/2021[b]
	INT 100.3	4.01E-18	9.09E-19	06/07/2021 - 06/21/2021[b]
	SDA 1.3	2.91E-18	8.93E-19	06/07/2021 - 06/21/2021[b]
	SDA 2.3	4.31E-18	9.63E-19	06/07/2021 - 06/21/2021[b]
	SDA 2.3	2.17E-17	3.01E-18	09/13/2021 - 09/27/2021[b]
	SDA 2.3	1.94E-17	2.8E-18	09/27/2021 - 12/20/2021
	SDA 4.3B	6.29E-17	5.67E-18	01/05/2021 - 03/30/2021
	SDA 4.3B	2.07E-17	2.37E-18	06/07/2021 - 06/21/2021[b]
	SDA 4.3B	1.95E-17	2.8E-18	09/13/2021 - 09/27/2021[b]
	SDA 4.3B	4.31E-17	5.59E-18	09/27/2021 - 12/20/2021
	SDA 6.3	2.88E-18	7.42E-19	01/05/2021 - 03/30/2021
	SDA 6.3	2.13E-18	6.31E-19	06/07/2021 - 06/21/2021[b]
	SDA 9.3	2.15E-18	6.32E-19	06/07/2021 - 06/21/2021[b]
	SDA 9.3	5.66E-18	1.87E-18	09/13/2021 - 09/27/2021[b]
Plutonium-239/240	SDA 1.3	1.13E-18	3.52E-19	09/27/2021 - 12/20/2021
	SDA 2.3	6.55E-18	1.18E-18	09/27/2021 - 12/20/2021
	SDA 4.3B	1.46E-17	2.39E-18	01/05/2021 - 03/30/2021
	SDA 4.3B	5.35E-18	1.17E-18	09/13/2021 - 09/27/2021[b]
	SDA 4.3B[c]	2.91E-17	3.37E-18	09/27/2021 - 12/20/2021
	SDA 9.3	5.06E-18	1.11E-18	09/13/2021 - 09/27/2021[b]
	SDA 9.3	6.53E-18	1.1E-18	09/27/2021 - 12/20/2021
	SDA 11.3	2.45E-18	6.97E-19	01/05/2021 - 03/30/2021
	SDA 11.3	2.34E-18	7.66E-19	09/13/2021 - 09/27/2021[b]

a. Results shown are ≥ 3σ.

b. Samples collected in calendar year quarters 2 through 4 were not composited 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 problems associated with employee turnover.

c. Results for SDA 4.2B, a replicate of SDA 4.3B, do not appear in the table.

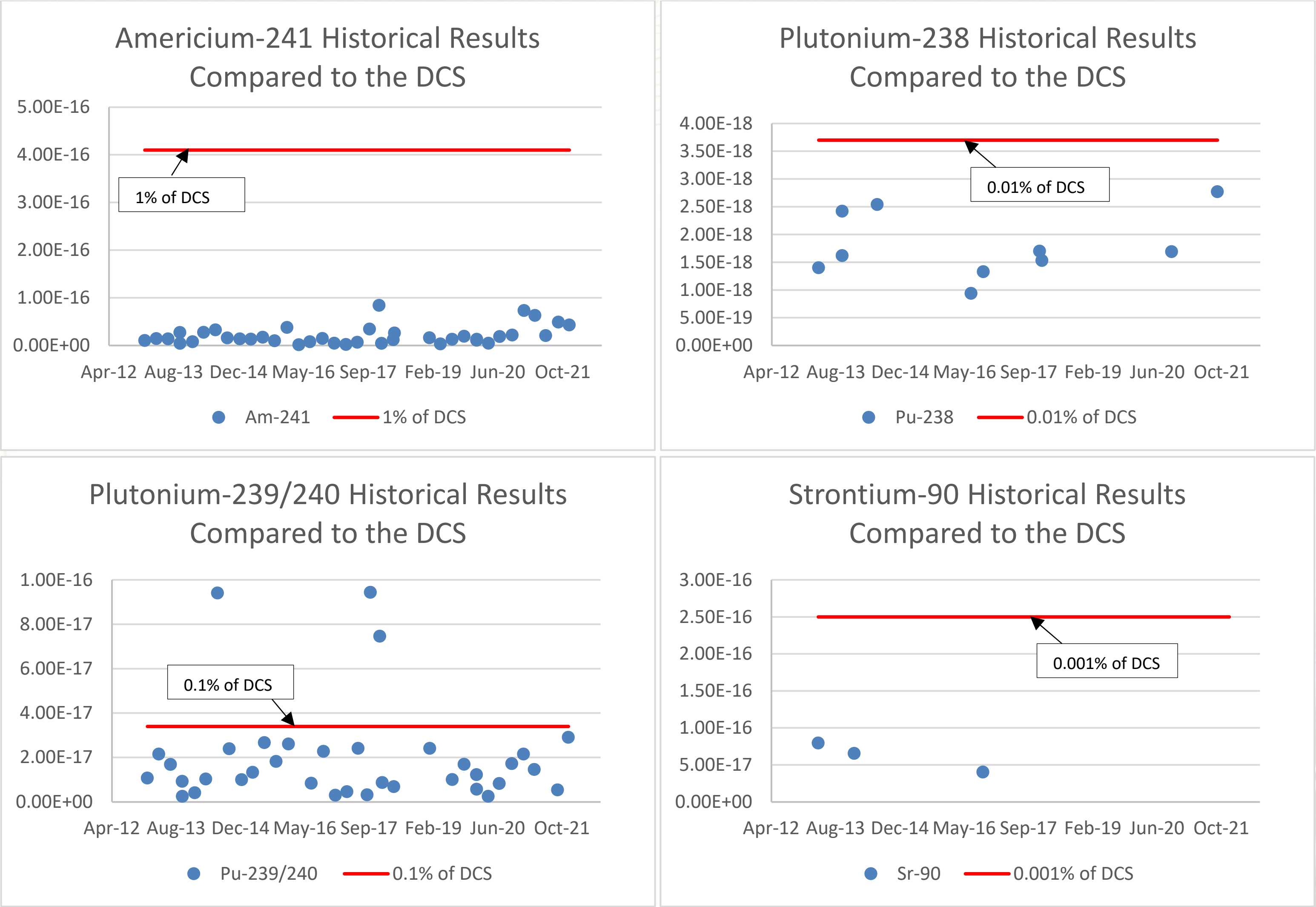


Figure 4-8. Specific human-made radionuclide detections (μCi/mL) from waste management air samples compared to various fractions of their respective derived concentration standards.

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